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Rethinking Learning in the Digital Age. Making the Learning Sciences Count Volume 3

Judy Kay and Rosemary Luckin

**Rethinking Learning in the Digital Age:
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Volume 3

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Judy Kay and Rosemary Luckin

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Preface

The International Conference of the Learning Sciences (ICLS) is a major international event, organized biennially by the International Society of the Learning Sciences (ISLS): a professional society dedicated to the interdisciplinary empirical investigation of learning as it exists in real-world settings and to how learning may be facilitated both with and without technology. The international and interdisciplinary field of the Learning Sciences brings together researchers from the fields of cognitive science, educational research, psychology, computer science, artificial intelligence, information sciences, anthropology, sociology, neurosciences, and other fields to study learning in a wide variety of formal and informal contexts (see www.isls.org). The field emerged in the late 1980s and early 1990s, with the first ICLS held in 1991 at Northwestern University in Evanston, Illinois, USA. Subsequent meetings of ICLS were held again in Evanston, USA (1996), Atlanta, GA, USA (1998), Ann Arbor, MI, USA (2000), Seattle, WA, USA (2002), Santa Monica, CA, USA (2004), Bloomington, IN, USA (2006), Utrecht, the Netherlands (2008), Chicago, IL, USA (2010), Sydney, NSW, Australia (2012), and Boulder, CO, USA (2014) and National Institute of Education, Nanyang Technological University of Singapore (2016).

A bumper crop of 965 submissions for ICLS 2018 were received in December 2017 (571 were received at the last ICLS Conference ion 2016). All submissions went through a process of rigorous peer review. The acceptance rate was 32% for full papers, 27% for short papers and 33% for posters. 110 of the full papers and 61 of the short papers were accepted as posters. For symposia, the acceptance rate was also 32%. At least three reviewers were recruited for each paper and a member of the Progamme Committee provided a metareview. The Programme Chairs made decisions, based on reading every review, metareview and the online discussion.

This meant that over 3000 reviews were completed by the ICLS community – many, many thanks. We are particularly indebted to the committee members and reviewers who responded to the call for volunteers to manage extra papers. We especially note those who managed at least 9 papers and those reviewers who responded so generously to calls for additional reviews: we could not have completed the selection process without you.

The UCL Institute of Education, London, is hosting the 13th International Conference of the Learning Sciences (ICLS), 2018, from June 23rd to 27th, 2018. It is a right and fitting venue to host the 13th International Conference of the Learning Sciences (ICLS). UCL Institute of Education (IOE) was founded in 1902, and is a world-leading centre for research and teaching in social science and education. For three successive years (2014, 2015, 2016 and 2017), the Institute has been ranked first for education worldwide in the QS World University Rankings, and was shortlisted for the 'University of the Year' title in the 2014 Times Higher Education (THE) awards. In January 2014, Ofsted judged it to be 'outstanding' in every category for initial teacher training across primary, secondary and further education programmes. In the most recent Research Excellence Framework, 94% of the IOE's research was judged to be world class. In 2016, it was awarded the Queen's Anniversary Prize for Higher and Further Education, for its innovative social research and contribution to policy and practice in education. The IOE currently has more than 8,000 students, 800 staff, and attracts students from over a hundred countries around the world. Since December 2014, it has been a school of University College London, formally called the UCL Institute of Education. University College London (UCL) was founded in 1826, and was the first English university established after Oxford and Cambridge, the first to admit students regardless of race, class, religion or gender, and the first to provide systematic teaching of law, architecture and medicine. We are among the world's top universities, as reflected by performance in a range of international rankings and tables. UCL currently has over 35,000 students from 150 countries and over 11,000 employees.

The theme for this year's conference is Rethinking learning in the digital age: Making the Learning Sciences Count. This reflects the fact that now, more than ever, the learning sciences have a key role to play in unpacking the complexity of the teaching and learning process. AI and Automation in the workplace, including within education, will alter what we need to learn and how we need to teach it. Therefore, as scientists and educators we need to explore learning in real-world settings in an interdisciplinary manner in order to understand how learning may be facilitated both with and without technology.

For the first time this year we also welcomed Crossover paper submissions to reflect the fact that ICLS 2018 is co-located with L@S and AIED, as part of the London Festival of Learning. Ten papers were accepted (acceptance rate 30%). These papers appeal to a broad audience of researchers from across the communities of the three conferences. The London Festival of Learning is a unique opportunity to bring together world experts in artificial intelligence in education, the learning sciences and technical innovations in education. There has never been a more important time for these three disciplines to meet and overlap, uniting academics to share their research and learn from each other, as well as engaging with a wider audience of educators, businesses and

learners. The Festival of Learning also offers an opportunity to showcase the important work being done by UCL IOE's EDUCATE programme in promoting the best in EdTech development currently taking place in the UK.

We hope you will enjoy what promises to be a week of fascinating debate, discussion and international networking.

Judy Kay, *Human Centred Technology Research, University of Sydney, Australia*
Rosemary Luckin, *UCL Knowledge Lab, UCL Institute of Education, UK*

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Posters

Equitable Science Outcomes and School Organizational Conditions

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Abstract: This poster describes research at the school level that investigated systems factors associated with variation in equitable science outcomes. A mixed methods approach uncovered multiple associations between organizational features and demographically adjusted academic measures. Schoolwide surveys of faculty perspectives about leadership along with social network analyses revealed complexities with real-world applications. Findings highlight the need to attend to organizational contexts while studying learning.

Although academic disparities based on social class, and race levy considerable economic costs on individuals and communities (Auguste, Hancock, & Laboissiere, 2009) decades of research offer rich descriptions but few solutions (Bohrnstedt, et al. 2015; Fryer & Levitt, 2004). Within the learning sciences, outcome disparities are framed as equity or social justice and typically invoke individual identity development or within classroom social contexts (Bell, Van Horne, & Cheng, 2017; Tabak & Radinsky, 2014). Less common are studies attending to schoolwide and organizational influences on equitable outcomes (e.g., Naris & Vakil, 2017). Extending Lee's (2017) claim that learning science has been expanding beyond the purely cognitive, it is valuable to engage in deeper consideration of institutional factors for their influences on student academic outcomes.

Typically, achievement gaps are reported using large scale examination data. While some scholars contend such assessments remain at the fringe of learning sciences community interests (Roschelle, et al. 2011), the tests' presence, most notably in American schools, create influences that cannot be ignored. Because legislation requires test results to report outcomes disaggregated by various demographic categories, these reports are regular reminders that discrepancies in "learning" by race and social class exist <u>within</u> schools. Put another way, achievement gap severity is not a matter of uneven resource distribution between towns or districts; rather, schools with comparable demographic profiles generate widely varied results. Inequities correspond to conditions inside schools. This predicament suggests that learning research would benefit by drawing upon sociological frameworks. Individual students are embedded within peer groups, classrooms are constituted by multiple inter-relationships, and school level learning is shaped by complex interactions amongst adults and children. My research has revealed multiple institutional factors strongly associated with student outcomes and those suggest that equity agendas should more intentionally attend to organizational factors.

Methods

Data were gathered from 6 elementary schools within a single economically depressed district. To capture the organizational and leadership conditions within the schools, we administered a validated infrastructure survey containing eight distinct factors. Interviews were used to collect systems-level perspectives about the school science program. The school's lead administrator was asked to describe decision-making, community involvement, and equity considerations connected to the school's science programs. The designated lead science teacher of the building was interviewed to understand their role as a quasi-administrator who had daily contact with science teaching and learning. Finally, we "interviewed" the building to uncover what it would say about the presence of science education within the school; this took the form of a school tour led during which we sought to identify where formal and informal science instruction took place, where professional development activities occurred, where/when parents were able to participate in science activities, and the locations and accessibility of science instructional materials and equipment.

Findings

Findings revealed strong associations between multiple organizational factors and demographically adjusted science test scores. Except for "Other Teachers' Trustworthiness" which exhibited a ceiling effect, responses to the School Infrastructure survey uncovered seven other factors correlating with science residuals: *Collaborative Teacher Learning*, *Families as Educational Partners*, *Principal Dependability*, *Principal's Advocacy for Equity*, *Shared Decision-Making*, *Supports for Science Teaching*, and *Teacher Pride and Orderly Environment*. If one would allow that a science test score is a proxy for science learning, then this study's findings offer evidence that school conditions, climate, or culture contribute academic performance and educational success.

There were varying configurations and quantitative differences within schools for the various forms of advice-seeking. At the sites we visited, the more centralized advice-seeking arrangements placed the principal, a lead science teacher, and sometimes a third individual at the core. It was to these leaders to whom the teaching faculty went for advice. Schools with less privatized professional relationships were also sites where performance equities

were less severe. The below figure presents survey items from the factor *Collaborative Teacher Learning* and describes teacher actions that reduce the barriers separating teachers from one another. This is not to suggest that open collaboration was prevalent in the participating schools. In truth, the factors making up the *School Infrastructures* survey were highly reliable in part because there was such a range in ratings.

Items From the Collaborative Teacher Learning Subscale of the School Infrastructure Survey

Instructional coaching specific to science teaching is provided to teachers at this school.

Professional development has deepened my understanding of science-specific subject matter.

Professional development has strengthened collaborations around science instruction.

I have found value in visiting a colleague while he or she is teaching science.

Teachers at this school regularly meet to plan science lessons and activities.

Feedback from a colleague at this school has improved my science teaching.

I admire the instructional strategies my colleagues use when teaching science.

Implications

This research may encourage the learning science to elevate its regard for organizational influences. In circumstances where it is desirous to replicate and/or bring learning interventions to scale, it is advisable to give increased attention to factors typically relegated to the background: policy, administrators, climate, etc. The findings from our investigations show clear links between organizational conditions and students' academic outcomes. Less clear are the connections between instructional design and school infrastructure. Whether one views the resolution of achievement disparities as an educational imperative, there are intellectual and practical reasons to incorporate organizational considerations into learning studies. In many respects, the findings from this research project reinforces the value in looking at the nested nature of learning. The field is no longer content to investigate individual learning as if it is disconnected from other sources. Science learning is dialogic as individuals and groups influence one another (Southerland, Kittleson, Settlage, & Lanier, 2005). Taking into account institutional influences should become a less uncommon dimension of the learning sciences

References

Allen, C. D., & Eisenhart, M. (2017). Fighting for desired versions of a future self: How young women negotiated STEM-related identities. *Journal of the Learning Sciences*, *26* (3), 407–436

Auguste, B., Hancock, B. & Laboissiere, M. (2009, June). The economic cost of the US education gap. *McKinsey Quarterly*. Available online: https://www.mckinsey.com/industries/social-sector/our-insights/the-economic-cost-of-the-us-education-gap

Bell, P., Van Horne, & Cheng, B. H. (2017). Designing learning environments for equitable disciplinary identification. *Journal of the Learning Sciences*, *26* (3), 367-375.

Bohrnstedt, G., Kitmitto, S., Ogut, B., Sherman, D., & Chan, D. (2015). *School composition and the black-white achievement gap*. NCES 2015-018. Washington, DC: National Center for Education Statistics.

Fryer, R. G., & Levitt, S. D. (2004). Understanding the black-white test score gap in the first two years of school. *The Review of Economics and Statistics*, *86* (2), 447-464.

Lee, C. D. (2017). Expanding visions of how people learn: The centrality of identity repertoires. *Journal of the Learning Sciences*, *26* (3), 517-524.

Nasir, N. S. & Vakil, S. (2017). STEM-focused academies in urban schools: Tensions and possibilities. *Journal of the Learning Sciences*, *26* (3), 376-406.

Roschelle, J., Bakia, M., Toyama, Y., & Patton, C. (2011). Eight issues for learning scientists about education and the economy. *The Journal of the Learning Sciences*, *20*, 3-49.

Southerland, S. A., Kittleson, J., Settlage, J. & Lanier, K. (2005). Individual sense making and group meaning making in an urban third grade classroom. *Journal of Research in Science Teaching*, *42* (9), 1032-1061.

Tabak, I. & Radinsky, J. (2014) Social justice research in the learning sciences. *Journal of the Learning Sciences*, *23* (3), 269-271.

Acknowledgments

Visual Feedback for Asynchronous Online Interaction: Exploratory Study on the Pattern of Other-regulation

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Abstract: This is a descriptive study of the other-regulation pattern in the asynchronous online discussion with the visual feedback. Visual feedback presented as a network diagram delivers intuitive and comprehensive information about the online interactions. Authors analyzed the messages *sent* and *received* and compared the data between more interactive and less interactive learners in terms of the other-regulation.

Introduction

A variety of group awareness tools have been suggested in order to promote interaction in CSCL (Reimann & Bannert, 2018). Enhancing the awareness of group's learning process as well as learner's own promotes the regulated learning in collaboration (Hadwin, Järvelä & Miller, 2018), because it allows monitoring the learning process that leads to feedback loop during learning. Although some studies examined the visualization of group interaction as a feedback tool to facilitate group awareness (Jo, 2009; Lim, Park, & Kim, 2014), more research on how the feedback tools on the group learning process change the quality of learning is still needed (Hadwin et al., 2018). This study aims to illustrate the regulation pattern when visual feedback on group interaction is provided.

Visual feedback in asynchronous online discussion

Data visualization, as a discovery tool, provides insight about the complex dataset. This advantage of data visualization makes it considered as a prescription in an education. For example, Lim and her colleagues (2014) used social network analysis (SNA) diagram as feedback on the interaction in the asynchronous online discussion. They compared the level of interaction (centrality) across visual-, text- and non-feedback groups. The result showed that the centrality of the visual feedback group was higher than the centrality of the text feedback and non-feedback group. The authors claimed that the visual feedback tended to provide intuitive and comprehensive information about the interaction. Given that SNA diagram illustrates the structure of group interactions, it is likely to support group awareness by facilitating monitoring of interaction at a glance. This study examines SNA diagram as visual feedback and its impact on interaction in line with the previous research. However, what is distinguished from relevant studies is its multi-dimensional approach. Despite that the interaction is not unidirectional but bidirectional, existing research gave attention on what learners sent, not what they received. Since an individual in the collaborative group is both sender and receiver, the impact of visual feedback also needs to be examined in two aspects: Changes in the interaction that learners a) *send* to, and b) *receive* from other learners.

Other-regulation

According to Hadwin et al. (2018), a large variety of terminologies used in the research of regulation in collaborative learning can be grouped into three primary modes: self-regulation in collaboration (SR: individual's metacognitive control), co-regulation (CoR: broad regulation through interpersonal interactions), and socially shared regulation (SSR: group-level regulation). Indeed, CoR is broadly defined so that it blurs the boundaries between SR and SSR (Lim, Lim, & Kim, 2017). Lim et al. (2017) suggested using the term other-regulation (OR) instead of CoR to specify the mechanism of individual's regulation toward other peers. They explained that the term CoR is rather a general term that covers a variety of regulation modes in collaborative learning. In this study, the term OR is employed instead of CoR following the framework suggested by Lim and her colleagues (2017) in examining the interaction. Since OR mainly concerns individual as its unit for process in describing the interpersonal interaction, this study gives attention to OR for exploring how each learners' behaviour change as a reaction to visual feedback.

Based on the review of the literature, following research questions have been examined: RQ1.When visual feedback is provided, is there any difference between messages relevant to other-regulation sent *from* learners with a high versus low level of the interaction? RQ2. When visual feedback is provided, is there any difference between messages relevant to other-regulation sent *to* learners with a high versus low level of the interaction?

Research method

Online discussion threads generated by 23 college students enrolled in media literacy course at the university located in South Korea were analyzed. Participants were randomly assigned to three different groups, and the discussion topics were changed on a weekly basis. After the weekly discussion, visual feedback based on SNA diagram was provided for each discussion group. Specifically, the weekly visual feedback illustrated structural relationships among the learners by representing the learners as nodes and their relationships as links. The size of the node indicated the in-degree centrality, which is one of the indices of the SNA that describes the level of the attention gained which particularly reflects the prestige and popularity of each node. The direction of the link means who sent the message to whom, and the thickness of the link means the intensity of the interaction.

The content of the online discussion messages was analyzed in terms of the theoretical framework of the OR. Messages were segmented into smaller units based on its meaning, which were coded afterwards following the coding scheme suggested by Janssen et al. (2010). The coding scheme initially categorizes messages as task-related and social activity. The task-related messages included informational activities relevant to performance and regulation of task progress, while social messages included activities relevant to relationship, shared mental model, and regulation of collaboration. Next, more interactive (high degree of centrality: HC) and less interactive (low degree of centrality: LC) learners were identified and analyzed according to their OR behavior patterns. That is, the coded messages relevant to OR 1) sent by HC and LC learners, and 2) received by HC and LC learners, were counted and compared.

Conclusion

For RQ1, messages sent from HC and LC learners were analyzed. Both HC and LC learners presented task-related messages more frequently than social messages. As the discussion progressed, the task-related activities gradually increased while the social activities decreased. In the 3rd week, social messages from the LC learners were not found. Specifically, it was inferred that more interactive learners use a variety of OR strategies than less interactive learners. More than 90.0% of the messages from LC learners were task-related messages that is mainly informational. On the contrary, the HC learners sent both task-related (80.3%) and social (19.7%) messages, and the HC learners' task-related messages included regulation of task progress as well as informational messages. For RQ2, messages sent to HC and LC learners were analyzed. Overall interaction pattern was similar to the result of RQ1. An interesting finding was that the HC learners received messages relevant to the relationship (11.7%) more than LC learners (3.8%) did. Also, only HC learners received messages relevant to the regulation of task progress (1.8%) and shared mental model (1.9%) while none of the LC learners did. This study illustrated the interaction pattern of OR when the visual feedback was provided. As Hadwin and her colleagues (2018) pointed, a visualization tool that informs the learning process such as learner dashboard can trigger and sustain regulated learning. When the SNA diagram was presented, the HC learners sent and received both personal and task-related messages, whereas LC learners mostly sent and received task-related messages.

References

Hadwin, A. F., Järvelä, S., & Miller, M. (2018). Self-regulated, co-regulated, and socially shared regulation in collaborative learning environment. In D. H. Schunk & J. A. Greene. (Eds.), *Handbook of self-regulation of learning and performance (pp. 83-106) (2nd Ed.).* New York, NY: Routledge.

Janssen, J., Erkens, G., Kirschner, P. A., & Kanselaar, G. (2010). Effects of representational guidance during computer-supported collaborative learning. *Instructional Science, 38*(1), 59-88.

Jo, I. H. (2009). The effect of social network diagrams on a virtual network of practice: a Korean case. *Asia Pacific Education Review, 10*, 525-534.

Lim, K. Y., Park, H., & Kim, H. (2014). Effects of social network-based visual feedback on learning in online discussion. *Journal of Educational Technology, 30*(3). 443-466.

Lim, K. Y., Lim, J. Y., & Kim, H. J. (2017). Exploratory study of the self-regulation in collaborative context scale for college students. *Journal of Educational Technology, 33*(3), 567-598.

Reimann, P., & Bannert, M. (2018). Self-regulation of learning and performance in computer-supported collaborative learning environments. In D. H. Schunk & J. A. Greene. (Eds.), *Handbook of self-regulation of learning and performance (pp. 285-303) (2nd Ed.).* New York, NY: Routledge.

Acknowledgements

Dropping in to Game Design: Iterations of a Skatepark Physics Game for a Children's Museum Exhibit

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Abstract: This poster paper describes how findings from playability tests of adult-child dyads changed our design approach for a design-and-play skatepark physics game. Played on a multitouch interactive tabletop, the game, which will be sited in a skatepark-themed children's museum exhibit, invites users to design their own skateparks using physics concepts, and then test out their designs. Less-structured 'sandbox' mechanics sometimes caused frustration, and interaction design issues could interrupt adult-child collaboration.

Overview

In this poster we present our iterative approach to creating a design-and-play skatepark game for a physics exhibit at a children's museum, and we focus in particular on how our design approach shifted after parent-child dyads test the game. Played on a 128cm wide multitouch interactive tabletop, the game invites users to design their own skateparks, explore physics concepts, and then test their designs by playing through them. We aim to create a game-based learning experience that helps: a) children develop interest in science-related design activities by seeing their relevance to the real-world practices; b) families engage in intergenerational learning and collaborative problem-solving. The larger in-development museum exhibit intends to help visitors ages five to eight, along with accompanying adults, make connections between physics, skateboarding, and design activities. This paper presents an initial design approach embodied in a game prototype, summarizes findings from playability tests with adult-child dyads, and explains our subsequent shift in design approach.

Initial design approach: Intergenerational tinkering in gameplay

Our overarching design goals centered on crafting a virtual space that would: a) invite users to engage in open-ended 'tinkering' with a skatepark environment; and b) foster collaborative play between generations of adult and child museum visitors. 'Tinkering' activities in museums are generally understood as creative exploration, modification and manipulation of materials or representations that are situated in an ill-defined problem space (Gutwill, Hido, & Sindorf, 2015). Exhibit-sited games that employ tabletop user interfaces can provide well-scaffolded tinkering experiences because they provide just-in-time feedback and visual cues for understanding a problem space, and support collaborative sense-making (Horn et al. 2012).

The first game prototype offered players the ability to design skateparks in a two-dimensional 'sandbox' space. Using an interactive panel along one edge of the screen, players could select skatepark elements like kickers, quarter pipes, and rails from a left-screen menu interface. They could choose to drag however many pieces from this menu into the skatepark, decide how to position said pieces, or delete them. Users could start the skater character wherever they liked, and adjust the mass of the skater using a slider bar. In doing so players had to make decisions about how skatepark elements were arranged at different heights and locations, and reason about how such arrangements might accomplish their endogenous design goals (see Figure 1). Our tentative conjecture was that interface buttons that were harder for children to reach might elicit parent involvement.
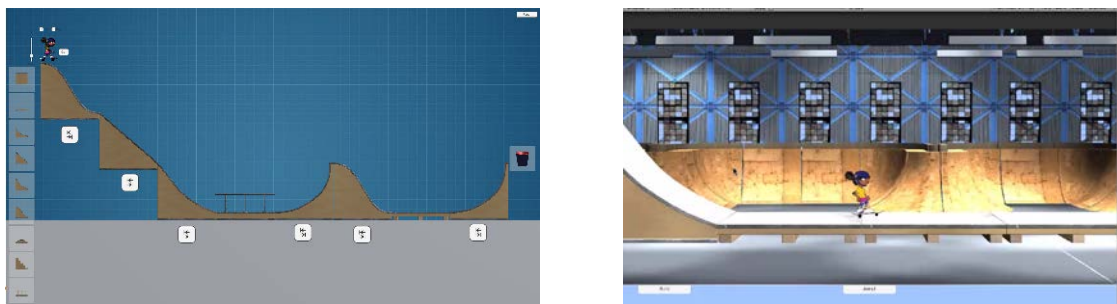
Figure 1. Design and play interfaces from the first game prototype.

Method: Playability testing and iterative agile development

This paper presents a design narrative from the projects' in-progress playability testing. Other empirical research on this project looks at the relationship between the design of the game and collaborative learning processes. The game development team has chosen to use the iterative framework of *agile development* for its processes, which emphasizes incremental and iterative organizational solutions to respond to users' engagement with early builds (Rajlich, 2006). As the exhibit is under-development, playability tests were conducted in a spare conference rom.

Playability test & redesign: Interaction, structure, and looking for 'learning'

While five out of six dyads reported that they enjoyed playing the game, we focus here on observations and feedback that resulted in changes in the game design. Three major areas for improvement were identified: a) players experienced frustration at trying to navigate interfaces, manage skatepark elements, and align skatepark elements; b) players were unsure how to initially position the skater-character and what goals they should have in designing the skatepark; and c) parents were uncertain about how they should help their children learn about physics. The interaction design of skatepark creation was a significant problem, as players spent most of their time trying to manage up to three dozen skatepark elements on the screen at once and making sure the fine boundaries of skatepark objects aligned so that the character did not collide with protruding edges. Children were frustrated at their inability to reach distant interface elements, and parents had to interrupt productive interactions with their child to help with reaching interface buttons or cleaning up skatepark elements. The full poster will present these findings in more detail.

We addressed these issues by: a) redesigning the interfaces and interactions involved in skatepark creation; b) giving the players optional exogenous goals in skatepark design and constraining where the skater could be positioned initially; and c) beginning to address the problem of parent support by displaying visual feedback about the skater's change in velocity during play mode (see Figure 2). We worked on smoothing the flow of interaction by limiting the number of virtual skatepark elements that could be on the screen, allowing players to change any given element into any other element, and implementing a snap-to-edge algorithm such that elements would automatically align if close enough together.

Figure 2. Design and play interfaces from the second prototype.

We have begun trying out implementation of simple optional goals (e.g. going fast, getting air, reaching a challenge) to help orient the players toward possible design challenges. Presently, development is examining ways to make the goals more meaningful, align progressively more-difficult challenges, and give players suggestive feedback on the design of their skatepark. We are also looking at design representations and signage, both in and out of the game, that suggest to adults how they might scaffold their child's engagement with design problems. If accepted, the poster will describe the results of these design approaches.

References

Horn, M., Atrash Leong, Z., Block, F., Diamond, J., Evans, E. M., Phillips, B., & Shen, C. (2012, May). Of BATs and APEs: an interactive tabletop game for natural history museums. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 2059-2068). ACM.

Gutwill, J. P., Hido, N., & Sindorf, L. (2015). Research to practice: Observing learning in tinkering activities. *Curator: The Museum Journal*, *58*(2), 151-168.

Rajlich, V. (2006). Changing the paradigm of software engineering. *Communications of the ACM*, *49*(8), 67-70.

The Role of Social-academic Goals in Chinese Students' Self-regulated Learning

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Abstract: Social-academic goals play an important yet unexamined role in self-regulated learning (SRL). Focusing on 11th-grade students from China, this study showed that parent-oriented goals were strongly associated with performance-avoidance goals while social status goals were strongly associated with mastery goals. Students' parent-oriented goals had a direct effect on SRL strategy use, while social status goals had an indirect effect on SRL strategy use through mastery goals.

Introduction

Self-Regulated Learning (SRL) has attracted increasing attention due to its significance in predicting academic success. SRL refers to a proactive learning process that encompasses motivation, metacognition, and strategy use (Zimmerman, 1990). Parent-oriented goals and social status goals are commonly endorsed social-academic goals, especially among the Chinese students. However, there is a dearth of research that has investigated the direct and indirect ways that social-academic goals may influence SRL. Informed by the hierarchical model of achievement motivation (Elliot, 1999), social-academic goals are posited as antecedents of achievement goals through which social-academic goals further influence the use of SRL strategies.

Methods

Participants

Two groups of students participated in the study. The first sample was 449 students in Shanghai. The second sample was 553 students in Jiangxi.

Measures

Parent-oriented goals were assessed with 12 items developed by Cheung and Pomerantz (2012). Social status goals were assessed with six items adapted from Dowson and McInerney (2004)'s Goal Orientation and Learning Strategies Survey (GOALS-S). These items assess students' purpose to obtain or maintain social status at present or in the future. Academic achievement goals were assessed with 14 items adapted from the Patterns of Adaptive Learning Skills (PALS) (Midgley et al., 2000). SRL strategy use was assessed with 22 items (Rao & Sachs, 1999). Two types of SRL strategies were assessed: 13 items on cognitive learning strategies and nine items on self-regulation.

Procedure

All the items were scored on a 5-point Likert scale from 1 (strongly disagree) to 5 (strongly agree). The first author administered the questionnaire, requiring participants to complete in around 15 minutes.

Results

Confirmatory factor analysis

First, after checking the univariate normality of variables, we posited a five-factor model comprised of mastery, performance-approach, performance-avoidance, social status, and parent-oriented goals. For the models in both areas, the majority of factor loadings were higher than .60, except two items were higher than .50.

Descriptive statistics and correlation analyses

Correlations for the Shanghai sample and the Jiangxi sample are presented below the diagonal and above the diagonal respectively (see Table 1). Parent-oriented goals and social status goals were positively correlated. The two kinds of social-academic goals both had positive correlations with achievement goals. More specifically, in both areas, parent-oriented goals were mostly associated with performance-avoidance goals, which followed by performance-approach goals, and lastly mastery goals.

Table 1： Correlations among the Central Constructs (N = 1002)

Variable	1	2	3	4	5	6	7	Alpha (JX)
1. Parent-oriented goals	—	.45**	.13**	.33**	.42**	.24**	.16**	.86
2. Social status goals	.46**	—	.33**	.31**	.25**	.18**	.16**	.83
3. Mastery goals	.27**	.44**	—	.29**	.08	.33**	.30**	.73
4. Performance-approach goals	.47**	.41**	.37**	—	.57**	.13**	.07	.77
5. Performance-avoidance goals	.50**	.38**	.23**	.66**	—	.16**	.08	.75
6. Cognitive learning strategies	.28**	.29**	.45**	.26**	.16**	—	.69**	.76
7. Self-regulation	.24**	.24**	.40**	.23**	.08	.71**	—	.74
Alpha (SH)	.93	.89	.82	.84	.81	.81	.73	

*Note. *p <.05. ** p < .01. *** p <.001.*

Structural equation modeling

The model reported a significant probability value: χ^2 (169 N = 1002) = 794.73, p < .001. Nevertheless, the model fit was considered reasonable according to other indexes: RMSEA = .06, CI = .06, .07, GFI = .92, CFI = .94, TLI = .92. Concerning social-academic goals' effects on achievement goals, social status goals significantly predicted mastery goals (γ = .504, p < .001), performance-approach goals (γ = .206, p < .001), and performance-avoidance goals (γ = .150, p < .001). Parent-oriented goals significantly predicted performance-approach goals (γ = .391, p < .001) and performance-avoidance goals (γ = .451, p < .001). But parent-oriented goals did not have significant effect on mastery goals. Regarding the direct effect of these goals on academic engagement, mastery goals positively predicted SRL strategy use (β = .416, p < .001), which followed by parent-oriented goals (γ = .205, p < .001).
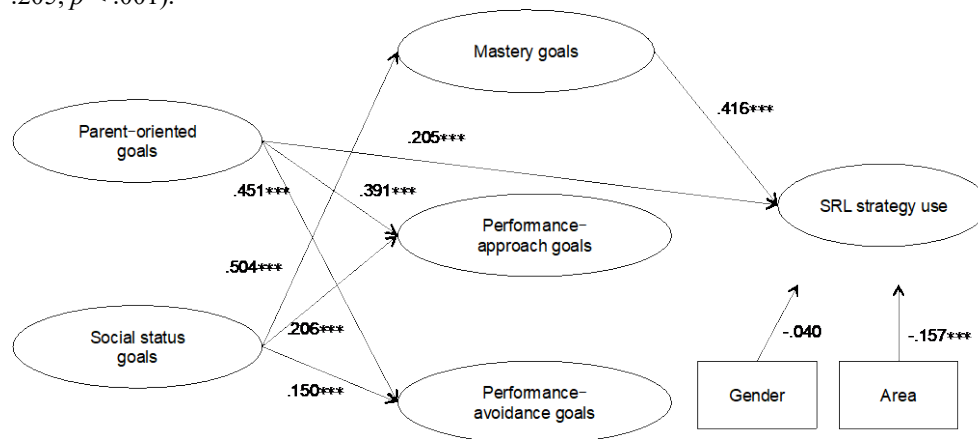
Figure1. Path coefficients of the hierarchical model.

Reference

Cheung, C. S.-S., & Pomerantz, E. M. (2012). Why does parents' involvement enhance children's achievement? The role of parent-oriented motivation. *Journal of Educational Psychology, 104*, 820-832.

Dowson, M., & McInerney, D. M. (2004). The development and validation of the Goal Orientation and Learning Strategies Survey (GOALS-S). *Educational and psychological measurement, 64*, 290-310.

Elliot, A. J. (1999). Approach and avoidance motivation and achievement goals. *Educational Psychologist, 34*, 169-189.

Midgley, C., Maehr, M. L., Hruda, L. Z., Anderman, E. M., Anderman, L., Freeman, K. E., & Urdan, T. (2000). *Manual for the Patterns of Adaptive Learning Scales (PALS)*. Ann Arbor: University of Michigan.

Rao, N., & Sachs, J. (1999). Confirmatory factor analysis of the Chinese version of the Motivated Strategies for Learning Questionnaire. *Educational and Psychological Measurement, 59*, 1016-1029.

Zimmerman, B. J. (1990). Self-regulated learning and academic achievement: An Overview. *Educational Psychologist, 25*, 3-17.

Design of a Virtual Internship to Develop Technological Pedagogical Content Knowledge

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Abstract: The purpose of this study is to design a new *virtual internship* (an epistemic game) for preservice teachers to develop their *technological pedagogical content knowledge* (TPACK). Virtual internships are learning environments in which participants can develop complex knowledge that make up the epistemic frame of a profession. The virtual internship designed for preservice teachers considers the components of TPACK as epistemic frame elements. As a subsequent step, this study also aims to evaluate preservice teachers' TPACK development using *Epistemic Network Analysis* (ENA). Adapted from social network analysis, ENA is an innovative data analysis method that affords investigation of dynamic interaction among frame elements. In this study, the "dynamic interplay" among TPACK components will be analyzed using ENA. Thus, this study proposes two novel approaches to the challenge of supporting and evaluating preservice teachers' TPACK development, which is considered essential to teach effectively with technology.

The purpose of this study is to design a new *virtual internship* (an epistemic game) for preservice teachers to develop their *technological pedagogical content knowledge* (TPACK). Extending Shulman's (1986, 1987) well-known pedagogical content knowledge (PCK) concept, TPACK aims to capture the essential qualities of teacher knowledge needed for technology integration in teaching (Mishra & Koehler, 2006). A *virtual internship* is a computer-based professional practicum simulation where participants assume the role of a professional, work on authentic tasks collaboratively, interact with mentors, and cultivate complex professional thinking. The theoretical background of virtual internships is the *Epistemic Frame Theory* (EFT) (Shaffer, 2004, 2006, 2007, 2012), which argues that it is not merely the amount of knowledge that makes up expertise in any given profession. It is the connections and configurations among different knowledge bases. Virtual internships are learning environments in which participants can develop complex knowledge that make up the epistemic frame of a profession. The virtual internship designed for preservice teachers considers the components of TPACK as epistemic frame elements. As a subsequent step, this study also aims to evaluate preservice teachers' TPACK development using *Epistemic Network Analysis* (ENA). Adapted from social network analysis, ENA is an innovative data analysis method that affords investigation of dynamic interaction among frame elements (Shaffer et al. 2009). In this study, the "dynamic interplay" among TPACK components will be analyzed using ENA.

Thus, this study proposes two novel approaches to the challenge of supporting and evaluating preservice teachers' TPACK development, which is considered essential to teach effectively with technology. First, it builds a new virtual internship, a computer-based professional practicum simulation that aims to cultivate TPACK. Secondly, it suggests employing ENA to assess preservice teachers' development of TPACK, for which portray of dynamic relationships among its constituent elements has been a challenge for researchers.

One novel approach to support TPACK development of preservice teachers is the use of a virtual internship (or epistemic game). Informed by Epistemic Frame Theory (EFT), *virtual internships* are computer-based games and professional practicum simulations where participants can develop the epistemic frame of a professional practice (Shaffer, 2004, 2006, 2007, 2012). Virtual internships are simulations of professional workplaces, and as such they provide authentic contexts in which learners work on complex design projects collaboratively.

In this study, the author designed a new virtual internship (epistemic game), namely *the School of the Future* (STF), to support the development of preservice teachers' TPACK. The design of this new virtual internship simulation is consistent with the general structure of the virtual internships that the Epistemic Games Group has been developing (Chesler, Arastoopour, D'angelo, Bagley, & Shaffer, 2013). However, it extends the use of this approach to a new area (developing complex teacher knowledge compared to STEM thinking) and targets a new population (preservice teachers compared to K-12 and undergraduate engineering students).

In the game, preservice teachers take the role of teacher interns at a fictitious school, *the School of the Future (STF)*. The school's program coordinator personally welcomes them, explains the purpose of the internship, and informs about their team assignment. The game is composed of eight sessions, called rooms. At the beginning of each session, participants receive an email from their program coordinator that details the tasks they are expected to complete. Each task is built on the previous one and designed to support the teams' completion of the final task: developing instruction that integrates technology (based on participants' majors) to

be used at the STF in the upcoming semester. Students engage in individual research, team discussion, and reflection to complete their tasks while interacting with their mentors (portrayed as mentor teachers) who will be online within the game.

The core data to be analyzed will come from preservice teachers' work at the virtual internship application and their interaction with peers and mentors that will be saved at the online platform. These data will be analyzed using Epistemic Network Analysis (ENA). Adapted from social network analysis, ENA is a data analysis method for quantifying and analyzing an epistemic frame (Shaffer et al., 2009). Built on the idea that simple collection of knowledge structures is not sufficient to characterize expertise, ENA enables to visualize the co-occurrences of frame elements in discourse (Shaffer & Ruis, in press). Thus, with ENA, one can analyze the co-occurrence of frame elements (i.e., the seven components of the TPACK framework) in discourse. It provides a picture of epistemic frames over time showing how they change character between individuals and in different interactional contexts (Nash & Shaffer, 2010). ENA, therefore, allows a new approach to assess TPACK development addressing the interconnected nature of technology, pedagogy, content knowledge. Applying ENA to TPACK development, one could treat each component of the TPACK framework as different frame elements, which become *nodes*, and the patterns of connections among them constitute the *links* between these nodes (Orrill & Shaffer, 2012). Using this method then, one could assess TPACK development in a unique way by capturing the complex interplay between TPACK components.

References

Chesler, N., Arastoopour, G., D'Angelo, C., Bagley, E., & Shaffer, D.W. (2013). Design of a professional practice simulator for educating and motivating first-year engineering students. *Advances in Engineering Education 3*(3), 1-29.

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record, 108*, 1017–1054.

Nash, P. & Shaffer, D.W. (2010). Mentor modeling: The internalization of modeled professional thinking in an epistemic game. Paper presented at the International Conference of the Learning Sciences. Chicago, IL.

Orrill, C.H. & Shaffer, D.W. (2012). Exploring connectedness: Applying ENA to teacher knowledge. Paper presented at the International Conference of the Learning Sciences. Sydney, Australia.

Shaffer, D. W. (2004). Epistemic frames and islands of expertise: Learning from infusion experiences. International Conference of the Learning Sciences. Santa Monica, CA.

Shaffer, D. W. (2006). Epistemic frames for epistemic games. *Computers and Education, 46*(3), 223–234.

Shaffer, D. W. (2007). *How computer games help children learn.* New York, NY: Palgrave Macmillan.

Shaffer, D. W. (2012). Models of situated action: Computer games and the problem of transfer. In C. Steinkuehler, K. D. Squire, & S. A. Barab (Eds.), *Games, learning, and society: Learning and meaning in the digital age* (pp. 403–431). Cambridge, UK: Cambridge University Press.

Shaffer, D.W. & Ruis, A.R. (in press). Epistemic network analysis: A worked example of theory-based learning analytics. *Handbook of Learning Analytics and Educational Data Mining*.

Shulman, L. S. (1896). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4-14. (AERA Presidential Address).

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review, 57*(1), 61-77.

Acknowledgments

Making Energy Easy: Interacting with the Forces Underlying Chemical Bonding Using the ELI-Chem Simulation

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Introduction

This study seeks to develop and explore high-school chemistry students' conceptual understanding regarding forces and energy involved in chemical bonding. Having no access to the molecular world and lacking the force-based explanation of chemical bonding, students rely on incorrect interpretations and intuitive heuristics, such as the 'octet-rule', i.e. eight electrons in the outer energy level (Taber, 2002). Most of them view chemical bonds incorrectly as attached solid spheres for which energy is needed to bring them together, or as coiled springs that release energy when relaxed (Boo, 1998).

We designed and developed an Embodied Learning Interactive environment - ELI-Chem, to alleviate these difficulties: (1) ELI-Chem removes the abstraction by providing bodily experience with the molecular level as proposed by embodied learning theory (Barsalou, 1999); and (2) ELI-Chem is based on a mathematical simulation of attraction-repulsion forces between atoms, supporting a force-based teaching approach (Nahum-Levy et al., 2007; Taber, 2002).

The working hypothesis is that more intense (in terms of force and distance moved) physical experience with the underlying electrical forces provides a stronger foundation for understanding energy changes during chemical bonding, and related concepts such as chemical stability or bond strength.

The learning environment

The base of the learning environment is a chemical bonding computer simulation displaying the attractive and repulsive forces between two atoms and the resulted potential-energy diagram. Using a mouse, students interact as an atom with another atom, exploring changes of forces and energy.

The users' interactions as an atom within the system were varied in the required motions, in terms of the distance along which the hand moves and the force necessary to move the atom. By connecting a joy-stick and a haptic device to the simulation, the ELI-Chem system offers sensory-motor experiences of the attractive and repulsive forces at four increasing degrees of embodiment (Figure 1): (1) *observing videos* that involve no action; (2) *using a mouse* to move an atom in the simulation; (3) *using a joy-stick* that moves a greater distance than the mouse, but similar force; and (4) *using a haptic device* with which motion takes place at a greater distance and greater force than the other devices.
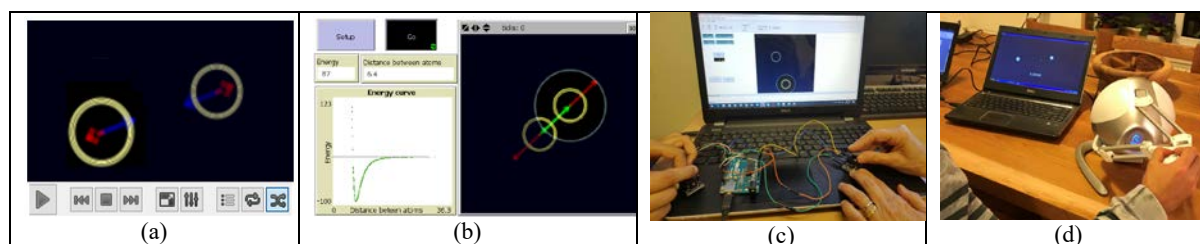
Figure 1. ELI-Chem degrees of embodiment. (a) No motion (video), (b) mouse interaction, (c) Joy-stick interaction and (d) Haptic device.

Methods

A DBR-mixed methods approach was used. Participants were high-school students majoring in chemistry. Study 1 focused on forces (N=23). Study 2 focused on energy (N=6). The Main Study included four conditions: video, mouse, joy-stick and haptic device with identical activities (N=48). Multiple-choice questionnaires, interview protocols, worksheets and screen-capture of their activities were used to generate the corpus of data. All studies had a pretest-intervention-posttest design, with the Main Study including four parallel groups.

Findings

We present the results of study 1 and study 2 that we conducted with students using a mouse (the base of the learning environment), followed by the results of the Main Study - the four degrees of embodiment.

Simulation-based reasoning with mouse interaction

Study 1: *Forces* involved in chemical bonding. Students were asked to describe chemical bond, why it is formed and what a stable bond means. Findings show that before the intervention, students did not consider repulsion forces when reasoning about the chemical bond, leading to an incorrect mental model of static "touching" balls. Learning with the ELI-Chem simulation helped students shift to consider the role of repulsion forces and perceive the chemical bond as a dynamic balance between attractive and repulsive forces.

Study 2: *Energy* involved in chemical bonding. Students were asked to describe the energy changes during bonding. Findings show that before the intervention students did not refer to forces when asked about energy; their responses were confused and inconsistent. In the post-interviews however, they described the correct energy changes using the force-base explanation.

Simulation-based reasoning with increasing degrees of embodiment

In both pre- and post-questionnaires students were asked about forces and energy involved in chemical bonding; questions were based on interviews and questionnaires of study 1 and study 2. Findings show that there was an increase in students' conceptual understanding in all four groups. Three groups - video, mouse and joystick - were indistinguishable in their learning effects. Using the haptic device showed nearly double learning gain.
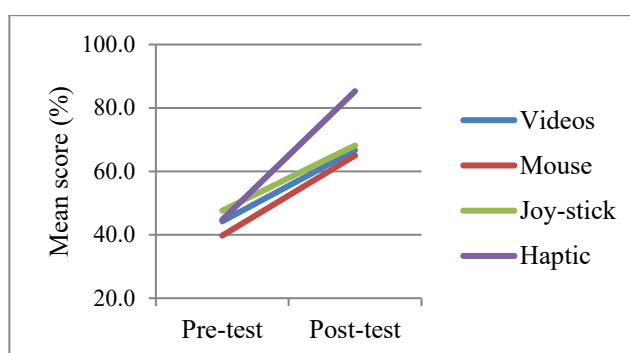
Figure 2. Change in students' understanding of conceptual knowledge.

Conclusions

Learning with the ELI-Chem environment provided students the vocabulary, concepts, principles and analogical sensorimotor schemes that are required to shift from an octet-based explanation to a force-based explanation. From inconsistency and rote articulations students moved to coherent explanation-based reasoning. They explained chemical stability as a dynamic balance between attraction and repulsion forces, they described correctly that bond formation is due to attraction forces and is associated with release of energy, and that bond breaking requires energy in order to overcome the balance between attraction and repulsion forces. Adding haptic information to create a multimodal experience of chemical bonding resulted with increased learning gain, indicating on the use of sensorimotor schemes in the building of a more accurate mental models and representations. Having the words, sensorimotor schemes, and powerful tools for explanatory force-based reasoning, students constructed a more scientific understanding of the forces and energy that are involved in chemical bonding.

References

Barsalou, L. W. (1999). Perceptions of perceptual symbols. *Behavioral and Brain Sciences, 22*(04), 637–660.

Boo, H. K. (1998). Students' understandings of chemical bonds and the energetics of chemical reactions. *Journal of Research in Science Teaching, 35*(5), 569-581.

Nahum-Levy, T., Mamlok-Naaman, R., Hofstein, A., & Krajcik, J. (2007). Developing a new teaching approach for the chemical bonding concept aligned with current scientific and pedagogical knowledge. Science Education, 91(4), 579-603.

Taber, K., & Coll, R. K. (2002). Bonding. In J. K. Gilbert, O. De Jong, R. Justi, D. F. Treagust, & J. H. Van Driel (eds.). *Chemical Education: Towards Research-based Practice* (pp. 213-234). Kluwer Academic Publishers.

Acknowledgements

Elementary Science Preservice Teachers' Use of Evidence From Rehearsals When Reflecting on Revisions of Their Practice

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Abstract: Teachers need opportunities to develop pedagogical reasoning around reflection on one's own teaching through the interpretation of evidence from interactions with students. Rehearsals have potential to allow for development of pedagogical reasoning. This study examines the evidence preservice teachers use in reflections on rehearsals in elementary science methods. The findings showed preservice teachers provided evidence from rehearsals to support their pedagogical reasoning; These analyses have implications for developing learning opportunities for developing teachers' pedagogical reasoning.

Introduction

Learning to teach is a complex, challenging activity, as teachers must learn how to use their *pedagogical reasoning* - the ability to use knowledge to make judgements in action- to coordinate interactions between students, content, and context (Shulman, 1987). This development of reasoning includes reflection on and learning from one's teaching practice in a process of analyzing a particular teaching event through the interpretation of evidence (Davis, 2006; Rosaen et al., 2008; Shulman, 1987). Preservice teachers often struggle to develop this pedagogical reasoning as they often attend to management concerns within classrooms rather than the student actions, statements, and work that are evidence of student learning (Davis, 2006; Dewey, 1965). Given these challenges, rehearsals within teacher education offer potential context for preservice teachers to develop pedagogical reasoning through limiting the complexity of the work of teaching (Kazemi et al., 2016). In rehearsals, preservice teachers approximate teaching by enacting elements of teaching practice with peers acting as students (Lampert et al., 2013; Beneditc-Champbers & Arum, 2017). Involvement in rehearsals seems to support reflective discussions on student thinking and content within elementary mathematics education, yet more information is needed about how these rehearsals can facilitate pedagogical reasoning, especially across different contexts (Kazemi et al., 2016). In this study, we ask: in written reflection on rehearsals within elementary science methods courses: what forms of evidence do preservice teacher use?

Methods

Using a qualitative case study approach (Miles, Huberman, & Saldana, 2014), this study considers how three cohorts of PSTs, 52 preservice teachers total, who were enrolled in an elementary science methods course during a four-year undergraduate teacher education program at three different institutions, used evidence in their pedagogical reasoning within their written reflections based on too-supported rehearsals (Benedict-Chambers & Aram, 2017). During these rehearsals, the PSTs enacted part of a science lesson (e.g., the opening of a lesson) with their peers acting as elementary students. Afterwards, the PSTs wrote reflections on their enactment, describing areas in need of revision, with differing prompts across the contexts. In Context 1 and 3, each PST taught a small group of peers whereas in Context 2, the PSTs worked in teams to teach the whole class. In Context 2 and Context 3, the PSTs videorecorded their enactments. We coded these written reflections using an emergent coding scheme to describe the type of evidence used to reason pedagogically about the revision with 90% percent agreement. Then, we use a matrix consider patterns across PSTs and across the different cohorts.

Findings

Across the three contexts, the preservice teachers used several types of evidence from their rehearsal in their reflection although some PSTs, especially those in context one, did not provide evidence (see Table 1). PSTs in all three universities often used broad descriptions of what happened during the rehearsal as evidence for their revision. An example of a very general description of *teacher practice* used to provide context for the needed revision is "when I asked how their ideas [changed] over time, I did not write anything on the board and quickly talked about their ideas." (Context 1, PST 7, R3). In contrast, others used more specific evidence connected to interpreting student learning to support their revisions including specific quotes from their peers acting as students, quotes of their responses to students, and patterns in student work to provide reasoning for their revisions. For instance, To support her reasoning for revising her enactment, a PST quoted a peer's "student work": "I predict that I can see an object when I have an object in front of me with nothing blocking the object,." She used this

quote *to* highlight a common pattern in student work that their prediction did not mention "the need for light and/or an eye... "(Context 2, PST 3, R1). This use of student work as evidence was more common in Context 2. Although some PSTs used only one type of evidence, 55% of the written responses used multiple types of evidence to support their revisions. In the following example, the PST used a *student quote* (italics), and a *teacher quote* (bold) to build a more complete picture of the interaction that they would change around helping students "see patterns and make connections within the data they collect:"

> After the students collected their data, I asked them "**Do you notice any overall patterns or trends within the data?**" and they simply replied "*Mmm, no.*" The pattern that I could see and wanted them to see wasn't clear to them because they didn't have enough data to support it. (Context 3, PST 1, R2.2)

This example highlights the teacher-student interaction, creating greater support for the PSTs' interpretation.

Table 1. Percent of PST revisions that include each type of evidence in each context

	Teacher Practice	Student action	Teacher Quote	Student Quote	Patterns in Student Work	Time Stamp	None
Context 1	39%	13%	2%	0%	0%	0%	48%
Context 2	52%	9%	2%	17%	14%	8%	6%
Context 3	53%	19%	29%	35%	3%	26%	7%

Discussion

Extending research on the potential of rehearsals in preservice teacher education (e.g., Lampert et al., 2013; Kazemi, et al, 2016), these findings suggest that the preservice teachers *can* use evidence from the rehearsals in their written reflection, suggesting these rehearsals can be used to develop preservice teachers' abilities to look back and interpret a particular teaching event, a key aspect of pedagogical reasoning (Shulman, 1987) The preservice teachers provided evidence of student work, quotes from students, and teacher interactions in order to consider how to improve student learning, a common struggle of elementary preservice teachers when observing in elementary classroom (Davis, 2006), despite the lack of authenticity of working with adults *acting* as children. Although some of the preservice teachers described their teaching practices rather than the interplay with students as in other studies where teachers examined their practice within elementary classrooms (Rosaen et al., 2008) there was variation in the types of evidence used in the reflections. Some of the variation seemed connected to the supports and settings of the rehearsal context. For example, in Context 2, the preservice teachers taught a larger classroom of peers in the rehearsal, likely allowing the PST more opportunity to attend to students' work and patterns in students' responses as compared to the other two contexts. The prompt for reflection in Context 1 did not explicitly ask for evidence from the enactment, likely leading to the less common use of evidence. These findings have implications for creating scaffolds for using evidence of student-teacher interactions in pedagogical reasoning during rehearsals.

References

Benedict-Chambers, A., & Aram, R. (2017). Tools for teacher noticing: Helping preservice teachers notice and analyze student thinking and scientific practice use. *Journal of Science Teacher Education*, *28*, 294-318.

Davis, E. A. (2006). Characterizing productive reflection among preservice elementary teachers: Seeing what matters. *Teaching and Teacher Education*, *22*(3), 281 – 301.

Dewey, J. (1965). The relation of theory to practice in teacher education. In *Teacher education in America: A documentary history* (pp. 140–171). New York: Teachers College Press.

Kazemi, E., Ghousseini, H., Cunard, A., & Turrou, A. C. (2016). Getting inside rehearsals: Insights from teacher educators to support work on complex practice. *Journal of Teacher Education*, *67*(1), 18-31.

Lampert, M., Frank, M. L., Kazemi, E., Ghousseini, H., Turrou, A. C., Beasley, H., … Crowe, K. (2013). Using Rehearsal to Support Preservice Teacher Learning of Ambitious Teaching. *Journal of Teacher Education*, *64*(3), 226–243.

Miles, M. B., Huberman, A. M., & Saldana, J. (2014). *Qualitative Data Analysis: A Methods Sources* (3rd ed.). Los Angeles: Sage Publications, Inc.

Rosaen, C. L., Lundeberg, M., Cooper, M., Fritzen, A., & Terpstra, M. (2008). Noticing Noticing How Does Investigation of Video Records Change How Teachers Reflect on Their Experiences? *Journal of Teacher Education*, *59*(4), 347–360. https://doi.org/10.1177/0022487108322128

Shulman, L. (1987). Knowledge and teaching: Foundations of the new reform, *57*(1), 1–23.

Using Machine Learning Techniques to Capture Engineering Design Behaviors

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Abstract: Engaging students in disciplinary practices can help students but many teachers face barriers implementing practice-based instruction as capturing, assessing, and providing feedback on practices can be labor and time intensive. This working paper reports on our early attempts to leverage machine learning techniques to analyze large process datasets of students engaged in engineering design projects within computer-aided environments. By identifying students' engineering design behaviors, we hope to examine how different sequences of these behaviors can be used provide intelligent feedback and guidance.

Background

As more precollege students engage in engineering design as part of formal schooling, teachers are challenged with supporting engineering design practices in classrooms (Purzer, Moore, Baker, & Berland, 2014). Engineering design projects present unique challenges for K-12 contexts as each student may have a unique solution instead of one "right" answer or explanation. Teachers need to debug and provide feedback on each individual solution while also helping students learn the content and practices of the domain.

Although research identifies various ways to document or capture design behaviors and practices such as video, think-alouds, or reflections, these methods are labor intensive and implemented in undergraduate or professional settings (e.g., Cross, 2011). This research uses Energy3D, a computer-aided design (CAD) program specifically designed for and implemented in K-12 educational settings. Energy3D enables students to construct energy efficient solutions, analyze a variety of performance variables, and learn and reflect upon earth and physical science principles through tutorials and reflective notes. Energy3D collects fine-grained mouse-click level actions that we wish to leverage to support teachers.

This working paper builds on other approaches to capture engineering design practices (e.g., Worsley & Blikstein, 2014) and descriptive analyses of students using Energy3D. To complement these approaches, we present machine learning techniques to identify student design behaviors. We use datasets gathered across multiple sites and multiple projects to explore if there are ways to automatically capture design behaviors that might map onto particular design heuristics or practices (e.g., Crismond & Adams, 2012) and that could be used to: 1) provide descriptive information to teachers about what design practices students are using, and 2) automatically generate support and guidance for students during design projects.

Methods

The data used in this study came from a total of 446 students across three sites within the United States: a midwestern middle school, a New England high school and a mid-Atlantic coast high school. The data were collected while students used Energy3D for different design projects. For example, at times students adjusted premade designs in order to investigate specific science concepts, and at other times students built new designs to meet specifications and constraints. The dataset consisted of a total of 708550 mouse-click initiated actions, including the time each mouse-click occurred and the specific project each student was working on at the time. Within the dataset, there were a total of 175 different mouse-click level *actions*. Examples of these actions include "change the tilt of the solar panel", "do annual energy analysis" and "animate the sun". If no clicks were recorded for more than two minutes, an action called "inactive" was added to the log during this time.

To explore design behaviors, we used three different analytic grain-sizes: *Actions*, *action categories*, and then *behaviors*. First, we grouped the 175 fine-grain mouse-click level *actions* into 12 *action categories* using a combination of 'ground up' and 'top down' procedures. Our 'ground up' procedure considered the dataset as sequences of actions ordered by time. We grouped the actions that more frequently transitioned to each other

using the Markov Clustering Algorithm, adjusting the algorithm's expansion and inflations power parameters manually so as to generate groups that were neither too big nor too small. Our 'top down' procedure refined these groups by moving actions that seemed, from the researchers perspective, as incorrectly grouped. For example, when "add wall" was found in a group with actions that edited different types of roof we manually moved it to a group that had other wall-related actions.

Second, we examined the sequences of *action categories* that occurred in the dataset and identified seven distinct states of student design *behaviors*, where each behavior is a set of action categories over a contiguous period of time that represents a distinct goal or task the student is undertaking at that moment. To identify different design behaviors, or design behavior states, we wrote an algorithm that would find the transition points in each student's sequence of action categories. These transition points were positioned to maximize the difference in characteristics between adjacent behavior states. Having created a total of 8640 states (an average of 19.4 per student), we grouped similar behavior states using a *k*-means clustering algorithm with seven centroids where the distance measure used the difference between the proportions of macro-actions within behavior states. The seven groups that this created were characterized by different distributions of the proportions of action categories (see rows in Figure 1). For example, in one group, 35% of the categories were "edit solar panels", 20% were "analysis", and 12% were "edit roof" (see first row of Figure 1). Therefore, we identified this group as containing design behavior states we called "analyze and iterate panels". In a similar manner, based on the different proportions of macro-actions in each group, we identified other design behaviors such as "analyze sun position" and "edit trees" (Figure 1).

Behaviors	Edit Solar Panels	Inactive	Edit Thermostat	Analysis	Edit Trees	View Sun	Edit Time/Location	Edit Roof	Edit Windows	Edit Walls	Edit Door	Edit Floor
Analyze and iterate panels	0.35	0.05	0.01	0.2	0.03	0.06	0.02	0.12	0.08	0.04	0.02	0.01
Analyze sun position	0.12	0.05	0	0.28	0.07	0.27	0.05	0.04	0.07	0.02	0.01	0.01
Edit trees	0.08	0.03	0.01	0.06	0.38	0.07	0.05	0.11	0.09	0.06	0.02	0.03
Add to building	0.12	0.03	0	0.05	0.04	0.05	0.02	0.09	0.38	0.06	0.15	0.01
Move sun position	0.04	0.18	0.02	0.01	0.04	0.34	0.14	0.08	0.04	0.06	0.04	0.02
Make building	0.04	0.03	0.01	0.04	0.02	0.04	0.02	0.31	0.06	0.3	0.06	0.08
Analyze	0.08	0.11	0.01	0.42	0.06	0.01	0.08	0.06	0.08	0.05	0.02	0.01

Figure 1. The proportion of each action category (horizontal axis) present in each design behavior state.

Next steps

To meet our goals of finding how different sequences of these behaviors can be used to assess design practices we plan to use a hidden Markov model with the design behaviors as hidden states. In this model, the proportions in Figure 1 give the emission probabilities from each behavior state, and the transition probabilities can be used to examine how students proceed from one design behavior state to the next.

References

Crismond, D. P., & Adams, R. S. (2012). The informed design teaching and learning matrix. *Journal of Engineering Education*, *101*(4), 738-797.

Cross, N. (2001). Design cognition: results from protocol and other empirical studies of design activity. In C. Eastman, W. Newstatter, & M. McCracken (Eds.), *Design knowing and learning: Cognition in design education* (pp. 79–103). Oxford, UK: Elsevier.

Osborne, J. (2014). Scientific practices and inquiry in the science classroom. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of Research on Science Education*. Abingdon: Routledge.

Purzer, S., Moore, T., Baker, D., & Berland, L. (2014). *Supporting the implementation of the Next Generation Science Standards (NGSS) through research: Engineering.* Retrieved from https://narst.org/ngsspapers/engineering.cfm

Worsley, M. & Blikstein, P. (2014). Analyzing engineering design through the lens of computation. *Journal of Learning Analytics*, *1*(2), 151-186.

Mapping Research and Writing Mentorship Assemblages in a Mixed Cohort Course-based Research Experience

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Abstract: This mixed methods study maps and characterizes assemblages of support in the context of a novel course-based undergraduate research experience (CURE). The CURE blends graduates and undergraduates and features a curricular emphasis on research mentorship, writing and antidisciplinarity. We find that explicit attendance to mentorship may contribute to an "open" and "safe" environment for intellectual risk-taking, and that non-supervisory, non-evaluative graduate student mentors may be uniquely useful to undergraduates navigating complex, high-stakes university research communities.

Introduction

Course-based undergraduate research experiences (CUREs) are increasingly appreciated as ways of making valuable undergraduate research experiences more inclusive (Bangera & Brownell, 2014) and scalable (Auchincloss et al., 2014). While mentorship has been recognized as critical to the success of these experiences, and the general roles and characteristics of good individual mentors have been characterized, it is also clear that mentees tend to draw different kinds of support from a variety of mentors (Linn, Palmer, Baranger, Gerard, & Stone, 2015). In order to effectively leverage distributed mentorship to support and scale CUREs at a given institution, it will be important to understand not only general roles and attributes of good mentorship, but also how mentoring is experienced and enacted across students' intersecting research networks in institutional context.

We present data from an ongoing program of design research, which particularizes our understanding of mentoring and student support in one major university geosciences research community. This iterative study is being carried out in the context of a novel type of research methods course which engages *both* graduate and undergraduate students in designing and conducting their own scientific studies, explicitly develops mentoring skills and relationships, places a special emphasis on writing and quantitative analysis (with R), and seeks to establish an open and antidisciplinary scientific culture. As design research, the goal is to simultaneously inform the iterative development of the course, address chronic learning and teaching issues related to CUREs in context, and generate new theoretical insights into learning and mentorship.

Framework and methods

We draw upon a cultural-historical activity theory framework (Engeström, 2008) and related concepts of contradictions, networks, and sociomaterial assemblages to analyze how mentorship is experienced and enacted across activity systems in and outside of the classroom. We frame mentorship broadly as teaching and learning educational process and build on work by Linn et al. (2015) who use *knowledge integration framework* to characterize typical activities of individual mentors, shifting the focus to how multiple mentorship (mosaic, constellation) emerges as a distributed sociomaterial phenomenon in one particular institutional context.

The mixed methods triangulation approach to this study integrates (1) quantitative assessment of scientific skills, conceptual knowledge, understanding of practice, confidence, identity development, and professional intentions based on a modified Undergraduate Research Student Self-Assessment (URSSA) instrument (Weston & Laursen, 2015); (2) an egocentric network analysis of support interactions and linkages among students; (3) qualitative analysis of student-generated coursework and reflective journaling to characterize knowledge gains and support relationships; and (4) a purposive sample of semistructured interviews with students on their classroom experience and learning to refine our understanding of how students experienced the course and used different kinds of support relationships. Of the 27 students in the Spring 2017 class, 20 participated in this study. All data was collected after the last day of the class. Data collection planned for Spring 2018 will also be included.

Findings and discussion

Students reported gains in research and writing skills as well as higher confidence in their scientific research abilities (Figure 1). They cited peer-to-peer forms of mentorship as important for developing their research ideas, refining their writing, and gaining confidence in the quality of their work. Some graduate students reported that

undergrads were either unable or unwilling to comment substantively on their writing, but grad-graduate feedback on writing and research was common and highly valued (Figure 2 c).
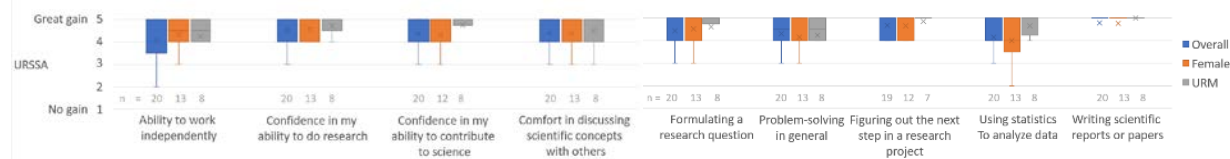
Figure 1. Self-reported gains in abilities and confidence. URM is underrepresented minorities.

Research and writing mentorship was distinctly distributed in nature, emerging via networked assemblages of support inside and outside of class (Figure 2). Formal, designed mentorship interactions in the CURE were reported by students as very important, as were pre-existing and emergent relationships. Undergrads gained insight into the diversity of lab norms, objectives, tools and techniques, and reported that in-class discussions with peers and graduate mentors helped them prepare for interactions with their external faculty research mentors. Students reported that the in-class focus on peer support contributed to a research environment that they described as "safe" and "open," an environment that they sometimes contrasted with other contexts in which they learned and acted as researchers. We find evidence that undergrads felt particularly comfortable learning from and working with graduate and undergraduate peers positioned as fellow student-researchers (i.e. rather than as TAs or lab managers). Access to non-evaluative, non-supervisory research mentors may be distinctly beneficial to emerging undergraduate researchers in this CURE context.
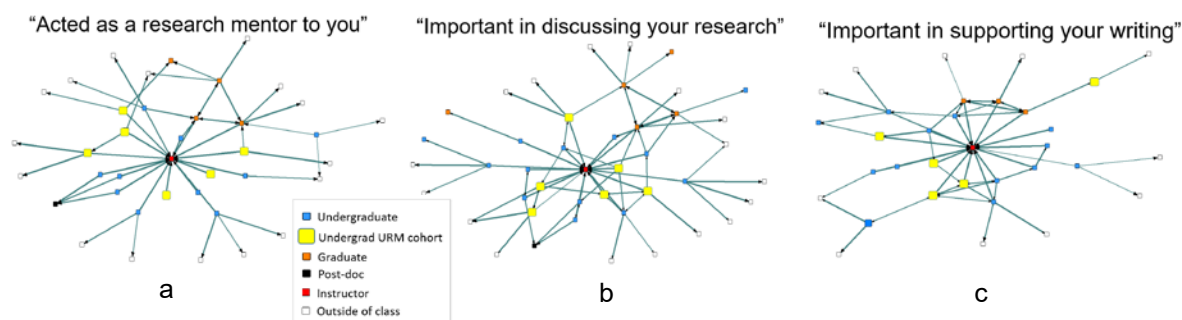
Figure 2. Support networks for research (a, b) and writing (c) as reported by course participants in a name generator survey instrument and visualized with UCINET and NetDraw.

Graduate students reported gaining a better understanding of the tensions and power dynamics between undergrads and their faculty mentors and advisors outside of the course, and suggested that the course could focus more specifically on preparing students to interact with their faculty research mentors. We find evidence that graduate student mentors in the class sought to provide professional and psychosocial support they saw as sometimes missing in undergrad-faculty mentoring interactions. This adaptation by graduate students may have been due to the way mentorship practices were specifically cultivated through readings and breakout discussions. Furthermore, grads and undergrads alike reported intentions and efforts to influence culture, research aims, tools and methods in their research labs external to the course. Adding spring 2018 data, we aim to move towards a typology of emergent mentorship assemblages and draw implications for the design and scaling of CUREs which more strategically leverage and influence the broader network and culture of research.

References

Auchincloss, L. C., Laursen, S. L., Branchaw, J. L., Eagan, K., Graham, M., Hanauer, D. I., … Dolan, E. L. (2014). Assessment of Course-Based Undergraduate Research Experiences: A Meeting Report. *CBE-Life Sciences Education*, *13*(1), 29–40. https://doi.org/10.1187/cbe.14-01-0004

Bangera, G., & Brownell, S. E. (2014). Course-Based Undergraduate Research Experiences Can Make Scientific Research More Inclusive. *CBE Life Sciences Education*, *13*(4), 602–606.

Engeström, Y. (2008). *From teams to knots: Activity-theoretical studies of collaboration and learning at work*. Cambridge University Press.

Linn, M. C., Palmer, E., Baranger, A., Gerard, E., & Stone, E. (2015). Undergraduate research experiences: Impacts and opportunities. *Science*, *347*(6222), 1261757. https://doi.org/10.1126/science.1261757

Weston, T. J., & Laursen, S. L. (2015). The Undergraduate Research Student Self-Assessment (URSSA): Validation for Use in Program Evaluation. *CBE-Life Sciences Education*, *14*(3), ar33.

Cueing Gestures in a Seasons Simulation: Outcomes of an Embodied Learning Approach to Supporting Explanations

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Abstract: This study involved middle school students using a gesture-augmented computer simulation to construct causal explanations. In individual interviews, students were prompted to explain what causes seasons before, during, and after using the simulation. We found strong evidence that students improved their explanations, and although students frequently used gestures in their post-simulation explanations, they infrequently used the specific gestures prompted by the interface.

Keywords: embodied learning, explanation, gesture-augmented simulations, science education

Introduction

Research on gesturing has suggested that there are deep connections between the ways we move our bodies and cognitive processes including how we reason and learn (Clark, 2013; McNeill, 2008; Roth, 2001). Emerging digital technologies are making it possible to integrate student gesturing with computer simulations that model critical science processes and phenomena. Devices can transform natural body movement such as gestures, performed in real time, into input that simulations can interpret as expressions of students' understanding.

The design of the gesture-augmented simulation environment used in this study draws from theories of embodied cognition (Shapiro, 2010; Wilson, 2002) and corresponding principles for creating effective embodied learning designs (Abrahamson & Lindgren, 2014). In particular, these simulations attempt to "cue" the performance of gestures shown to be productive for developing new understandings.

The focus of the current study is a gesture-augmented simulation of seasons and how the cued gestures interact with students' explanations. Crowder and Newman (1993) have shown that gestures play a pivotal role not only in the communication of scientific insights, but also in their construction. The construction of explanations in this work is viewed as involving the development of imagistic mental models that visualize unobservable causes for observable effects (Clement, 1989). The particular ways of configuring cued gestures with visualizations, and their interplay with explanations, is ripe for exploration. In this study, we investigated the following questions: (1) To what extent do students' explanations of seasons change after using a gesture-augmented simulation? (2) Does using a gesture-augmented simulation elicit gesturing in post-simulation explanations of seasons? (3) To what extent do students use cued gestures in their explanations of seasons after using the simulation?

Methods

The initial design conjecture (Sandoval, 2014) guiding this cycle of research from a broader project was that cueing gestures that are congruent with key explanatory elements of the system would support learners in constructing more sophisticated explanations of the seasons. We posited that students would subsequently draw upon the cued gestures as resources for explanation even after they were done using the simulation.

A total of 26 students from multiple middle schools located in a small urban community participated in this study. There were 20 males and 6 females, and participants' ages ranged from 12-15 years old (average 12.8 years old). Students were recruited to participate in the study during study hall periods and after school programs, and they were compensated ten dollars for their participation.

The seasons simulation in this project afforded embodied interaction using three gestures cued by the system and embodying different aspects of the phenomena: (1) angle of light rays, (2) concentration of light rays, and (3) angle of earth relative to the sun. Students used the simulation on a laptop computer with a *Leap Motion* device plugged in via USB that can track hand movement with infrared cameras.

Interviews on the topic of seasons were conducted individually and lasted approximately thirty minutes. During interviews, students were asked for their ideas about what causes the seasons before using the gesture-augmented simulation. While using the simulation students were presented with several explanatory challenges, which involved making something happen in the simulation and explaining how that action affected the seasons. After using the simulation, students were asked again about their explanation of the causes of seasons, and then they were asked to explain a second time with an explicit request that they use their hands.

This study uses mixed methods, with quantitative analyses to compare the quality of pre-simulation explanations and post-simulation explanations and to identify instances of the cued gestures, and qualitative analyses to examine how students used cued gestures in their explanations. To address RQ1, explanations were coded for the presence of two normative explanatory elements (tilt and intensity of light rays) and one non-normative explanatory element (distance). These data were transformed to ordinal data for analysis. An iterative approach was used to address RQ2-3, in which the researchers began with closed coding, using an initial set of top-down codes, and then used open coding to expand and refine these codes (Saldaña, 2012).

Findings

Research Question 1: A Wilcoxon signed ranks test was calculated, and it indicated that students' post-simulation explanation scores were statistically significantly higher than pre-simulation explanation scores, $Z = 153.000$, $p < .001$. Kendall's W was calculated as a measure of effect size, and $W = 0.654$, indicating a large effect.

Research Questions 2 and 3: Twenty students used representational gestures post-simulation when they were initially asked for their explanations and were not prompted to gesture, and 24 students used representational gestures when they were asked to use their hands to help show their explanations. However, very few students (1 student unprompted and 3 students when prompted) used the gestures cued by the simulation.

Discussion and Conclusions

The results showed that after using a simulation that cued their gestures, students improved their explanations of causes of the seasons (RQ1) and often used gestures in their final explanations (RQ2). This indicates that gesture-augmented simulations can be effective for creating a space where students can more adeptly integrate physical representations into their explanations. However, students rarely used the specifically cued gestures in their final explanations (RQ3). It is possible that while these simulation-cued gestures encouraged embodied interaction generally, they did not afford specific explanatory power for students on this topic.

A simulation that cued gestures led to subsequent student explanations that were rich with gestures and were assessed to be more sophisticated compared to the explanations given prior to using the simulation. These findings suggest a genuine affordance of these designs for integrating verbal and spatial representations. Additional research on the effects of embodied cueing, and how these cues intersect with specific learning content, is needed to fully understand the applications of gesture-augmented simulations.

References

Abrahamson, D., & Lindgren, R. (2014). Embodiment and embodied design. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences (2nd edition)* (pp. 358-376). New York, NY: Cambridge University Press.

Clark, A. (2013). Gesture as thought. In Z. Radman (Ed.), *The hand, an organ of the mind: What the manual tells the mental* (pp. 255-268). Cambridge, MA: MIT Press.

Clement, J. J. (1989). Learning via model construction and criticism: Protocol evidence on sources of creativity in science. In J. A. Glover, R. R. Ronning, & C. R. Reynolds (Eds.), *Handbook of creativity: Assessment, theory and research* (pp. 341–381). New York, NY: Plenum Press.

Crowder, E. M., & Newman, D. (1993). Telling what they know: The role of gesture and language in children's science explanations. *Pragmatics & Cognition, 1*, 341-376.

McNeill, D. (2008). *Gesture and thought*. University of Chicago Press.

Roth, W. M. (2001). Gestures: Their role in teaching and learning. *Review of Educational Research, 71*, 365-392.

Saldaña, J. (2012). *The coding manual for qualitative researchers* (2nd ed.). Los Angeles, CA: Sage.

Sandoval, W. (2014). Conjecture mapping: An approach to systematic educational design research. *Journal of the Learning Sciences, 23*, 18-36.

Shapiro, L. (2010). *Embodied cognition.* Routledge.

Wilson, M. (2002). Six views of embodied cognition. *Psychonomic Bulletin & Review, 9*, 625-636.

Acknowledgments

The Effects of Inquiry-Based Learning in Higher Education Statistics Tutorials on Students' Self-Efficacy, Attitudes, and Achievement Emotions

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Abstract: This pilot investigation explored the effects of an inquiry-based learning environment on students' self-efficacy, attitudes, and achievement emotions in the context of higher education statistics tutorials. Results showed positive effects of the learning environment, leading to increased self-efficacy, and more positive attitudes and achievement emotions. First evidence on the intercorrelations among the three variables point towards positive, pairwise relationships. The findings emphasise the need for future research and a larger scale investigation on the topic.

Introduction

Statistics is an increasingly important and relevant subject in the age of big data. The ability to analyse and interpret data is becoming essential in many professional tracks. Despite the subject's importance, large proportions of students in higher education do not like statistics classes, and up to 80% of these students show signs of statistics anxiety (Onwuegbuzie & Wilson, 2003). To effectively reduce this high figure, research needs to investigate the mechanisms underlying students' negative reactions towards statistics, and try to improve the current situation, for example via changes in the instructional design of statistics classes.

Here, the instructional design inquiry-based learning (IBL) appears promising, as it was found to increase students' confidence in and attitude towards mathematics in higher education (Laursen, Hassi, Kogan, Hunter & Weston, 2011). Based on these findings in mathematics, our project aimed to explore the effects of IBL in the context of statistics, which is the most relevant aspect of mathematics in most social sciences. For this, we designed an inquiry-based learning environment within a postgraduate-level statistics tutorial and measured its effects on students' self-efficacy to learn statistics, as well as their attitudes and achievement emotions towards the subject.

Background

Prior research on the emotions of university students showed that statistics anxiety is negatively correlated with students' self-efficacy to learn the subject (Perepiczka, Chandler & Becerra, 2011), which provided grounds for our project to further examine self-efficacy in the context of higher education statistics. However, several other variables have been indicated to influence students' overall view of a subject, such as attitudes and achievement emotions (Di Martino & Zan, 2011; Pekrun, 2006). Although IBL was shown to have a positive effect on the variables individually, these three aspects have not been investigated together in this context up to now.

The observed positive effects can be related to the fact that IBL encourages students to overcome obstacles on their own, providing grounds for encountering authentic success, which was emphasised as the most effective way to induce self-efficacy in academic settings (Bandura, 2009). The positive effects as well as the connectedness of the three variables can further be explained by the control-value theory (Pekrun, 2006), which highlights the influence of students' perceptions of their control over a given task, as well as the subjective value of that task.

Research Questions

1. Does IBL lead to an increase in students' self-efficacy to learn statistics, positive attitudes, and positive achievement emotions towards statistics?

For this question, positive results were expected based on similar findings in higher education mathematics, and the similarity between both subjects.

2. Are self-efficacy, attitudes, and achievement emotions positively correlated in the context of statistics?

Method

The intervention spanned over five subsequent tutorials for a Master's level statistics class. Each session consisted of the distribution of a real-life scenario to help students understand the practical applications of statistical

methods. Based on the scenario and other related documents, students would embark on individual journeys of inquiry, and complete a series of steps: formation of research questions, data analysis, interpretation of results, and presentation of research findings. The tasks were created to match the stages of the inquiry cycle (Murdoch, 2006).

Testing was carried out at three timepoints: during the first ($N = 20$), the third ($N = 14$), and the fifth session ($N = 8$). The first and last measurements assessed all three variables, providing a pre-post comparison, whereas the second measurement only assessed students' achievement emotions. We measured students' responses on three Likert-type scales from existing literature, which were adapted to the context. The scales measured the three variables of interest, namely self-efficacy (Finney & Schraw, 2003), attitudes (Schau & Emmioglu, 2012), and achievement emotions (Pekrun, Goetz & Perry, 2005). All three scales were found highly reliable ($\alpha > .92$).

Results

Compared to the start of the intervention, students showed higher levels of self-efficacy to learn statistics ($d = 1.10$), more positive attitudes ($d = 0.94$), and more positive achievement emotions ($d = 1.42$). Achievement emotions showed a positive trajectory from the first to the third ($d = 1.04$), as well as the third to the fifth session ($d = 0.31$). A significant correlation was only found between attitudes and achievement emotions at the pre-test ($\rho = .85$, $p < .001$). The other correlations did not reach significance, but showed partially moderate relationships: attitudes and achievement emotions (post: $\rho = .47$, $p = .243$), achievement emotions and self-efficacy (pre: $\rho = .42$, $p = .098$, post: $\rho = .17$, $p = .691$), and attitudes and self-efficacy (pre: $\rho = .21$, $p = .366$, post: $\rho = .24$, $p = .570$).

Discussion

Results underline that the use of IBL has a positive influence on students' self-efficacy to learn statistics, and on their attitudes and achievement emotions towards statistics, which is in line with prior research (Laursen et al., 2011). Our results further expand the scope of previous research by analysing the relation among the three variables, showing a strong connection between attitudes towards learning statistics and students' achievement emotions during the IBL sessions. The other correlations did not reach significance, likely due to the small sample size in this first investigation. Moreover, the lack of a control group requires cautious interpretation of the longitudinal results. The continuation of the project aims to overcome these limitations and to allow a more detailed analysis of the relationship between IBL and students' affective outcomes in higher education statistics.

References

Bandura, A. (2009). Cultivate Self - efficacy for Personal and Organizational Effectiveness. *Handbook of Principles of Organization Behavior, 179–200.*

Di Martino, P., & Zan, R. (2011). Attitude towards mathematics: A bridge between beliefs and emotions. *ZDM - International Journal on Mathematics Education, 43(4)*, 471–482.

Finney, S. J., & Schraw, G. (2003). Self-efficacy beliefs in college statistics courses. *Contemporary Educational Psychology, 28(2)*, 161–186.

Laursen, S., Hassi, M.-L., Kogan, M., Hunter, A.-B., & Weston, T. (2011). *Evaluation of the IBL mathematics project: student and instructor outcomes of inquiry-based learning in college mathematics*. University of Colorado Boulder, (April), 204.

Murdoch, K. (2006). Inquiry learning: journeys through the thinking processes. *Teacher Learning Network, 13(2),* 32-34.

Onwuegbuzie, A. J., & Wilson, V. A. (2003). Statistics Anxiety: Nature, etiology, antecedents, effects, and treatments--a comprehensive review of the literature. *Teaching in Higher Education, 8(2)*, 195-209.

Pekrun, R. (2006). The control-value theory of achievement emotions: Assumptions, corollaries, and implications for educational research and practice. *Educational Psychology Review, 18(4)*, 315–341.

Pekrun, R., Goetz, T., & Perry, R.P. (2005). *Academic Emotions Questionnaire (AEQ). User's manual.* Department of Psychology, University of Munich.

Perepiczka, M., Chandler, N., & Becerra, M. (2011). Relationship Between Graduate Students' Statistics Self-Efficacy, Statistics Anxiety, Attitude Toward Statistics, and Social Support. *The Professional Counselor, 1(2)*, 99–108.

Schau, C., & Emmioğlu, E. (2012). Do introductory statistics courses in the United States improve students' attitudes? *Statistics Education Research Journal, 11(2), 86–94.*

Competing Epistemologies in the Construction of Popular Science

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Abstract: This paper focuses on how the personal epistemologies of scientists and science communicators shape their practices and interact with one another in the construction of popular science news. I present data from observations and interviews with scientists and reporters as they work together to produce science news to show how competing epistemologies result in compromises that—when presented to the public—might lead readers to form understandings that are at odds with disciplinary knowledge.

There is a rich thread of research in the learning sciences that deals with learners' (and educators') sense of what it means to know something. Often categorized together as studies of "epistemology" (e.g. Hofer & Pintrich, 2008), this thread is concerned with people's understandings of what it means to know and learn in a given context and how this impacts how people engage in knowledge construction. Scientific inquiry is a socio-epistemic practice. As such, science is not a collection of inerrant facts, but rather a process through which groups of people work together to construct shared knowledge by means of questioning, observation, experiment, and analysis. Researchers interested in both science education and communication argue that when teaching or communicating science it is important to make the process of scientific knowledge construction visible (e.g. Lederman, 1998). Of course, this is often not an easy task. This is particularly true when trying to communicate scientific research to the public through popular science news articles. That is because scientists must convey their research through mediators, like journalists. Journalism, too, is a socio-epistemic practice, but one with very different values, customs, and forms of discourse. Many argue that certain journalistic practices make it difficult to convey the process of science in news articles. In particular, the episodic nature of print stories is blamed for resulting in few descriptions of the scientific process or research methods (Dunwoody, 2008). Empirical studies of the content of science stories in the popular press seem to support this claim. Studies show that the majority of science stories contain little or no details about the methodological process of the research on which they report (Dimopoulos & Koulaidis, 2002). These competing socio-epistemic practices cause tensions between scientists and journalists with scientists often blaming journalists for not fully portraying the uncertainty of scientific research. Is this truly the sole fault of the journalists?

In this paper, I present research findings from a study of the individual interactions between various actors involved in science communication. In particular, this paper reports on observations and interviews with scientists and university news reporters. Four scientists were interviewed about their recently published research. The interviews took the form of semi-structured clinical interviews. The questions required the scientists to perform a variety of tasks, including describing their research in detail, explaining their beliefs about communicating science to the public, and making judgments about the most and least important aspects of the research for the public to understand. Three news reporters, assigned by the university news service to write about the research of the four scientists, were individually interviewed about their understanding of the research, their process of writing about the research, and their beliefs about what aspects of the research will appeal to the public. Furthermore, the interactions between the scientists and the news reporters were observed and video recorded. These interactions usually took the form of interviews of the scientists by the reporters. Additionally, email exchanges and notes between the scientists and the reporters were collected.

An analysis of the interviews and observations revealed that the reporters often struggled to understand the methods employed in the research. However, during interactions with the reporters, the scientists often left out details of the methods. In particular, they often failed to explain the justifications for many methodological decisions. Furthermore, when asked during interviews what is the least important part of the research for the public to understand, the scientists frequently referenced methodological details. However, when the scientists explained their research to me they gave much more detail about methods, justified their decisions more frequently, and provided caveats.

Gilbert & Mulkay (1985) argue that scientists frequently adopt two conflicting discursive repertoires within their practice. The *contingent repertoire* treats research as socially constructed and tentative, and treats claims as open for debate. The *empiricist repertoire* treats research as objective and unproblematic, and treats claims as confirmed facts. The contingent repertoire is often seen as "private" as it is commonly adopted between scientists themselves, while the empiricist repertoire is frequently use in "public" communications (Gilbert & Mulkay, 1985). I believe the differences in the depth of methodological description shows that the scientists in this study were treating me as a fellow scientist and, thus, utilizing their contingent repertoire. Whereas, interacting with the reporters they adopted the empiricist repertoire.

I argue that the mechanism that underlies these shifts in discourse is the instantiation of particular *epistemological resources* (Hammer & Elby, 2002) depending on the function and intent of their presentation of their research and claims. When presenting to the reporters, the participant scientists attempt to convey their findings as legitimate and important, and they are concerned with their knowledge claims being accepted rather than understood. However, when explaining their research to me, the participant scientists are less concerned with legitimizing their work, after all I am no power to aid in communicating their research. Instead, they treated me as a "knowledgeable outsider" who can appreciate the nitty-gritty details of laboratory life and the scientific process. So, the lack of provided details about methods can be seen, as at least partially, the result of variation within the discursive and epistemic practices of science. However, that only explains the scientists' failure to provide details, not the journalists' failure to ask for more detail.

Journalists also utilize a variety of roles within their epistemic practice. For example, Fahy & Nisbet (2011) map nine distinct roles—each with particular commitments and practices—that a journalist might adopt. Most important for my analysis is the role of *conduit* that accurately explains scientific information. When acting as conduits, journalists concentrate on portraying information from a single source as accurately as possible, rather than attempting to evaluate the validity of that information through multiple sources. This shifts the focus from whether the claim is supported by evidence to whether there is a match between what a source says and what a journalist presents. In this way, the journalist acts as a "neutral transmitter" of information (Dunwoody, 2008). This appears to be the stance adopted by the participant reporters. In essence, the participant reporters are treating the participant scientists as *epistemic authorities*—the most significant sources of information in the formation of knowledge (Kruglanski, 1989). One can imagine reporters who, instead of given sole epistemic authority to the scientist, relies on other sources and their own perspectives. These reporters may have demanded the additional information needed to make sense of the methods. In fact, other journalistic roles, such as *watchdog* and *interpretive reporter* (Fahy & Nisbet, 2011), do adopt such epistemologies. Of course, the same university employs both the reporters and the scientists in this study. The journalists have investment in "selling" the research, rather than engaging critically with it, but this results in representations that are difficult to understand or justify.

The lack of detailed methods in popular science news likely has many contributing factors. In this paper, I have argued that one of those factors is a network of competing epistemologies both within and between epistemic practices. Both scientists and journalists rely on multiple epistemologies and often, as is the case with the participants in this study; their epistemologies work together to construct understandings that obfuscate details of process in representations of science. When these representations are presented to the public they might lead readers to form understandings that are at odds with disciplinary knowledge (Corbett & Durfee, 2004). This is neither the fault of the scientist, the journalist, nor the lay public. Rather, all actors can be viewed as the source of failure and success in the communication of science. If the goal is to increase successful communication and public science engagement then scientists and journalists need work together to begin devising ways to coordinate epistemological resources to form a joint epistemic practice.

References

Corbett, J. B., & Durfee, J. L. (2004). Testing public (un)certainty of science: Media representations of global warming. *Science Communication, 26*(2), 129–151.

Dimopoulos, K. & Koulaidis, V. (2002) The socio-epistemic constitution of science and technology in the Greek press: an analysis of its presentation. *Public Understanding of Science, 11*, 225–41.

Dunwoody, S. (2008). Science journalism. In M. Bucchi & B. Trench (Eds.). *Handbook of Public Communication of Science and Technology*. London and New York: Routledge.

Fahy, D. & Nisbet, M. (2011). The science journalist online: Shifting roles and emerging practices. *Journalism 12*(7), 778–793

Gilbert, G. N., & Mulkay, M. (1984). *Opening Pandora's Box: A Sociological Analysis of Scientists' Discourse*. Cambridge University Press.

Hammer, D., & Elby, A. (2002). On the form of a personal epistemology. In B. K. Hofer & P. R. Pintrich (Eds.), *Personal epistemology: The psychology of beliefs about knowledge and knowing.* (pp. 169-190).

Hofer, B. K., & Pintrich, P. R. (Eds.). (2002). *Personal epistemology: The psychology of beliefs about knowledge and knowing*. Mahwah, NJ: Erlbaum.

Kruglanski, A. W. (1989). *Lay Epistemics and Human Knowledge: Cognitive and Motivational Bases*. New York: Plenum.

Lederman, N. G. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of Research in Science Teaching, 29*(4), 331-359.

Measuring Integrated Knowledge – A Network Analytical Approach

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Abstract: Scientific literacy is an important part of education. Students that demonstrate scientific literacy can organize and coordinate their science ideas to interpret and explain a diverse range of phenomena. However, the complex thinking connected to this ability is not captured by most assessments today. We address this issue by investigating how the little researched construct of knowledge integration which describes how students coordinate their ideas in explanations can be measured using network analysis.

Measuring what matters

A central goal of education is to prepare students to act independently and responsible in society and the world. In a world increasingly dominated by science and technology, scientific literacy is an important part of this education (National Research Council, 2012). A key component of scientific literacy is students' ability to use their knowledge about science to interpret and explain phenomena in diverse real-life contexts. To explain real life phenomena, students must be able to produce coherently organized accounts by coordinating a range of relevant scientific ideas with evidence. As Schwartz & Arena (2013) argue, assessments of scientific literacy should measure how well students are prepared to do so. However, instead of measuring how much students are prepared to engage in complex thinking, i.e., to what degree they are able to coherently organize relevant ideas, most current assessments focus primarily on how much knowledge students have acquired (Pellegrino, Chudowsky, & Glaser, 2004). The ability to coherently organize relevant ideas is emphasized in the knowledge integration perspective on learning (Linn, 2006). It focuses on how students develop increasingly more coordinated networks of ideas, i.e., ideas are added, new connections established, and others are refined. Students that have a coherently organized knowledge can rely on strongly developed idea networks that allow them to explain real world phenomena by coordinating relevant ideas.

Measuring knowledge integration

Although knowledge integration is important for the development of scientific literacy, there is little consensus on how best to measure it. A number of cross sectional studies used different approaches to measure knowledge integration. While Lee & Liu (2010) focused primarily on the number of connections between ideas and the quality of these ideas that students use to explain phenomena, Nordine, Krajcik, & Fortus (2011) operationalized integrated knowledge as students' ability to consistently use central ideas across a range of phenomena. This illustrates that there are different perspectives on measuring knowledge integration that focus on different aspects of the construct while leaving out others. For example, the holistic measure of the extent to which students connect ideas used by Lee & Liu (2010) does not provide information about *which* ideas are most central to students' thinking or the relative strength of connections between ideas. However, this is helpful information for educators to, for example, adjust teaching or helps to improve curriculum. We address this issue by using network analysis to characterize the extent to which students' ideas are well-integrated and how the strength and coherence of connections between ideas changes during instruction. As this research is part of a broader project on the teaching and learning of energy, we ask the following research question: How can network analysis be used to more fully measure and describe the extent to which students possess integrated knowledge of energy?

Methods

A unit on energy was implemented in 7th grade at two schools in the US with $N = 311$ students. The teachers selected a sample of $N=30$ students that are representative sample regarding grades. Students were interviewed before and after the unit using semi-structured interviews in which students were presented 5 different phenomena from everyday life, e.g., a bouncing ball. The students were asked "How would you explain this phenomenon?". The interviewers then used non-instructive probes to clarify students' answers. Using qualitative content analysis, we coded which ideas students used to explain the phenomena (inter-coder reliability $\kappa = 0.87$). In a next step, we analyzed which ideas students used in the explanation of a single phenomenon. We then created maps of co-occurrence of ideas across phenomena. The resulting dataset is a network that can be analyzed on individual and aggregate level for each of the measuring time points using network analysis methods (e.g., Grunspan et al., 2014).

Results

The following preliminary results are based on the analysis of interviews from 17 out of the 30 students in our sample. Based on background measures such as grades etc. we do not expect the full results which we will present at the conference to change significantly. Figure 1 shows the aggregated pre and post networks. The ideas used by students are depicted as circles where the size of the circle represents the number of co-occurrence with other ideas. The lines between the circles represent that two ideas occurred together and the width of the lines shows often those ideas were used together. From pre to post we see a substantial development concerning which ideas co-occur and how often they co-occur. The energy unit used in this study emphasizes energy transfers and fields between objects, and we see that those ideas are used increasingly more often with other ideas and that the number of those co-occurrences has increased after instruction. Energy transfer has become a more central idea during the unit as it becomes strongly connected with many other ideas. To what extent those connections are coherently organized can be investigated using a coherence measure from network analysis (see e.g. Koponen & Huttunen (2013)). We find, that the post network as a whole has become more coherently organized. We used the pre to post difference in this coherence measure to predict the pre to post difference on a test that assesses how well students can use energy ideas to interpret and explain phenomena. As a validity check, we used Bayesian methods to fit a linear model that predicts the gain on the energy test using the gain on the coherence measure. The standardized coherence regression coefficient has a value of $\beta^2 = .6$ [.2, .9] [89% probability interval] and $R^2 = .34$

Discussion and outlook

Concerning our research question, the presented networks show that network analysis has the potential to show how students integrated knowledge develops over time, e.g., the analysis shows that students develop an integrated understanding around the central idea of energy transfer and to a lesser degree integrate the idea of fields. Further, we interpret the strong relationship between the coherence measure and performance on the energy test that asks students to use energy ideas to make sense of a range of phenomena (not part of the interviews) as evidence that the approach is valid. Based on these results, we consider network analysis of integrated knowledge a promising approach to provide insight into not just whether, but how, students use a range of science ideas to make sense of the world. We feel that ICLS 2018 provides an excellent opportunity to share what we believe is a promising method of assessing integrated knowledge and to discuss potential improvements with other researchers.
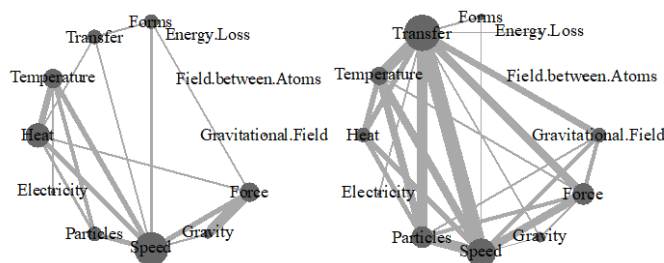
Figure 1. Aggregated idea networks pre (left) and post (right).

References

Grunspan, D. Z., Wiggins, B. L., & Goodreau, S. M. (2014). Understanding Classrooms through Social Network Analysis: A Primer for Social Network Analysis in Education Research. *Cell Biology Education*, *13*(2), 167–178.

Koponen, I. T., & Huttunen, L. (2013). Concept Development in Learning Physics: The Case of Electric Current and Voltage Revisited. *Science & Education*, *22*(9), 2227–2254.

Lee, H.-S., & Liu, O. L. (2010). Assessing learning progression of energy concepts across middle school grades. *Science Education*, *94*(4), 665–688.

Linn, M. (2006). The Knowledge Integration Perspective on Learning and Instruction. In *The Cambridge handbook of: The learning sciences*. New York, NY: Cambridge University Press.

National Research Council. (2012). *A framework for K-12 science education*. Washington, D.C.: The National Academies Press.

Nordine, J., Krajcik, J., & Fortus, D. (2011). Transforming energy instruction in middle school to support integrated understanding and future learning. *Science Education*, *95*(4), 670–699.

Pellegrino, J. W., Chudowsky, N., & Glaser, R. (2004). *Knowing what Students Know* (3. print). Washington, DC: National Acad. Press.

Schwartz, D. L., & Arena, D. (2013). Measuring What Matters Most.

Comparison of 3D Display Technologies for Embodied Interaction in Virtual Hands-On Experiential Learning

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Abstract: This study aims to explore the effect of different 3D display technologies on hands-on virtual experiential learning environment (VELE). We tested three display technologies, VR HMD, 3D projection and AR HMD, in two math learning scenarios. Different display techniques significantly affected user experience in learning. Results on visual comfort, flow experience, and learning experience in the VR HMD condition are significantly higher than those in 3D projection and the AR condition. We conclude that VR HMD contributes to better viewing experience and learning experience for hands-on VELE in the scenarios tested. Whether the results still hold reliably in more complex learning activities and long-term learning need to be further studied.

Introduction

Experiential learning can be an effective way to promote learning interest. Through interactive and hands-on experience, learners not only can transfer the experience gained through learning activities into the construction of knowledge, but also develop positive intrinsic interest and extrinsic behaviors (Huang et al., 2016). Experiential learning requires appropriate tools, locales, and equipment, some of which are difficult to create (e.g. different ecosystems) or experience (e.g. surgical operations). It has been therefore often limited with fixed locations (e.g. mechanical assembly). With the advancement of digital media, real-time virtual reality (VR), and augmented reality (AR) technologies, various types of experiential learning now can be designed in new ways. These new technologies support the creation of vivid, lifelike virtual experiential learning environment (VELE), with some already showing superiorities over traditional learning (Furió, Juan, Seguí† & Vivó, 2015; Alhalabi, 2017).

In VELE, embodied interaction (EI) design is a way to enable people to interact mentally as well as physically with information technology and has been considered as a human-computer interaction approach for improving interaction efficiency and interaction experience (Zhang, Li, & Wachs, 2016). Learners in a VELE is supported with intuitive embodied experience which may reduce their cognitive load and contributes to the internalization of knowledge (Furió, Juan, Seguí† & Vivó, 2015). Different VR technologies have been applied in VELEs where display characteristics maybe a key factor influencing user experience, especially for EI design. In this paper, we present a study of three immersive display technologies to test how they each enhances viewing experience and interaction efficiency in experiential learning.

Participants and experimental design

A total of 26 volunteers (15 males and 11 females, 23.00 ± 3.34 years) participated in the experiment. We adopted a single-factor within-subject design. The within-subject factor is 3D display modes which include 3 conditions: VR HMD, 3D projection, and AR HMD. Except for the display technology, other factors were controlled among the three conditions. There are six dependent variables: visual comfort, flow experience and four learning experience indicators (intrinsic interest, concentration, behavior intention, and presence). The presentation order of different display modes was counterbalanced.

Experimental mission and apparatus

We constructed a VELE for math learning and designed two learning scenarios (Figure 1). Users explore the digital scenes and manipulate virtual objects using HTC vive handheld controllers which are represented in the virtual environment as a pair of virtual hands. Users may feel like that they are manipulating the virtual objects with their own hands (Figure 1). The two learning scenarios are used with three display modes (Figure 2).

Scenario 1: Calculation of Cone Volume

Scenario 2: Tower of Hanoi problem

Figure 1. Two mathematic learning

VR HMD   3D projection   AR HMD

Figure 2. Experiencing the VELE in three display conditions.

Results and discussion

We performed repeated measurement analysis of variance. Results are shown in Table 1. Different display techniques/conditions are indeed an important factor affecting experiences in VELE. As illustrated in Table 1, for the majority of the indicators of visual comfort and learning experience, the values in VR HMD condition are significantly better than those in 3D projection and AR HMD condition. Within the scenarios tested in this study, VR HMD contributes to better viewing experience and learning experience for hands-on VELE.

Table 1: Descriptive statistics and Difference test results in different display condition.

Display conditions	3D experience $M(S.D)$	Naturalness $M(S.D)$	Image quality $M(S.D)$	Viewing experience $M(S.D)$	Avoidance of discomfort $M(S.D)$	Flow $M(S.D)$	Intrinsic interest $M(S.D)$	Behavior intention $M(S.D)$	Concentration $M(S.D)$	Presence $M(S.D)$
VR HMD	4.42 (0.95)	4.28 (0.93)	4.31 (0.84)	13.58 (2.18)	8.92 (1.32)	63.77 (8.04)	12.88 (1.92)	12.50 (1.96)	9.08 (1.96)	12.58 (1.90)
3D Projection	3.88 (0.95)	3.88 (0.88)	4.08 (0.84)	10.38 (3.20)	8.15 (1.84)	56.12 (11.68)	11.23 (2.97)	10.69 (2.91)	9.19 (1.67)	10.42 (3.32)
AR HMD	3.73 (1.04)	3.64 (0.99)	3.77 (0.91)	9.770 (3.15)	7.65 (2.19)	52.12 (16.2)	11.19 (3.32)	10.38 (3.59)	8.69 (1.59)	10.81 (3.15)
F value	3.404*	2.933	2.204	12.532**	3.638*	6.206**	3.018+	4.406*	0.585	4.211*

References

Alhalabi, W. S. (2017). Virtual reality systems enhance students' achievements in engineering education. *Behaviour & Information Technology, 35*(11), 1-7.

Furió, D., Juan, M. C., Seguí, I., & Vivó, R. (2015). Mobile learning vs. traditional classroom lessons: a comparative study. *Journal of Computer Assisted Learning, 31*(3), 189-201.

Hsu, T. C. (2017). Learning English with augmented reality: do learning styles matter? *Computers & Education, 106*, 137-149.

Huang, T. C., Chen, C. C., & Chou, Y. W. (2016). Animating eco-education: to see, feel, and discover in an augmented reality-based experiential learning environment. *Computers & Education, 96*, 72-82.

Parmar, D., Bertrand, J., Babu, S. V., Madathil, K., Zelaya, M., & Wang, T., et al. (2016). A comparative evaluation of viewing metaphors on psychophysical skills education in an interactive virtual environment. *Virtual Reality, 20*(3), 1-17.

Zhang, T., Li, Y.-T., & Wachs, J. P. (2016). The Effect of Embodied Interaction in Visual-Spatial Navigation. *ACM Transactions on Interactive Intelligent Systems, 7*(1), 1–36.

Contextual Dimensions of an Ambient Intelligent Classroom

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Abstract: The classroom is the classical environment where the formal education process traditionally takes place. Ambient intelligence is the artificially intelligent way of how to render a specific environment aware and responsive to a human being within that same environment. In this paper, we present a case of how the engagement of ambient intelligence within a classroom can be apportioned into three basic aspects that collectively can change the way we visualise classical teaching spaces. Three contextual dimensions of ambient intelligence are presented and espoused within an academic framework to shed instrumental insights and strategic directions on the future of ambient intelligent classrooms.

Introduction

The use of technology within an educational environment has proved to increase learner engagement levels as well as enhance the learning process in general (Oakman, 2016). Nowadays we find classrooms that are overflowing with technology that not only enhances the learners' engagement levels, but also ameliorates the learning process as it is able to adapt to the diverse learning styles of the same learners. Ambient Intelligence (AmI) is a digital technology that employs Artificial Intelligence (AI) to manage an electronically controlled and enclosed environment in a way that it responds and adjusts to the specific needs and characteristics of a person within that environment. This paper has been motivated by the ongoing research within the domain of intelligent learning environments where we exclusively focus on the academic and pedagogical connotations of AmI applied to the classroom, merging AI in education (AIED) with numerous other areas.

Ambient intelligence in education

The notion of personalisation has been applied to various domains especially when the goal is to enhance a service or a product that closely fits the corresponding requirements of a human user. Personalizing education is perhaps the goal of every educator to ensure that each learner experiences a learning scenario that perfectly fits the background, academic needs and interests of the same learner (Montebello, 2017). In order to achieve such personalisation capabilities, the use of artificially intelligent techniques are required, as a user profile needs to be generated in order to match the specific service attributes or product specifications to the intended user. The application of AmI to education is not abundant, comprehensive and coherent even though it can be traced back to prior to the millennium. A number of research studies investigated the physical aspect of the classroom (Ramadan, 2009; Winer & Cooperstock, 2002) that involves monitoring students and teacher occupying the classroom, and automatically controlling the lights, air-conditioning, multi-media displays and acoustics. Other AmI researchers (Antona, et al., 2010) investigated how to create a smart educational environment through the development of some kind of piece of furniture that sits in the classroom. Additional AmI projects, like those by Shen, Wu, & Lee, (2014) and Ramadan (2009) made use of wireless technologies, NFC (Near Field Communication) and RFID respectively, to be less intrusive and remain loyal to the covert nature of AmI while providing a context-aware environment. To some extent the above mentioned AmI research projects failed to focus directly on the academic content in a way that accommodates the unique learning needs of each individual student, which is what AmI in education should be focusing on. Leonidis, et al., (2010) offer a better insight in the way they tackle the application of AmI to education as they present a theoretical framework, called ClassMATE, that enables pervasive interactive and context aware instruction within a smart classroom. Apart from the indispensable contextual awareness and a technologically-enhanced classroom, is the need of adaptive educational content coupled with the learning profile of each individual student. What we propose in the next section is conceivably a deeper and thorough insightful analysis of what the key elements are as we investigate these factors within an academic context and substantiated within sound and established learning theories.

Case for the classroom

Applying AmI within a classroom presents a delicate situation due to the complex and sensitive nature of dealing with learners within an environment that is susceptible to major disruptions at the minimal change in the conditions. The fact that the same learners are the source of such changes, one has to keep in mind our responsibility towards each learner and their education, as it is imperative and indispensable that an AmI classroom is optimally designed and precisely devised. We propose a model made up of three dimensional aspects that collectively make up the AmI environment required within a classroom. The first of the three dimensions,

that we believe forms an essential part of the AmI paradigm when applied to education, is the human aspect. This aspect is obviously part of any AmI application as the enhanced environment is purposely boosted to add value to people's quality of life. However, we specifically chose to use the social concept rather than the human one due to the classroom's social connotations and the intricately dynamic complexities that occur within a traditional classroom. Group dynamics play an important role within the social aspect of a class, and the Connectivism learning theory, that was proposed in 2005 by Siemens (2004) and Downes (2005), is frequently associated with the use of social networks for educational purposes. This theory justifies how learners employ networked resources, as potentially those within an AmI classroom, to form connections and links to learn and share knowledge and ideas. The second dimension from the AmI paradigm within a classroom being proposed is the technological aspect that, apart from the physical instrumentation, incorporates the application of artificial intelligent technologies to personalize the entire process and match the respective profile of every learner. We propose the use of learners' academic portfolios as part of the learning profiling process and personalisation which are generated with the help of established machine learning techniques that AI researchers have employed over the years. Modelling the specific characteristics of a learner requires a direct mapping of the individual portfolio to the unique learner as they map the distinctive attributes and academic features including educational background, extra-curricular interests, personal preferences, and specific learning goals. Associated with this line of thought is the adaptive learning theory as it supports the personalisation and customisation of services, information, and products to the specific requirements and profile of each individual user. The final dimension of the proposed smart classroom paradigm is the educational aspect, that requires the support and adoption of relevant learning theories to which the researcher subscribes and associates his or her philosophical reasoning. In our third dimensional aspect, we apply the connectivism and adaptive learning theories as the basis of our pedagogical methodologies to address the education aspects of our proposed model. This model is based on the concepts of a personal learning environment whereby technology and social aspects come together within a classroom as learners and educator interact through electronic and face-to-face interventions. The educator is responsible of setting up the learning 'scene', providing potential resources, physical and/or electronic, give any required support, while facilitating the entire educational process. The students, on the other hand, have access to their personal portal, which acts as an arena for all of them to share resources and experiences, as each of them is individually assisted and supported through the smart environment. This support is manifested through classroom displays, interventions by the educator to a single student or the class, or through the networked peers themselves.

Conclusions

In this paper, we have presented a proposal on a systematic and thorough way on how to deploy an AmI classroom through the proper analysis and investigation of three basic aspects, namely: social, grounded within the connectivism learning theory; technological, grounded in the adaptive learning theory; and educational, that brings together the other two aspects. This has enabled us to ensure that a proper and structured process has been established to develop comprehensive and complete AmI classrooms in the near future.

References

Antona, M., Margetis, G., Ntoa, S., Leonidis, A., Korozi, M., Paparoulis, G., & Stephanidis, C. (2010). Ambient Intelligence in the Classroom: an Augmented School Desk. *3rd Inter. Conf. on AHFE*. Miami: AHFE.

Downes, S. (2005). *An Introduction to Connective Knowledge*. Retrieved 10 13, 2017, from http://www.downes.ca/post/33034

Doyle, W. (2006). Ecological Approaches to Classroom Management. In C. Evertson, & C. Weinstein, *Handbook of classroom management* (pp. 97-125). New Jersey: Lawrence Erlbaum Associates .

Leonidis, A., Margetis, G., Antona, M., & Stephanidis, C. (2010). ClassMATE: Enabling Ambient Intelligence in the Classroom. *International Journal of CEACIE, 4*(6), 1058-1061.

Montebello, M. (2017). *Personalised e-Learning, EdD thesis.* Sheffield: University of Sheffield.

Oakman, H. (2016). *The rise of game-based learning*. Retrieved 09 15, 2017, from Education Technology: http://edtechnology.co.uk/Article/the-rise-of-game-based-learning

Ramadan, R. (2009). Leveraging RFID Tech. for Intell. Classrooms. *4th Inter Design & Test Workshop*, 1-6.

Shen, C., Wu, Y., & Lee, T. (2014). Developing a NFC-equipped smart classroom: Effects on attitudes toward computer science. *Computers in Human Behavior, 30*, 731-738.

Siemens, G. (2004). *Connectivism: A Learning Theory for The Digital Age*. Retrieved 10 13, 2017, from Elearnspace: http://www. elearnspace.org/Articles/connectivism.htm

Winer, L., & Cooperstock, J. (2002). The "Intelligent Classroom": changing teaching and learning with an evolving technological environment. *Computers & Education, 38*, 253-266.

Uncovering the Rich Club Phenomenon in an Online Class

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Abstract: Social interaction is key for learning. In this study on student interaction in a social learning environment, we identified two student groups with contrasting levels of social *prestige*—defined as the level of discursive attention one receives in relation to one's discursive activities. The higher-prestige group was found to form a densely connected "rich club" less likely to interact with the lower-prestige group. Further network analysis linked this phenomenon with the timing of students' relationship formation and weekly participation.

Introduction

Social interaction is an important element of learning. The present study explored a so-called "rich club phenomenon" in an online discussion environment. Members of the rich club have higher social *prestige*, are closely connected with each other, and are more capable of constraining information flows and idea exchanges. In this study, we applied social network analysis (SNA) to answer three questions: (1) To what extent did students demonstrate varied levels of prestige in their online discussion? (2) Can a rich club be observed in the network? (3) Which factors might explain the emergence of varied prestige or the rich club phenomenon?

Methods

The research context was an undergraduate, fully-online course participated by 20 undergraduate students. The course was taught on Yellowdig, a social learning platform with features similar to Facebook. On Yellowdig, students could contribute *pins* (similar to Facebook posts), which can be reacted to (e.g., "Like") or commented on. Compared to a traditional discussion forum, Yellowdig provides richer features for social learning.

Discussion data used to answer research questions included 274 pins, 514 comments, 36 mentions, and 74 reactions exported from Yellowdig. Conceptualizing prestige as the level of discursive attention one receives in relation to one's discursive activities, we constructed a social network based on their replies and divided students into two groups based on the ratio of weighted *indegree* to weighted *outdegree* in the network. We examined differences between the high- and low-prestige groups in a number of network measures and probed the possibility of a rich club phenomenon in the course. Finally, we examined temporal dynamics and ego networks to explore factors potentially contributing to the varied prestige and the rich club phenomenon.

Findings

Characterizing prestige in the reply network

To characterize prestige, students were divided into two groups according to the ratio of one's weighted indegree to weighted outdegree. The categorization resulted in two groups: Group A (*n*=8) constituted by students with a ratio greater than 1; and Group B (*n*=12) comprised of students with a ratio equal or smaller than 1. We found students from two groups initiated equivalent amount of interactions with equivalent number of peers, but Group A students received more replies than others, occupied more favorable network positions, and maintained stronger ties with peers they became connected with.

Uncovering the rich club phenomenon

To examine a possible "rich club" in the network, we focused on the direction of student interactions, breaking all interactions into four categories: A→A, B→B, A→B, and B→A. We found that Group A students seldom replied to Group B students (9.61%), even though Group B were actively initiating contact with them (37.77%); Group A students were essentially more likely to launch interactions with other Group A students (33.18%). These network characteristics provided initial evidence of a rich club phenomenon (Vaquero & Cebrian, 2013).

Explaining the emergence of prestige and the rich club

To address the third research question, we inspected two aspects—the timing of student posts and the temporal evolution of the network. For the timing of posts, we found most Group B students' pins were barely on time, whereas most Group A students posted their pins one day in advance. Group A students contributed their initial posts significantly earlier than Group B students ($t(180)= -6.520, p<.001$); the same happened for comments.

As for the temporal evolution of the network, we investigated how those four categories of interactions (i.e., A→A, B→B, A→B, and B→A) accumulated over the course. Figure 1 shows the saturation curves of four interaction types. As the curves indicated, Group A students did not only establish nearly 90% of all possible connections among themselves, they also built their connections quickly. Group B students were trying to connect with Group A throughout the course and made more than 80% of all possible B→A connections. However, they received much less attention from Group A students.
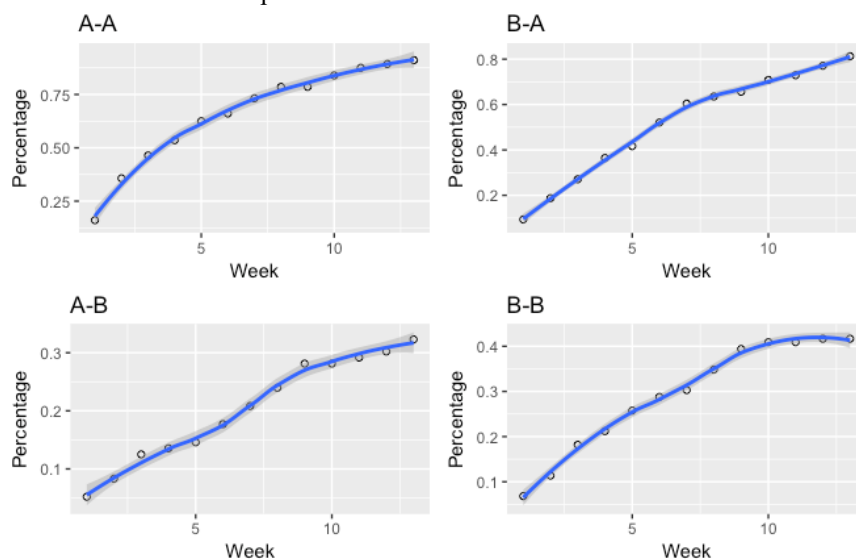
Figure 1. The saturation curves of four types of connections. The y-axis represents the percentage of accumulated unique ties in comparison with all possible ties for a connection type.

Analysis of temporal ego networks of all students told a complementary story at the local level. Comparisons found Group A students' ego networks had larger *network sizes* and lower *dyadic constraints* than Group B students. In other words, Group A students were immediately connected with more peers and they were more likely to broker or constraint others' connections. These findings indicated Group A students were not only better connected but also had stronger brokerage presence in their local neighborhoods.

Conclusions

Social participation figures as an important aspect of online learning. This study contributes to the literature, especially to the line of work on using online discussion to support student interactions. In this study, we divided an online class into two groups in light of an operationalization of social prestige based on SNA. Analysis of the directionality of student interactions showed students from the high-prestige group connected more frequently with similar prestige peers, and students from the low-prestige group received few interactions from the high-prestige group. Further analysis was conducted to explain these findings. Preliminary results pointed out the significance of temporality. The high-prestige group established inner-group connections much faster than the low-prestige group in the first four weeks; they also generally posted earlier in weekly discussions, leaving peers ample opportunities to react to their ideas.

Findings regarding network prestige and the rich club phenomenon build on prior work on student interaction patterns in online discussion (Dawson, 2010) and course communication (Vaquero & Cebrian, 2013). While earlier research using course performance data found low-performing students more likely to connect with similarly low-performing peers, this study found lower-prestige students in online discussion were willing to connect with higher-prestige peers, but their attempts were not reciprocated. The explicit recognition of such an engagement gap in online discussion, together tentative explanation of its emergence offered by the study, contributes to the literature and calls for future research and design efforts to mitigate this gap.

References

Dawson, S. (2010). "Seeing" the learning community: An exploration of the development of a resource for monitoring online student networking. *British Journal of Educational Technology, 41*(5), 736–752.

Scott, J. (2012). *Social Network Analysis*. SAGE. https://doi.org/10.5040/9781849668187

Vaquero, L. M., & Cebrian, M. (2013). The rich club phenomenon in the classroom. *Scientific Reports, 3*, 1.

Peer Tutor Matching for Introductory Programming: Data-Driven Methods to Enable New Opportunities for Help

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Abstract: The number of students that can be helped in a given class period is limited by the time constraints of the class and the number of agents available for providing help. We use a classroom-replay of previously collected data to evaluate a data-driven method for increasing the number of students that can be helped. We use a machine learning model to identify students who need help in real-time, and an interaction network to group students who need similar help together using approach maps. By assigning these groups of struggling students to peer tutors (as well the instructor), we were able to more than double the number of students helped.

Introduction

While a typical classroom may be full of students experiencing the same problem and students who have solved that problem, this expertise is rarely utilized. Instead, often the only source of help is the instructor, who is most likely unable to help all the students who need help within the time constraints of the class period. To address this problem, we propose and evaluate several methods for improving the efficiency of student assistance using machine learning. Diana et al. (2017b) showed that low-level log data from the Alice introductory programming environment can be used to accurately predict student grades, and that they could increase the number of students helped by matching struggling students to a peer tutor based on the similarity of their code. A subsequent study (2017a) found that the accuracy and interpretability of the previously reported predictive model could be improved by increasing the grain size of the features from a vocabulary of terms derived through natural language processing (NLP) to small snippets of code. We explore how this improvement impacts peer tutor matching and the efficiency of providing help more generally. Also, we use an interaction network graph to test if students who may benefit from the same kind of help can be grouped together, increasing the efficiency of the instructor or peer tutor.

Methods

The data used in the current study were originally collected by Werner et al. (2012) as part of a two-year project exploring the impact of game design and programming on the development of computer science skills. The students were asked to complete an assessment task called the *Fairy Assessment*. The current experiment closely follows the data transformation methodology reported in (Diana et al., 2017b) to convert raw log data into program representations called *code-states* and the code-state complexity reduction methodology reported in (Diana et al., 2017a) to reduce code-states to smaller, *code-chunks*.

We used ridge regression to predict students' grades. We compared two methods for generating the features inputted into the regression. In the first method, features were a vocabulary of NLP terms generated from the students' code-states. In the second method, each code-state was first converted into a list of code-chunks, and then into a *chunk-frequency vector*. A chunk-frequency vector is a vector whose length is equal to the total number of features being considered in the model. Each value in the vector corresponds to the frequency of the respective code-chunk.

The predicted grades were also used to estimate which students need help and which students may be able to provide help. We call the students classified as needing help using their actual grades *low-performing students*. This classification serves as the ground-truth that we use to evaluate our predictive model. In a real-world implementation, we would not have access to the actual grades, so we must estimate them and use those estimates to classify students as needing help. If a student's predicted grade was in the bottom quartile, and they have not been helped or are not currently being helped ("helped" status persists across time), then that student was added to the group of students who still need to be helped, which we call the *Help Pool*. If a student's predicted grade was in the top quartile, and they are not currently helping a student, then that student was added to the group of students who may be able to help other students, which we call the *Tutor Pool*. For each student in the *Help Pool*, we first checked to see if the instructor was available to help. If so, the instructor was assigned to that student. If the instructor was unavailable (i.e., helping another student), then we searched for a peer tutor. We used a network graph of each code-state (or code-chunk frequencies) for each user to match tutees to tutors. We

searched for tutors who shared a common ancestor node (i.e., shared a previous program state) with the tutee. These tutors were added to a pool of potential tutors. From that pool, we selected the tutor with the common ancestor node that was closest (i.e., least number of steps away) to the tutee's current node. The same method applied if segmenting was used, except that instead of matching the instructor or peer tutor to one student, the instructor or tutor was matched to a segment of students with a similar problem.

While the primary goal of our previous work (Diana et al., 2017b) was to evaluate how well our model could correctly classify students who would go on to have a low final grade (low-performing students), the primary goal of the current experiment is to evaluate how efficient this intervention would be. That is, we were interested in what percentage of those low-performing students could be helped, and how we can maximize that percentage. We call this ratio the *Efficiency Index* (EI), and define it formally as:

$$EI = \frac{Low\ Performing\ Students\ Helped/Being\ Helped}{Low\ Performing\ Students}$$

Results

We compared models using a linear mixed model with the measure of interest as the dependent variable, model as a fixed effect, and time bin as a random effect. We hypothesized that we can use low-level programming data to group similar low-performing students together so that they can be helped as a group. To test this, we first replicated our previously reported model to use as a baseline measure. Then, we generated a new model that incorporated segmenting. Both models used NLP features in a ridge regression and an interaction network graph built using code-states as nodes. We found that the EI (M=0.467, SD=0.210) of the model that incorporated segmenting was significantly higher (p<.001) than the baseline model (M=0.305, SD=0.190).

We also hypothesized that using the presence or absence of code-chunks as model features would improve the performance of the model. To test this, we generated a model using a sample of the code-chunks from our previous work that were shown to be good predictors of learning outcomes (Diana et al., 2017a). We generated a model using these 16 code-chunk features (rather than the NLP-derived terms used in the baseline model), and found that this code-chunk model had a significantly lower (p<.001) RMSE (M=0.246, SD=0.064) than the baseline model (M=0.263, SD=0.073).

Finally, we hypothesized that a network graph generated using code-chunks as nodes would lead to greater coverage and a higher EI. To test this, we generated a model using the same 16 code-chunks described above as features in the regression. A network graph was also generated to incorporate segmenting. However, instead of each node corresponding to a code-state, each node corresponded to a chunk-frequency vector. Representing nodes as chunk-frequency vectors more than doubled the coverage (coverage=0.924) compared to the network graph generated using code-states (coverage=0.374). The EI of the model using chunk-frequency vectors to generate the network graph (M=0.813, SD=0.128) also had a significantly higher (p<.001) EI than the model using code-states (M=0.428, SD=0.217).

Conclusion

In this paper, we explored a method for increasing the amount of help given in a typical class period. Our previous work demonstrated that we can use a predictive model to accurately identify students who may need help. We built off of this work in two ways. First, we improved the accuracy of the predictive model by using more relevant features. Second, we drastically increased the number of students able to be helped from, on average, 3.72 to 9.92 by grouping low-performing students together to be helped as a group (in combination with better model features). These results suggest that using low-level log data to group and match low-performing students to peer tutors may be an effective way to increase the amount of help given in a classroom.

References

Diana, N., Eagle, M., Stamper, J., Grover, S., Bienkowski, M., & Basu, S. (2017a). Data-driven generation of rubric parameters from an educational programming environment. Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics) (Vol. 10331 LNAI). http://doi.org/10.1007/978-3-319-61425-0_47

Diana, N., Grover, S., Eagle, M., Bienkowski, M., Stamper, J., & Basu, S. (2017b). An instructor dashboard for real-time analytics in interactive programming assignments. In ACM International Conference Proceeding Series (Vol. Part F1267). http://doi.org/10.1145/3027385.3027441

Werner, L., Denner, J., & Campe, S. (2012). The Fairy Performance Assessment : Measuring Computational Thinking in Middle School. Proceedings of the 43rd ACM Technical Symposium on Computer Science Education - SIGCSE '12, 215–220. http://doi.org/10.1145/2157136.2157200

Sketching and Gesturing for New Ideas in Collaborative Design

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Abstract: In searching for practices that feed creativity, we compared sketching—an acknowledged design practice that facilitates creativity—with gesturing, which shares many of the features important for ideation by sketching. Analyzing two higher education textile design projects, we found that sketching and gesturing fulfilled differing epistemic roles, although there were some parallels. We suggest that both sketching and gesturing should be treated as epistemic practices that extend beyond easing communication to eliciting new ideas.

Introduction

Creative practices are the core of design education. Creativity is also an important twenty-first century skill (Sawyer, 2018). Collaborative design includes communication and coordination, but these two functions are not sufficient for successful designing. Creative design not only reproduces existing solutions but entails emergence —that is, solutions are unexpected and cannot be foreseen or reduced to individual contributions (Sawyer, 2003). Successful designing requires "seeing things differently" through exploration rather than systematic search and combining of ideas (Cross, 1982). One important design practice that facilitates creativity (i.e., idea generation) is freehand sketching (Purcell & Gero, 1998). However, while sketching appears beneficial to professional designers, it does not always deliver for novices (for a review, see Härkki, Seitamaa-Hakkarainen & Hakkarainen, 2016a). In search of practices for design education, we compared sketching with a practice that shares many of the same emergence-facilitating features; that practice is gesturing. In particular, we set out to identify *the epistemic roles of sketching and gesturing in collaborative design.* Further details of the three studies summarized here are available in Härkki, Seitamaa-Hakkarainen and Hakkarainen (2016a, 2016b).

Designers benefit from sketching and gesturing

As a skill, design sketching differs from artistic drawing. According to Goel (1995)*, sketches are deliberately left imprecise, ambiguous, fluid, amorphous, and indeterminate. Sketches are abstractions, schematizations, and conceptualizations* (Tversky, 2011); *they are not realistic depictions like drawings*. In this way, sketches allow for multiple interpretations, which is considered central to idea generation (Goel, 1995). Gesturing is also based on ambiguous abstractions. Gestures serve several important functions for education (Alibali & Nathan, 2012), which gesture researchers summarize as follows. Through activation, manipulation, packaging, and exploration of spatio-motoric information*, gesturing can lead to changes in both the content and direction of speech and thought, generation of new ideas and ideas that cover a wider range of conceptualizations, to revealing emerging knowledge not available through speech, as well as enhancing abilities to perform spatial transformations* (Kita, Alibali & Chu, 2017). Yet, despite this evidence, gestures are rarely studied as a resource for idea generation. According to our literature review (Härkki, Seitamaa-Hakkarainen & Hakkarainen, 2018), gestures are important for idea generation because *the ambiguity and spatio-temporal character of gestures facilitates the expression and study of ideas in visual, spatio-motoric and kinesthetic dimensions and invokes new interpretations—new ideas to steer the work in unforeseen directions.*

Methods

The research setting encompassed two textile design projects: 3D textile puzzles for visually-impaired children and sea creature accessories for kindergartners. The participants (first-year students on a craft teacher program at the University of Helsinki) worked in teams of three. In total, 7 teams and 9 hours of video were analyzed. Focusing on the epistemic roles of sketching and gesturing challenged existing methods of analysis in terms of how to preserve their indigenous visual, spatio-motoric and kinesthetic character. To that end, a rigorous micro-level method of *video-based qualitative content analysis* was developed. Rather than transcripts, the analysis utilized video and segmentation principles that separated each gesture stroke and sketching act (continuous pen-movement) for each participant. Categorizations of the characteristic uses, i.e., the epistemic roles, were developed for each study.

Major findings

The developed categorizations revealed that the epistemic roles of sketching and gesturing in collaborative design did align in some respects. Both *introduced several hundred meanings* into the design conversation *that were not*

available in accompanying speech. Those meanings (e.g., round; cabin; soft; this; write; that class) often related to structure and metacommunication. Even those parts that did not provide complementary meanings (or could be considered redundant) could not simply be deemed unnecessary; rather, *they are co-expressive* and *engage modalities other than language in a communicative move*, making messages easier to understand. On the other hand, sketching and gesturing played several epistemic roles that differentiated them in line with their indigenous character. *Sketching was favored for structural explorations, especially those requiring precision and memory. Gestures, as spatio-kinesthetic analogues, were favored for sensory, spatio-motoric, and experiential content.* For designing, all of these are central aspects.

Conclusions and discussion

This research contributes to the discussion on transforming pedagogy into creative learning outcomes (Sawyer, 2018). We suggest that, in the search for productive epistemic practices for creative ideation, gestures should not be disregarded. Gestures are co-expressive and make messages easier to understand. More importantly, as ambiguous abstractions restricted by the affordances of our motor-system, gestures share features that are central to idea generation by sketching. The ambiguity of sketches is advantageous for design ideation (Goel, 1995); in the same way, the ambiguity of gestures should be seen as advantageous for generating new ideas.

In collaboration, the individual designer's thought processes are interconnected, nourished, stimulated, and inspired by the actions of other team members. Rich and varied use of all available resources (i.e., language and other modalities intertwined) serves to multiply the number of meanings fed into the conversation. That multiplication in turn enhances the potential to engage various sensory channels, sparking inspiration and enhancing the team's capacity to share, evaluate, and build on each other's contributions, as well as their potential for idea generation. *At best, active and rich gesturing and sketching in combination with speech can turn interaction into inspiraction—that is, interaction that inspires—eliciting new ideas and (even) more productive interaction.* Likewise, *the epistemic roles of sketching and gesturing could entail the ability to elicit more ideas by enhancing the intensity and richness of collaborative designing.* We therefore contend that sketching and gesturing should be approached as epistemic activities—ways of thinking, developing, and inducing new thoughts, as well as enriching the plateau of inspirational material for ideation.

Unfortunately, increased potential and more cues do not automatically enhance idea generation. Shared cues need to be noticed, and appreciative perception may be the requisite counterpart to unreserved sharing. Our tentative conclusion is that engaging multiple modalities in sharing ideas as they emerge and recognizing each other's contributions may benefit students as much as any single creative practice. It seems reasonable, then, to ask if sharing and paying attention should be seen as important epistemic practices for creative collaboration.

References

Alibali, M. W., & Nathan, M. J. (2012). Embodiment in Mathematics Teaching and Learning. *Journal of the Learning Sciences*, 21(2), 247–286.

Cross, N. (1982). Designerly ways of knowing. *Design Studies,* 3(4), 221–227.

Gero, J. S. (2000). Computational Models of Innovative and Creative Design Processes. *Technological Forecasting and Social Change*, 64(2), 183–196.

Goel, V. (1995). *Sketches of though.* Cambridge: MIT Press.

Härkki, T., Seitamaa-Hakkarainen, P., & Hakkarainen, K. (2016a). Line by line, part by part: collaborative sketching for designing. *International Journal of Technology and Design Education,* online first.

Härkki, T., Seitamaa-Hakkarainen, P., & Hakkarainen, K. (2016b). Material knowledge in collaborative designing and making: A case of wearable sea creatures. *FORMakademisk,* 9(1), Art. 5. 1–21.

Härkki, T., Seitamaa-Hakkarainen, P., & Hakkarainen, K. (2018). Hands on design: Comparing the use of sketching and gesturing in collaborative designing. *Journal of Design Research,* in press.

Kita, S., Alibali, M.W., & Chu, M. (2017). How Do Gestures Influence Thinking and Speaking? The Gesture-for-Conceptualization Hypothesis. *Psychological Review*, 124(3), 245–266.

Purcell, A.T., & Gero, J.S. (1998). Drawings and the design process. *Design Studies,* 19, 389–430.

Sawyer, R.K. (2003). Improvised Dialogues. Westport: Ablex Publishing.

Sawyer, R.K. (2018). Teaching and Learning How to Create in Schools of Art and Design. *Journal of the Learning Sciences*, 27(1), 137–181.

Tversky, B. (2011). Visualizing Thought. *Topics in Cognitive Science*, 3(3), 499–535.

Acknowledgments

Developing Assessment Tasks to Promote Student Sensemaking of Phenomena and Flexible Thinking

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Abstract: The knowledge-in-use perspective states that useable knowledge allows for problem solving, explaining real-world phenomena, and constructing new ideas. We developed assessment tasks that measure students' capacity to solicit and select from an array of the dimensions of scientific knowledge to make sense of an unfamiliar phenomenon. Evidence of knowledge-in-use includes *depth* of usable knowledge; *flexibility* in applying various ideas; and a robust *community perspective*. Our work shows that assessments can measure growth in knowledge-in-use.

Problem and objective

Knowledge-in-use (Pellegrino & Hilton, 2012) focuses on building and refining knowledge, solving problems, investigating the natural world and learning more when needed and results in deeper, more sophisticated knowledge. The knowledge-in-use perspective reflects an increased awareness by learning scientists, science educators and policymakers of the proficiencies learners will need as global citizens. (National Research Council, 2012; Finnish National Board of Education, 2015). They will need to use and apply knowledge in novel ways to solve the current and emerging challenges facing our world (OECD, 2016)

Designing assessments that can measure knowledge-in-use is a formidable task, and the field continues to struggle with how to construct assessments that challenge students to solve problems and makes sense of phenomena. Assessments that align with this perspective must engage learners in a complex phenomenon, similar to those learners experience in daily life, and assess students' capacity to apply multiple practices and ideas as affordances for sensemaking. In this research, we developed and used assessments that allow students to use multiple ideas and practices as tools to make sense of unfamiliar phenomena by promoting flexible thinking and developing alternative explanations for these phenomena. For flexible thinking, students need to access and evaluate all of the ideas that they may use to make sense of the phenomenon. Our research questions include: 1) *How can we design assessment tasks that measure students' flexible use of knowledge to solicit and select from an array of the dimensions of scientific knowledge to make sense of an unfamiliar phenomenon or solve problems*? 2) *How can we gather information to measure students' capacity to engage in socially-situated practice of considering and weighing possible alternatives for making sense of the phenomenon under study*?

This research presents one systematic method and related analysis for designing and evaluating assessments that will engage learners in making sense of unfamiliar and complex phenomena. The tasks engage students in the figuring out process of using multiple ideas and practices to make sense of phenomena as well as gauge their depth and flexibility of knowledge, and connections to science as a social endeavor developed by and for communities. We present related questions of teaching practices that develop knowledge-in-use.

Theoretical framework

Our approach stems from social constructivist theory that purports that sensemaking is an ongoing dialogue and as such, incorporating assessment elements that reflect the *context-rich* processes of learning allows for a more accurate portrayal of the figuring out process and of developing science competencies (Lave & Wenger, 1991). Thus building assessments that require a multiplicity of approaches to making sense of a phenomenon more authentically aligns with the language and activities of sensemaking. These assessments provide more access to underrepresented groups who draw from diverse intellectual resources (Ladson-Billings, 2006).

Methodology and analysis

Our work is situated in upper elementary project-based learning environments in the third year of the Multiple Literacies in Project-based Learning Project (ML-PBL; (Krajcik, Palincsar, & Miller, 2015). In this paper, we report on data from a third grade project focusing on adaptation, ecology, climate, and extinction. The work for this paper took place during SY2016-17 and SY2017-18. Our method for assessment development uses an iterative design-based research process. Our methods for designing tasks have three main objectives: 1) elaboration and synthesis of unit learning goals to develop enduring understandings and affordances, 2) creation of performance tasks and performances based on related phenomena and the enduring understanding, and 3)

testing and redesign of tasks to provide evidence of student learning. Evidence that students have developed knowledge-in-use includes *depth* of knowledge of affordances; *flexibility* in applying an array of key scientific ideas and practices; and a robust *community perspective* in which students make explicit connections to their local environment or social community.

The data for this study stem from pre- and post-unit assessments of the Grade 3 ML-PBL Unit: *Why do I see so many squirrels but I can't find any stegosauruses?* We used rubrics to score student responses. We analyzed the pre- and post-unit assessments of 80 students from four teachers and schools for depth, flexibility and application of community resources.

Major findings

Our analysis suggests that students can demonstrate knowledge-in-use as evidenced by full application and flexible use of science knowledge to make sense of complex phenomena. Learners' depth of knowledge, flexible use of affordances and robust community perspective increased over time in a majority of cases, but in some classes more than others, as well as across students with varying degrees of affordance. We found that students developed more sophisticated models and explanations in the post- than the pre-assessment, even for those students who did not show growth in flexible thinking. Students who grew in flexible thinking also developed sophistication of ideas.

Discussion and significance

Assessment and "what we can measure" informs instruction. We keep this in mind as we develop assessment tasks that are aligned to socially meaningful context-rich project-based learning environments. We integrate ideas from the practice world of scientists, and the knowledge-in-use perspective to inform teachers about what evidences of students learning we care about. Based on our findings, questions emerged such as why some classrooms fostered more growth than others in knowledge-in-use, and which instructional practices and contexts promote such development. We wonder about the relationship between richness of sensemaking discourse and the development of knowledge-in-use. Our hope is that we not only use unit assessments to gather understanding of what students know, but also an understanding that learning is inseparable from what students can perform *in the PBL socially-situated context* with a multiplicity of perspectives and community-grounded motivators for the science learning (Gee, 2010). Our work demonstrates that assessments can elicit depth of student knowledge, flexibility in thinking, and community perspective.

References

Finnish National Board of Education (FNBE) (2015). National Core Curriculum for General Upper Secondary Schools 2015. Helsinki: Finnish National Board of Education (FNBE).

Gee, J. P. (2010). A situated-sociocultural approach to literacy and technology. *The new literacies: Multiple perspectives on research and practice* (pp. 165-193). Guilford Publications.

Krajcik, J.S., Palincsar, A., Miller, E., (2015). Multiple Literacies in Project-Based Learning, Lucas Education Research, a division of the George Lucas Educational Foundation.

Ladson-Billings, G. (2006). Yes, but how do we do it? Practicing culturally relevant pedagogy. In J. Landsman & C.W. Lewis (Eds.), *White teachers/diverse classrooms: A guide to building inclusive schools, promoting high expectations and eliminating racism* (pp. 29–42). Sterling, VA: Stylus Publishers.

Lave , J. , & Wenger , E. (1991). *Situated learning: legitimate peripheral participation*. New York: Cambridge University Press.

National Research Council (NRC). (2012). *A framework for K - 12 science education: Practices, crosscutting concepts, and core ideas.* Washington, DC: National Academies Press.

OECD (2016), *PISA 2015 Assessment and analytical framework: Science, reading, mathematic and financial literacy.* Paris: OECD Publishing.

Pellegrino, J. W., & Hilton, M. L. (Eds.). (2012). *Education for life and work: Developing transferable knowledge and skills in the 21st century*. Washington, DC: The National Academies Press.

Acknowledgements

Data Transformations: Restructuring Data for Inquiry in a Simulation and Data Analysis Environment

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Abstract: We explore *data transformations*, actions investigators take to make datasets more useful for intended inquiries. Fourteen young adults were interviewed while they interacted with online science and engineering games and were provided their own gameplay log data to improve their scores. We investigate the conditions under which data transformations are likely to emerge; provide examples of data moves as enacted by participants; and propose an initial taxonomy of data transformations and potential developmental supports.

Working with data is an important epistemic practice across disciplines, including within K–12 education. However, students often treat data as a static representation of "the answer", rather than as a source of evidence. Specifically, we are interested in how learners come to engage with provided or "second-hand" data (Hug & McNeill, 2008) as transformable (Duschl, 2008). Using provided data has the potential to engage learners with topics and scopes of analysis that would be difficult in a classroom setting. But students may not automatically see those data as relevant for inquiry, or engage in critical reasoning about those data. Thus, we argue that just as students should learn to construct, represent, and analyze their own data in service of an investigation (Konold & Pollatsek, 2002), they should also learn how to re-construct, re-represent, and re-analyze provided data.

Theoretical framework

To engage in data transformation, learners must navigate three nested, interactive processes (Figure 1). The first involves identifying a goal and deciding whether provided data are *relevant* for that goal. The second involves considering the *context* in which provided data were generated, including the data collection instruments used, for what purposes the data were constructed, and how well the data reflect their own experiences of the context. The third concerns making data more useful through restructuring, supplementing, or subsetting, constructing new measures or visualizations, and so on. Such *reconstructions* are made possible, and reified as valuable, by an emerging genre of data analysis software (e.g., Tableau, RStudio) used by practitioners and increasingly the general public (Wickham, 2014). The Common Online Data Analysis Platform (CODAP) used in this study makes reconstructions accessible to K-12 students. These nested processes are similar to others' descriptions of evidence construction and use in the science education literature (e.g., Kelly, Regev, & Prothero, 2007).

Relevance	Context	Reconstruction (includes *Data Moves*)
Can this dataset be useful for my goals?	Does this dataset's context and purpose affect its appropriateness for my investigation?	What manipulations help me visualize, reduce, or otherwise transform the data in needed ways?
Does the dataset reveal patterns I'd like to learn more about?	Given my knowledge of this system, is the dataset valid and trustworthy?	Can I make the transformations easily and reliably?

Figure 1. Data transformation includes determining the relevance, context, and required manipulations of data.

Methods

Data Science Games (IIS-1530578) seeks to develop students' data transformation skills through games about core science and engineering ideas. Each game, and the data it generates, is embedded within CODAP, which allows players to visualize, organize, and manipulate their data. The data require some degree of transformation before they are useful for making decisions or understanding the game's underlying principles. In this study, Stebbins (Figure 2, left) is designed to engage learners with basic ideas underlying natural selection through analyzing the convergence of data toward a favorable trait. BARTy (Figure 2, right) is designed to engage learners in optimizing engineering solutions for a large transit system (Bay Area Rapid Transit, or BART), by exploring

patterns in nested data structures.

We conducted guided cognitive interviews with 14 public high school and community college students as they played Data Science Games. We captured synchronized video of students' computer screen activity and audio-video records of their comments and interactions with one another and the interviewers. Several team members engaged in co-viewing and interpretive coding of each interview video (Jordan & Henderson, 1995). After several rounds of analysis, we focused specifically on moments in the interviews at which the need for data moves arose (for example, a student suggests data should be represented or structured differently), or when data moves were actually executed by participants within the CODAP environment.
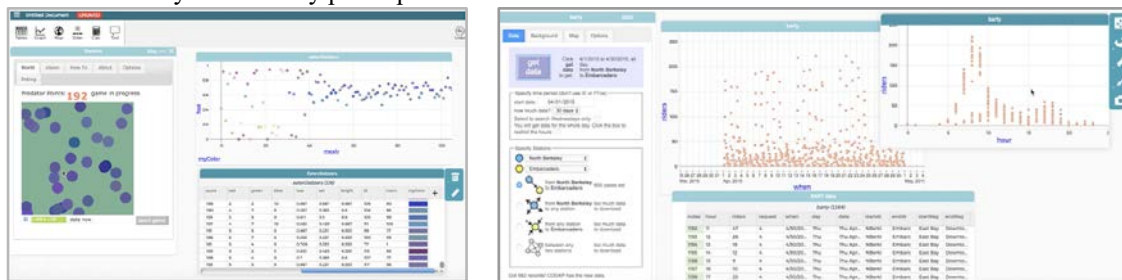
Figure 2. Stebbins (left) focuses on natural selection; BARTy (right) focuses on public transit ridership data.

Results

Across all interviews, participants only engaged in data reconstruction once they identified the relevance of the data for addressing some need, and had made enough sense of the data context. This led to vastly different treatments of data across interviews: *data rejected as irrelevant*, *data for inquiry about gameplay*, and *data for inquiry about phenomenon*. Participants also reconstructed data in different ways. Re-representing data was common; fewer engaged in re-structuring or re-scoping data. For example, Figure 3 demonstrates the back-and-forth nature of data transformation with a focus on re-representation. Here, a participant (Pam) chose to explore the relationship between color and score (3, 4). A mismatch between the data and her experience (6) led her to recognize the dataset as inappropriate (7); she then answered her question with a more appropriate dataset (8).
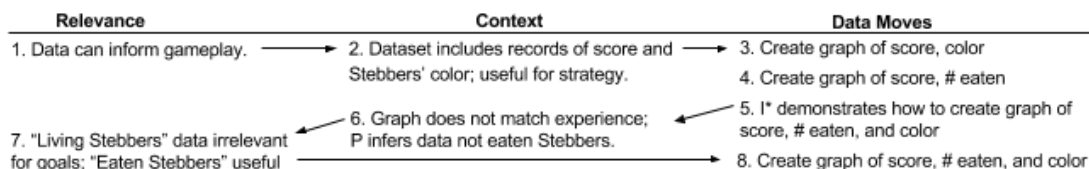
Figure 3. Summary analysis of Pam's engagement with data; classified as *data for inquiry about gameplay*.

The analyses demonstrate how particular data moves are deeply situated within specific goals, and are shaped by learners' consideration of data context. It is important for learners to recognize data as a resource for inquiry, and data transformation is an important part of this process. This project represents an initial step toward understanding the contexts in which students learn to manipulate large datasets.

References

Duschl, R. (2008). Science education in three-part harmony: Balancing conceptual, epistemic, and social learning goals. *Review of Research in Education*, 32(1), 268-291.

Hug, B., & McNeill, K. L. (2008). Use of first-hand and second-hand data in science: Does data type influence classroom conversations? *International Journal of Science Education, 30*(13), 1725-1751.

Jordan, B., & Henderson, A. (1995). Interaction analysis: Foundations and practice. *Journal of the Learning Sciences, 4*(1), 39-103.

Kelly, G. J., Regev, J., & Prothero, W. (2007). Analysis of lines of reasoning in written argumentation. In S. Erduran & M. P. Jimenez-Aleixandrae (Eds.), *Argumentation in Science Education* (pp. 137–158). Dordrecht, The Netherlands: Springer.

Konold, C., & Pollatsek, A. (2002). Data analysis as the search for signals in noisy processes. *Journal for Research in Mathematics Education, 33*(4), 259-289.

Wickham, H. (2014). Tidy data. *Journal of Statistical Software, 59*(10), 1-23.

Acknowledgments

Is Student Frustration in Learning Games More Associated With Game Mechanics or Conceptual Understanding?

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Abstract: Digital games have evolved as an engaging medium for learning. This paper studies the interaction between game design and student affective experience. Data from 137 students playing a learning game was analyzed to identify the factors correlating with student frustration. Results suggest that in this well-designed game, difficulty associated with conceptual understanding is more predictive of student frustration than difficulty with the game mechanics.

Introduction

In the past couple of decades, researchers from various fields like math, science, reading, language arts, health, and physics have looked into using digital games as vehicles for learning (Ke, 2009). The cognitive-affective state of frustration plays a significant role both in the experience of students and their learning (Iepsen, Bercht, & Reategui, 2013). It is relatively poorly understood what elements in the design of games or specific levels in those games are associated with the emergence of this affective state. In this paper, we focus on examining the relationship between two keys elements of a game level - conceptual understanding and game mechanics -- and student frustration. Thus, the main research question of this paper is whether difficulty with game mechanics or conceptual understanding is more strongly associated with student frustration, in a puzzle-based learning game.

Method

Physics Playground (PP; Shute & Ventura, 2013) is a two-dimensional game which has been developed to help secondary school students understand conceptual physics. The primary physics concepts in PP include Newton's laws of motion, energy, and torque. The player creates simple machines (i.e., ramp, springboard, pendulum, and lever) to guide a green ball to hit a red balloon (goal) by using a mouse and drawing directly on the screen. The player analyzes the givens (what he/she sees on the screen) and sketches a solution by drawing new objects on the screen (see Figure 1). Each level (total of 74) in PP has been scored on two types of difficulty: Game Mechanics (GM), and Physics Understanding difficulty (PU). In simple terms, game mechanics difficulty relates to the aspects of the level that makes it harder to solve whereas physics understanding difficulty corresponds to complexity of the content-related aspects of the game.

We used rubrics developed by the PP research team (including learning science researchers, instructional designers, game developers, and physics experts) to score the game mechanics (GM) and physics understanding (PU) difficulties of each level. The GM rubric included the following aspects of the level - position of the ball (over or below the balloon), the number of obstacles between the ball and the balloon, whether a hint was given within the name of the level, whether the player needs to synchronize actions in order to solve the level, and the number of sub goals needed to solve the level. For the PU rubric, the physicists identified the primary and secondary physics concepts for each level. The rubric considers the conceptual order of the primary concept of the level (force and motion = 0, momentum and energy = 1, torque = 2), the need to either balance the forces (i.e., equilibrium or Newton's third law = +1) or conservation of energy (i.e., energy can transfer or conservation of momentum = +1), and checks if primary and secondary concepts are the subtopics of same parent topic (e.g., Newton's first and second law) or of a different parent topic (e.g., Newton's first law of motion and energy can transfer)=1. Each level has been scored by two raters, and conflicts between the raters were then resolved through dialogues. The raw GM and PU scores are rescaled to 1-5.

Participants of the study consisted of 137 8th and 9th grades students (57 male, 80 female) enrolled in a public school in the southeastern U.S. They played PP in their 55-minute class period in a computer-enabled classroom over two days. Observers used the Baker Rodrigo Ocumpaugh Monitoring Protocol (BROMP 2.0) (Ocumpaugh et al., 2015) to label students' affective states while they played the PP game. Frustration was observed 11.3% of the time in this environment.

Results

Among the 74 levels in PP, tutorial levels and levels with less than 15 labeled students were filtered out to focus on levels with an adequate number of data points. In the 27 levels that remained, the mean GM and PU values are 2.10 (SD = 0.62) and 2.88 (SD = 0.99). For each level, the percentage of students who were labeled as frustrated at least once was calculated resulting in an average of 15.02% (SD = 6.56%) across the final levels.

Regression analysis was conducted to estimate the relationship between student frustration and the GM and PU individually (see Table 1). An ordinary least squares model was used for all regression analysis. The results show that PU is a significant predictor of frustration ($p < 0.05$, Cohen's $d = 0.96$). However, GM is not a significant predictor of frustration. Among the game levels included in this analysis, PU only takes values of 2 and 4. The Cohen's d indicates a large effect size between these two groups.

To further understand the effects of PU, the levels were analyzed based on the primary physics concept involved to solve the level. The top three concepts were energy can transfer (EcT), Newton's 1st Law (N 1st L) and properties of torque (PoT). We see that EcT as a primary concept is the most predictive of student frustration ($p < 0.01$, $d = 1.48$; see Table 2).

Table 1: Results of regression analysis on GM and PU (individual models)

Predictors	B	t	p	R^2	Cohen's d
GM	0.59	0.28	0.776	0.003	-
PU	5.68	2.39	0.025^*	0.185	0.96

$^*p < 0.05$

Table 2: Results of regression analysis on the primary concepts (individual models)

Predictors	B	t	p	R^2	Cohen's d
EcT	7.52	3.46	0.002^*	0.32	1.48
N 1st L	-4.66	-1.78	0.087	0.11	-
PoT	-3.38	-1.02	0.317	0.04	-

$^*p < 0.01$

Discussion

This study examined the association between student frustration and two key elements of a learning game. Our results suggest that frustration is significantly correlated with the conceptual understanding of the physics content, but not to the mechanics of the game itself. This indicates that a student is less likely to get frustrated when he/she has a conceptual understanding of the solution even when implementing it within the game itself is harder. Further, we also observed that frustration is closely related to a specific physics concept, "energy can transfer", a concept that is more complex and also involves relatively more difficult machines. It is important to understand the causes and triggers of frustration in order to design interventions that can meaningfully improve student engagement and learning. This study is a first step towards identifying how student frustration relates to the characteristics of this specific game. Further research is warranted to see if our findings generalize to other student demographics, learning game settings, and domains of study, and to understand causal relationships between elements of game design and student emotions.

References

Ke, F. (2009). A qualitative meta-analysis of computer games as learning tools. *Handbook of research on effective electronic gaming in education*, 1, 1-32.

Iepsen, E. F., Bercht, M., & Reategui, E. (2013, October). *Detection and assistance to students who show frustration in learning of algorithms.* In Frontiers in Education Conference, 2013 IEEE (pp.1183-1189). IEEE.

Ocumpaugh, J., Baker, R. S., & Rodrigo, M. M. T. (2015). *Baker Rodrigo Ocumpaugh monitoring protocol (BROMP) 2.0 technical and training manual.* New York, NY and Manila, Philippines: Teachers College, Columbia University and Ateneo Laboratory for the Learning Sciences.

Shute, V. J., & Ventura, M. (2013). *Measuring and supporting learning in games: Stealth assessment.* Cambridge, MA: The MIT Press.

Transitioning to an Integrated Science Teaching Model: Easier Said than Done

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Abstract: This poster presents a study of eight school districts implementing a new integrated model of science instruction in the middle grades aligned with NGSS. The analysis uncovers how districts created implementation plans and how teachers and administrators initially are responding to them, sometimes in more limited ways than envisioned. The findings suggest the importance of attending to transitional as well as end-goal implementation phases of innovations, and the importance of administrators facilitating the transition.

Introduction

The Next Generation Science Standards (NGSS) advocate for an integrated model of science instruction in which different science domains are connected rather than separated. For example, the NGSS calls for basing instruction on authentic phenomena, which are best explained by examining all of the science disciplines involved (National Research Council, 2012). This shift is unique because it has equally important implications at the classroom level (e.g. what phenomena teachers use in instruction) and the systemic level. In particular, all scientific disciplines, such as earth, space, life, and physical science, in addition to engineering, should be included and connected in a single year of instruction, leading schools and districts to reorganize their course sequences. During recent decades in California and the US, middle school science has most frequently been taught in discipline specific courses (e.g. California's sequence of earth science in grade 6, life science in grade 7, and physical science in grade 8). With the advent of NGSS, California's State Board of Education has shifted to give preference to an integrated model for middle school science. This new context represents a key state-wide policy shift with important, but potentially diverse, impacts for schools and teachers.

This study investigates how teachers, schools, and districts in California initially made sense of the transition from discipline-specific to integrated models, and the challenges teachers identify with that transition. As such, this study aims to contribute to literature on teacher change, teacher learning, and implementation across educational systems. This focus on districts, schools, and teachers reflects an actor-oriented perspective toward NGSS implementation, which highlights how NGSS implementation depends on the sense-making and decisions of relevant actors (Coburn, 2006; Penuel, Phillips, & Harris, 2014; Spillane, 2012).

Methods

The data informing this study come from a project involving eight public school districts across California that are early implementers of NGSS (http://k12alliance.org/ca-ngss.php). This project provided ongoing and intensive professional development and other support to K-8 teacher leaders and administrators around NGSS implementation, and included integration as one of many topics. The districts represent a variety of locations, sizes, and demographics within California, and were selected through a competitive application process, which required districts to commit to California's preferred integrated model of science education at the middle grades.

The following analyses are based on data from the first two years of the project, and include written artifacts created by the district, interviews with each district's project director and leadership teams, and surveys completed with school and district administrators, as well as teacher leaders participating in the project activities. All districts created comprehensive plans for NGSS implementation. These artifacts were qualitatively analyzed for mentioning the transition plan toward the integrated model for science instruction. Interviews with project directors asked about plan for integration, and these responses were summarized holistically and triangulated with the district plans. The surveys administered contained an open-ended question that asked respondents to identify the "biggest challenges in implementing the integrated science model." These responses were open-coded (Strauss & Corbin, 1998) to identify common challenges across participants.

Findings

All of the districts' initial NGSS implementation plans included the goal of integrated middle school science. However, only two of the eight included specific, multi-year plans for transitioning to integration. Instead, most districts indicated they would develop plans in the future or named activities that would support integration (e.g. teacher PD on integration with their curriculum). The two specific plans considered how to provide continuity for

both students and teachers (e.g., avoid gaps in instruction and repeated science content as a result of the shift in course sequence), and had transitional models of incomplete integration, such as a "coordinated" model in which science classrooms engage students in each discipline each year, without making vital connections between them.

Interviews with leadership teams in the districts revealed the complicated negotiations and transitions for individual teachers and administrators, reflecting different concerns than continuity or dedicated project activities around integration, which were highlighted in the district plans. For example, one principal shared a challenge for teachers, letting go of teaching their favorite science topics, when supporting integration,

> The Integrated Model calls for cells to be taught in grade 6 instead of 7. But my 7th grade life science teacher loves teaching cells and really didn't want to let go of this topic. And the 6th grade teacher was intimidated…the need to transition over several years turned out to be a blessing…the 7th grade teacher still gets to teach it for one more year. But the 7th grade teacher also had to seriously help the grade 6 teacher with cells…[after that transition year] the 7th grade teacher initially was caught off guard by the reality of not being able to teach cells anymore…[but] was getting excited about teaching some new things.

The school administrators and teachers also noted challenges related to science equipment and materials. One principal shared her role in negotiating the transition as it related to equipment,

> Everyone had to be transparent about what [supplies] they actually already had…It took my low-key involvement in some meetings to inventory everything and figure out where it should now be. And since sometimes more than one grade is teaching a topic during the transition, when and how two different teachers had them had to be synchronized.

These challenges were also expressed by teacher leaders in the study. In teachers' responses to an open-ended prompt about the biggest challenges in transition to the Integrated model, 17% indicated a lack of existing curricula and/or science material resources, and 16% mentioned a specific science topic that would be challenging to teach. Teachers also indicated a lack of content knowledge required by the revised courses (12%); time needed to learn, plan and implement changes (10%); opportunity to collaborate with other teachers (7%); and ability to identify real-world phenomena that authentically involve multiple disciplines (7%).

Conclusions

The findings presented showcase how different challenges and concerns arise for actors working at different levels in the implementation process (i.e., district, school, classroom). These challenges highlight the importance of paying attention to the implementation process, as well as considering the learning happening during this process across a district or educational system. In particular, there were concerns that frame the problems with transition in terms of a resource management logic, such as access to materials, as well as a resource development logic, such as developing teachers' capacity to teach new science topics (Horn, Kane, & Wilson, 2015). The findings also highlight how school administrators can be active agents in facilitating teachers' transition challenges, supporting teachers to work collaboratively across boundaries of grade and science discipline. Future data collection from subsequent years of implementation in this project will shed further light about the final stages of the transition toward the integrated model across districts and schools.

References

Coburn, C. E. (2006). Framing the Problem of Reading Instruction: Using Frame Analysis to Uncover the Microprocesses of Policy Implementation. *American Educational Research Journal*, *43*(3), 343–349.

Horn, I. S., Kane, B. D., & Wilson, J. (2015). Making Sense of Student Performance Data: Data Use Logics and Mathematics Teachers' Learning Opportunities. *American Educational Research Journal*, *52*(2), 208–242. https://doi.org/10.3102/0002831215573773

National Research Council. (2012). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Washington, DC: The National Academies Press.

Penuel, W. R., Phillips, R. S., & Harris, C. J. (2014). Analysing teachers' curriculum implementation from integrity and actor-oriented perspectives. *Journal of Curriculum Studies*, *46*(6), 751–777.

Spillane, J. P. (2012). Data in Practice: Conceptualizing the Data-Based Decision-Making Phenomena. *American Journal of Education*, *118*(2), 113–141. https://doi.org/10.1086/663283

Strauss, A., & Corbin, J. (1998). *Basics of qualitative research techniques*. Thousand Oaks, CA: Sage Publications.

The Interaction of the Need for Cognitive Closure With Implicit and Explicit Guidance in Wiki-Based Learning

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Abstract: One purpose of wikis is the collaborative generation of content. During generation processes, controversies about content can emerge that authors might elaborate on the article's talk page. Research suggests that controversies based on opposing points of view and contradictory evidence can be fruitful to trigger individual elaboration processes. However, research also showed that many wikis are not necessarily suited to highlight relevant discussion contents and thus users could need guidance as support. In an experimental study ($N = 181$) on wiki talk pages, we investigated two scaffolding measures in conjunction with the Need for Cognitive Closure: (1) visual markers to highlight controversy status (implicit) and (2) a collaboration script that directs users towards discussions (explicit). The results show that both guidance types in interaction with the Need for Cognitive Closure can affect learning outcomes.

Introduction

Regarding the effects of modified wikis for learning activities, studies on implicit and explicit guidance measures have shown that they can trigger intended behaviours. Implicit guidance with controversy awareness highlights can lead to a more focused selection of relevant content-related topics and explicit guidance with a discussion-centric collaboration script can lead to more meaningful a-priori discussion of proposed article changes (Heimbuch & Bodemer, 2017). Such cognitive group awareness tools as implicit guidance are focused on gathering and visualising knowledge-related contextual cues and have been successfully implemented as helpful aids to structure collaborative learning processes (Bodemer & Dehler, 2011). Research has also proposed alternative measures such as explicit guidance to incorporate in wiki-based learning environments to improve the overall quality of knowledge artefacts and for better coordination processes of students. The implementation of one possible measure for explicit guidance are collaboration scripts where the activities of writers and editors within a social system are coordinated and optimised. A collaboration script is essentially a set of instructions that specifies the group formation, modes of interaction and task management between collaboration partners (Dillenbourg, 2002). Research has also shown that individual differences can have an impact on learning-related processes and outcomes. There are indications that the effort a learner is willing to invest in searching for solutions to a problem can be influenced by the individual's Need for Cognitive Closure (NCC) (Webster & Kruglanski, 1994). This cognitive construct is a motivational continuum between the need to get a clear answer in an ambiguous situation and the avoidance of quick and unambiguous answers. Various empirical results and discussions illustrate that it can be regarded as a relevant construct in knowledge creation processes. Although there are close ties between the Need for Cognitive Closure and inter-individual differences in learning and knowledge construction, there are only few studies in technology-enhanced learning addressing this construct. To further support and extend on earlier findings, we wanted to compare the effects of one implicit and one explicit guidance measure for wiki environments in interaction with the individual NCC of learners.

Methods

We used an experimentally controlled laboratory setting with individual participants ($N = 181$) in a between-subjects design to investigate the interplay between different guidance types and NCC in wiki-based learning. The first independent factor was the type of talk page guidance (implicit vs. explicit). The second factor of interest was the individual NCC, which we factorised in two levels (low vs. high). According to the original literature on the scale 16-NCCS that we used in this study, post-hoc median splits were applied for classifying low NCC and high NCC participants (Schlink & Walther, 2007). As main dependent variables, we measured individual learning outcome, metrics of article and discussion contributions, and process log data. Participants performed the experiment's stages individually in their own wiki instance. We surveyed their interest in and prior knowledge of the study's subject matter (forms of energy). Both groups had the same task of contributing to a Wikipedia-like base article about different forms of energy and taking part in up to three of the corresponding discussions. Participants received the information that the discussions hold enough arguments and evidence to enrich the original article, since we did not give any other added material about the subject matter elsewhere. We gave no further instructions on how to start their wiki task (e.g., reading the article or any discussion first) or what kind of

reply they should make to a self-selected discussion. After the wiki contribution phase, participants were asked to fill out several questionnaires to some of the study's dependant variables.

Results

In the knowledge test, participants in the implicit controversy highlight group achieved an average score of $M = 15.84$ ($SD = 3.43$) in comparison to $M = 15.47$ ($SD = 3.60$) in the explicit scripting group. A mean test score difference between both guidance groups of 0.37 points is equivalent to zero in a 90% CI [-0.50, 1.23] and not significantly different from zero in a 95% CI [-0.66, 1.40]. This result gives evidence that no group outperforms the other per se. In the knowledge test, low Need for Cognitive Closure participants scored on average $M = 16.05$ ($SD = 3.29$) in comparison to an average score of $M = 15.24$ ($SD = 3.70$) of high Need for Cognitive Closure participants. A mean test score difference between both guidance groups of 0.82 points is equivalent to zero in a 90% CI [-0.04, 1.68] and not significantly different from zero in a 95% CI [-0.21, 1.85]. This result gives further evidence for equivalence in learning outcomes when only one factor is analysed in isolation. Regarding the potential effects of the guidance type and the NCC on the learning outcome, with a 2x2 ANCOVA a small to moderate effect was found, $F(2, 175) = 5.30$, $p = .023$, $\eta^2_p = .03$. Using the full Need for Cognitive Closure data spectrum with a hierarchical linear regression model, the effect of the interaction itself was weakened, $b = -0.03$ ($SE = 0.05$), $t(176) = -0.67$, $p = .502$ within a moderate total effect model, $F(4, 176) = 3.20$, $p = .014$, $R^2 = .07$.

Discussion

In earlier wiki-related research individual cognitive differences of learning-related variables were often measured only as secondary variables (Notari, Reynolds, Chu, & Honegger, 2016). Therefore, we wanted to focus on one of these constructs that had been previously found as potentially relevant for learning scenarios with ambiguous information, namely the Need for Cognitive Closure. At first, we analysed the equivalence of implicit and explicit guidance in the overall sample, since we had no reason to believe that one measure alone should outperform the other. The results show that participants do not differ between the kinds of guidance in the test scores. Additionally, there were no meaningful differences between participants in the two categorised levels of their Need for Cognitive Closure on any of the measured process variables or in the learning outcome. When analysing the learning outcome, the interaction of guidance type and Need for Cognitive Closure was following an expected pattern. Participants with a high Need for Cognitive Closure scored higher in the knowledge test when working in a wiki enriched with implicit guidance rather than explicit guidance. The pattern reversed for low Need for Cognitive Closure participants. As persons with a high Need for Cognitive Closure have the desire to resolve ambiguity as quickly as possible and care less for the best possible solution they tend to rely on simpler heuristics to select and process information (Webster & Kruglanski, 1994). Implicit guidance with our visual highlights for controversy awareness gives them exactly this, a quick possibility to assess and to decide how to proceed further. In contrast to that, persons with a low Need for Cognitive Closure prefer to elaborate in discussions and resolve ambiguity by finding better solutions than just the quickest (Dreu, Koole, & Oldersma, 1999). Thus, a more explicit guidance like the used discussion-centric script that tries to motivate the participation in discussion is better suited for these persons.

References

Bodemer, D., & Dehler, J. (2011). Group awareness in CSCL environments. *Computers in Human Behavior*, *27*(3), 1043–1045. https://doi.org/10.1016/j.chb.2010.07.014

Dillenbourg, P. (2002). Over-scripting CSCL: The risks of blending collaborative learning with instructional design. *Three Worlds of CSCL. Can We Support CSCL?*, 61–91.

Dreu, C. K. W. de, Koole, S. L., & Oldersma, F. L. (1999). On the Seizing and Freezing of Negotiator Inferences: Need for Cognitive Closure Moderates the Use of Heuristics in Negotiation. *Personality and Social Psychology Bulletin*, *25*(3), 348–362. https://doi.org/10.1177/0146167299025003007

Heimbuch, S., & Bodemer, D. (2017). Controversy awareness on evidence-led discussions as guidance for students in wiki-based learning. *The Internet and Higher Education*, *33*(2017), 1–14. https://doi.org/10.1016/j.iheduc.2016.12.001

Notari, M., Reynolds, R. B., Chu, S., & Honegger, B. D. (2016). *The wiki way of learning: creating learning experiences using collaborative web pages*.

Schlink, S., & Walther, E. (2007). Kurz und gut: Eine deutsche Kurzskala zur Erfassung des Bedürfnisses nach kognitiver Geschlossenheit. *Zeitschrift Für Sozialpsychologie*, *38*(3), 153–161. https://doi.org/10.1024/0044-3514.38.3.153

Webster, D. M., & Kruglanski, A. W. (1994). Individual differences in Need for Cognitive Closure. *Journal of Personality and Social Psychology*, *67*(6), 1049–1062. https://doi.org/10.1037/0022-3514.67.6.1049

Research Questions to Support Conversational Learning in the Era of Ubiquitous, Mobile Agents

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Abstract: This poster explores the major question: How can conversational agents, such as smart speakers, be used for opportunistic learning that complements formal teaching? We discuss design questions that arise as devices are to be used for encouraging effective, brief conversational learning. We highlight aspects of efficacy in supporting learning through interdisciplinary study, and list research questions that need to be addressed.

Ambient conversational devices as a new interaction modality for learning

One-on-one or small group interaction of learners with skilled and sympathetic teachers has shown to increase learning outcomes. This observation served as a motivation for several research efforts in utilizing Artificial Intelligence for Education, leading to the development of sophisticated tutoring systems for one-on-one human tutoring (VanLehn, 2011). In this paper, we study the opportunities enabled by *ubiquitous conversational agents,* which can use some of the strategies employed by successful human teachers. These continuously available teaching agents, accessed at different times of the day or different places through various physical interfaces, can extend the functionality of existing intelligent tutoring systems by using multimodal signals uniquely provided by rapidly available mobile technology: location services, off-classroom time, bio-sensor data, and communication with cloud-enabled devices in the office, home, classroom, and vehicle.

The number of people of all ages using conversational agents is growing (Lenhart, 2015; Druga, Breazeal, Williams, & Resnick, 2017). Voice-based agent work builds on 50 years of technical exploration (Pieraccini, 2012). While sophisticated agents that move beyond simple information retrieval are just over the horizon, these developments are currently driven by non-learning applications. As the number of learners who access and use conversational agents outside the formal education facility grows past a tipping point, learning sciences can guide interdisciplinary research agendas and enable learning to happen *anytime* and *anywhere*.

Continuously Accessible Conversational Learning Agents (CA-CLAs)

By a learning agent, we mean software used in a learning experience, directly by a learner, and which plays a supportive role in helping the learner achieve the needed learning goals. By a Conversational Learning Agent (CLA), we mean one that can appropriately communicate to the learner in a multimodal, often speech-centric manner: it has a narrative sequence that recognizes the learner's knowledge and gaps, emotions, cultural context, and implicit or explicit goals. By a Continuously Accessible CLA (CA-CLA), we mean a CLA that can be addressed by the learner at different times and in different places, with nearly instantaneous re-start time. Some CA-CLAs retain a history of the previous conversations with the learner, while others treat each conversation as an isolated exchange of information. But all CA-CLAs can be used when a teacher is not present and, in some cases of student-initiated learning, when no teacher is even identified.

We specify research challenges that we believe are important for deploying and understanding the impact of CA-CLAs. Our research questions are driven by our own experiences building learning technology aids. We aim to stimulate discussion within the Learning Sciences community and to encourage investigations into the validity and efficacy of newly developed or proposed CA-CLAs. We believe this community is best situated to provide technologists with the design recommendations to build enjoyable and effective CLAs.

Design questions for CA-CLAs

The most basic type of CA-CLA is a conversational agent for Information Retrieval (IR). However, simply reading and hearing search results is not synonymous with learning. This raises the following **questions**:

How can the presence of IR-enabled conversational systems promote useful learning? Should there be any limitation on how much shallow question answering can be used by the learner? Is unlimited access to agent-supplied information demotivating for mastery? If access should be limited, how should it be limited?

How can conflicting sources of information that complicate the learning process be presented? Should full and complete retrievals, including different disputed observations, interpretations and theories, be displayed to all users? How does learner expertise influence IR presentation?

More advanced CA-CLAs enable experiences beyond IR, and their effectiveness may be domain-dependent. Some subjects such as music may naturally work better as audio, while others, such as science and engineering, may naturally work better with a mix of text, visual representations, or even sketching. Several works argued for the importance of multiple representations and spatial reasoning (Wai, Lubinski, Benbow & Steiger, 2010), and auditory processing (Overy, 2000; Tallal & Gaab, 2006) across different domains. Such CA-CLA systems that employ multiple representations in multiple modalities will be required to foster sustained engagement and long-term effectiveness. *How do we interpret the multimodal expressiveness or engagement value of a CA-CLA during learning?*

Haptic feedback has been used for simulating interactions among multiple participants at a distance and for communicating directions to individuals through wearable devices (Prasad, Taele, Olubeko, & Hammond, 2014). These technologies could be applied to CA-CLAs: to guide students through tasks that have them move, observe, or interact with their physical environment. *What is the value of such feedback for teaching physical activities, such as sports, versus activities where the learner remains mostly stationary but uses haptic feedback to understand some physical phenomenon?*

Past works have shown the importance of affect on learning (Woolf, Burleson, Arroyo, Dragon, Cooper, & Picard, 2009) especially during prolonged learning sessions; it is less understood how affect could play a role in opportunistic learning during a multitude of short-term interactions. *What is the most effective way to provide subtle affective feedback during learning via CA-CLAs?*

As learners hear or read new information, humans instructors can observe facial expressions or body language and interpret these non-verbal cues ("I'm getting lost, go slower"; "This is obvious, go faster") to modify information delivery. Modern methods in naturalistic environments (McDuff, El Kaliouby & Picard, 2016) suggest that scalable facial expression interpretation in mobile learning is within reach. However, when constructing mobile learning environments, we need to consider the following: *What kind of hardware is needed to observe learner facial expression which is a feedback for CA-CLAs? How can we improve the effectiveness of interpreting and responding to non-verbal cues?*

In researching and building Conversational Learning systems at IBM, as we apply AI methodologies to the design of intelligent tutoring systems that personalize the teaching and learning experiences of disparate users under different constraints, we are gathering data and generating new questions from these real-world interactions. We will demo commercial systems for Conversational Learning during the interactive session.

References

Carnavale, A. P., Smith, N., Melton, M., & Price, E.W. (2015). Learning While Earning: The New Normal. Center on Education and the Workforce, Georgetown University.

Druga, S., Breazeal, C., Williams, R., Resnick, M. (2017, June). "Hey Google is it OK if I eat you?" Initial Explorations in Child-Agent Interaction, IDC '17.

Lenhart, A. (2015, April). Teen, Social Media and Technology Overview 2015, Pew Research Center.

McDuff, D., El Kaliouby, R., & Picard, R. W. (2015, September). Crowdsourcing facial responses to online videos. In Affective Computing and Intelligent Interaction (ACII), 2015 International Conference on (pp. 512-518). IEEE.

Overy, K. (2000). Dyslexia, temporal processing and music: The potential of music as an early learning aid for dyslexic children. Psychology of music, 28(2), 218-229.

Pieraccini, R. (2012) The Voice in the Machine: Building Computers That Understand Speech. MIT Press.

Prasad, M., Taele, P., Olubeko, A., & Hammond, T. (2014, February). HaptiGo: A navigational 'tap on the shoulder'. In Haptics Symposium (HAPTICS), 2014 IEEE (pp. 339-345). IEEE.

Tallal, P., & Gaab, N. (2006). Dynamic auditory processing, musical experience and language development. Trends in neurosciences, 29(7), 382-390.

VanLehn, K. (2011). The relative effectiveness of human tutoring, intelligent tutoring systems, and other tutoring systems. Educational Psychologist, 46(4), 197-221.

Wai, J., Lubinski, D., Benbow, C. P., & Steiger, J. H. (2010). Accomplishment in science, technology, engineering, and mathematics (STEM) and its relation to STEM educational dose: A 25-year longitudinal study. Journal of Educational Psychology, 102(4), 860.

Woolf, B., Burleson, W., Arroyo, I., Dragon, T., Cooper, D., & Picard, R. (2009). Affect-aware tutors: recognising and responding to student affect. International Journal of Learning Technology, 4(3-4), 129-164.

Middle School Student Ideas on the Relative Affordances of Physical and Virtual Models

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Abstract: This research investigates students' perceived differences between doing activities in hands-on versus virtual environments. Students explored an interactive virtual model of a solar oven and then built and tested a physical solar oven. We found that students often questioned the accuracy of virtual models, yet come to recognize the value of features in the virtual model, including visualizations of energy flow and ability to analyze trends in graphs.

Objectives

When designing inquiry curriculum, we often use interactive virtual models to allow students to investigate how variables in a system may be related. This study compares student perceptions of virtual and physical models. Models improve student learning by abstracting away unnecessary features and making invisible phenomena more visible (Snir, Smith, & Grosslight, 1993). Virtual models are now quite ubiquitous, however, their ubiquity is still relatively new, and while there is a wealth of research on supporting student learning of science concepts through the use of virtual models, not much work has been done to explore how students understand the practices involved in utilizing these virtual models.

Many studies have found students learn concepts, inquiry skills, and scientific practices at the same level or at a higher level through the use of virtual laboratories (versus physical laboratories) (e.g., De Jong, Linn, & Zacharia, 2013; Brinson, 2015). Virtual models allow students to develop their own knowledge by asking scientific questions, answering those questions using evidence, and connecting explanations to scientific knowledge. However, students may develop additional questions relating to the practice of using models (e.g., why do scientists use models? What can models tell us? What are the limitations of models?).

We use the knowledge integration framework to develop the curriculum about solar ovens, because the framework focuses on building coherent understanding (Linn & Eylon, 2011). The knowledge integration framework has proven useful for design of instruction featuring dynamic visualizations (Ryoo & Linn, 2012) and engineering design (McElhaney & Linn, 2011). The framework emphasizes linking of ideas by eliciting all the ideas students think are important and engaging them in testing and refining their ideas. Helping students to distinguish which sources of evidence are relevant and supportive (or not) of their ideas is a particular challenge for instruction. In order to develop relevant instruction, we need to know how they naturally think about the relative affordances of each type of model.

Methods

Five teachers from three different schools participated in this study, along with their students (*N*=640). All students were in the 6th grade, and all schools are in the suburbs of a large U.S. city serving mainly middle SES communities. Teachers A (*N*=137) and B (*N*=80) teach at school A, teachers C (*N*=190) and D (*N*=78) teach at school B, and teacher E (*N*=155) teachers at school C. Students completed pre- and posttests individually; during the curriculum, students worked in pairs or triads.

This study was implemented in a curriculum unit entitled *Solar Ovens*. The goal of the unit was to familiarize students with the way energy transforms from solar radiation to heat using a hands-on project and interactive models, covering the modeling aspect of the Science and Engineering Practices of the NGSS, as well as the standards associated with energy (NGSS Lead States, 2013). Students engaged with the curriculum in WISE (Web-based Inquiry Science Environment), utilizing a variety of instructional and assessment tools (Linn & Eylon, 2011). Students followed the design, build, test cycle with two iterations. During each design phase, students use the interactive model to test different features on a virtual solar oven.

We aim to find ideas students hold about the benefits and drawbacks of physical and virtual models by assessing student responses to a pre-/posttest question called *David's Claim*. This question asks students to help a fictional student, David, decide whether the box he will use for his solar oven should be tall and skinny or short and wide. Students are told that David thinks the tall and skinny box will heat up faster because the window on the top is smaller and will let less energy leave the box. Students are then asked whether David is correct or incorrect, and to explain their answer using evidence from the interactive model (where they can only manipulate box shape).

To understand student thoughts about affordances of physical and virtual models, we analyze a follow-up question, asking students whether they would rather use a physical or virtual model to help David (item: *Opinion*). While more students preferred to use the physical model at both the pretest and the posttest, there was a sight shift toward students preferring to use the virtual model or to use both models at the posttest. We found that students had ideas about benefits (or drawbacks) of physical and virtual models that fell in 10 categories, shown in Table 1.

Table 1: 10 categories for student ideas about the relative affordances of physical and virtual models, with description and name

Name	Description
Virtual Accurate	Virtual models are more accurate or valid than physical models
Physical Accurate	Physical models are more accurate or valid than virtual models
Virtual Visible	Virtual models have features that make them easier to use for explaining and learning how energy works (e.g., graphs, depiction of energy using symbols)
Physical Visible	Physical models are better because you can see them and see what's happening from any angle
Virtual Fun	Virtual models are more fun than physical models
Physical Fun	Physical models are more fun than virtual models
Virtual Fast/Easy	Virtual models are faster and easier to use than physical models, and do not require materials
Physical Fast/Easy	Physical models are faster and easier to use than virtual models
Physical Experience	Physical models give a better experience, and help students learn and focus better
Virtual Limitations	Virtual models have limitations and cannot show all the options that exist in real life

Results

By far the most common responses to the *Opinion* item were that students felt the physical model was more accurate than the virtual model and students found value in the features of the virtual model (e.g., the graph, the visualization of the phenomenon). From pre- to posttest, students' belief in the greater accuracy of the physical model compared to the virtual model increased, as did student appreciation for the visibility offered by the virtual model. Student reasoning about the limitations of the virtual model also increased drastically from pretest to posttest. In contrast, student statements about the benefits of the visibility of the physical model decreased, as did student statements that the experience of building a solar oven would help them to explain.

Conclusion

This work takes advantage of a curriculum featuring both physical and virtual models of solar overs to explore benefits and drawbacks. Moreover, the virtual model acts as a representation of the physical model students will build, providing students with an opportunity to explore the relative affordances of each type of model. This study reveals limitations in student understanding of virtual models that deserve attention to increase effectiveness of instruction featuring models. Focusing on increasing student consideration about *relative* benefits of physical and virtual models could help students appreciate virtual models and have lasting impact on their use of models.

References

Brinson, J. R. (2015). Learning outcome achievement in non-traditional (virtual and remote) versus traditional (hands-on) laboratories: A review of the empirical research. *Computers & Education*, *87*, 218-237.

De Jong, T., Linn, M. C., & Zacharia, Z. C. (2013). Physical and virtual laboratories in science and engineering education. *Science*, *340*(6130), 305-308.

Linn, M. C., & Eylon, B. S. (2011). *Science learning and instruction: Taking advantage of technology to promote knowledge integration*. Routledge.

McElhaney, K. W., & Linn, M. C. (2011). Investigations of a complex, realistic task: Intentional, unsystematic, and exhaustive experimenters. *Journal of Research in Science Teaching*, *48*(7), 745-770.

Ryoo, K., & Linn, M. C. (2012). Can dynamic visualizations improve middle school students' understanding of energy in photosynthesis?. *Journal of Research in Science Teaching*, *49*(2), 218-243.

Snir, J., Smith, C., & Grosslight, L. (1993). Conceptually enhanced simulations: A computer tool for science teaching. *Journal of Science Education and Technology*, *2*(2), 373-388.

Detecting Patterns of Dynamic Teacher-Learner Interactions in Online Adult Learning Through a Dynamic Systems Approach

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Abstract: This study investigated teacher-learner interaction patterns in the context of adult online learning. This study shows the applicability of dynamic systems approach in research on online adult learning. We employ a dynamic systems approach method, the State Space Grid, to capture dynamic interaction patterns between a teacher and learners. Results showed that the interaction patterns and their characteristics were distinct in each experimental class but also indicated that some interaction patterns were recurrent over the course.

Introduction

In this paper, we describe the detection and visualization of complex and dynamic interaction patterns in online adult learning by utilizing one of the methods in dynamic systems approaches, the State Space Grid (Granic, Hollenstein, Dishion, & Patterson, 2003; Hollenstein, 2013; Lewis, Lamey, & Douglas, 1999). Prior research has utilized the approach in the context of parent-child interaction (Granic & Lamey, 2002); in the study presented in this paper, we apply it to teacher-student interaction to detect patterns and show how the patterns change over time.

The research questions are: "What kinds of combination of utterances can be seen in the interaction between a teacher and learners?" and "How do the combinations change over the course?"

Methods

11 Japanese adults participated in this study (two females and nine males). Their ages vary from early 30s to mid 50s. The professional backgrounds of the participants varied (e.g., CEO, business consultant, business/personal coach). The high variability of the participants allows inferences on the ability of the approach to detect recurring dynamic patterns. All of the participants voluntarily participated in this study.

The data in this study are obtained from recordings of an online course held by the first author in 2015. The course consisted of 5 two-hour classes over two months. Teaching consisted primarily in discussing topics introduced in the first class of the course. The course aimed at offering academic and practical knowledge of adult development theory. The coding scheme was developed using a Grounded Theory Approach (Glaser & Strauss, 1967); the coding categories are listed in table 1. The Cohen's Kappa statistic was .87, showing strong inter-rater reliability of the coding system.

Table 1: Codes for utterances of teacher (left column) and learners (right column)

Number	Teacher Utterance Category	Learner Utterance Category
1	Instruction	Spontaneous Simple Comment
2	Open Question	Spontaneous Meaningful Comment
3	Closed Question	Spontaneous Open Question
4	Encouraging Open Question	Spontaneous Closed Question
5	Encouraging Closed Question	Encouraged Simple Comment
6	Reframe Response	Encouraged Meaningful Comment
7	Simple Response	Encouraged Open Question

State Space Grid

State Space Grid (SSG) is a software program to analyze a dynamic system's behavior in a state space (Granic et al., 2003; Hollenstein, 2013; Lewis et al., 1999). The uniqueness of the method is to highlight recurrent patterns within the interaction of two state variables. The method can also generate automatically the trajectory of the change of interaction patterns. In addition, SSG can provide researchers with a number of indicators on the screen of the software to examine a specific characteristic of an interaction.

Results

Interaction patterns and the trajectories

SSG generated the following figures (See Figure 1). Each numeric symbol in the figures corresponds with the contents in Table 1.
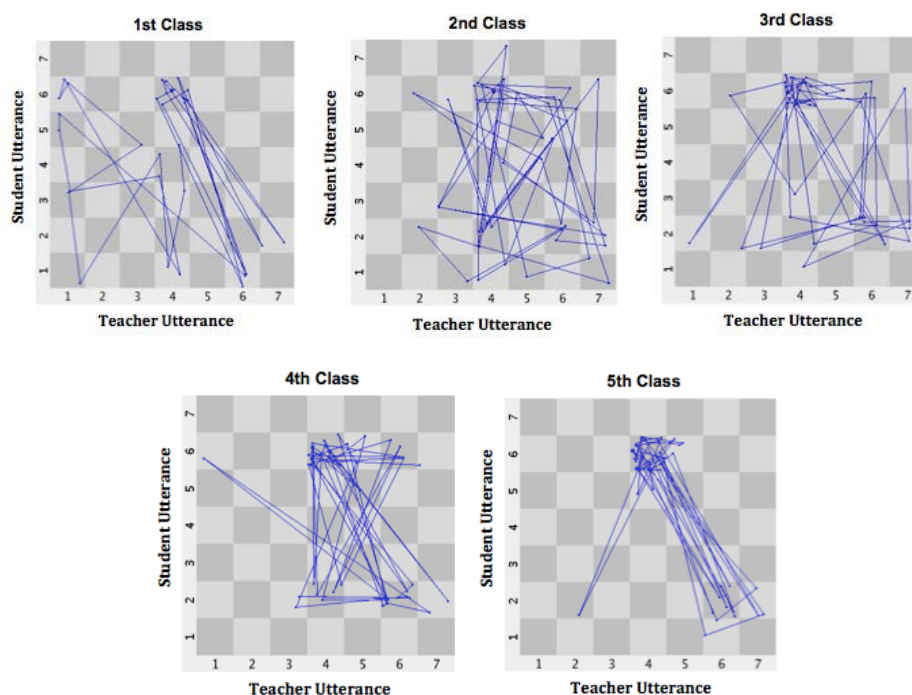
Figure 1. State space grids for five classes in terms of behaviors.

Figure 1 illustrates that each class showed different types of trajectories. It also demonstrates that a couple of cells frequently appeared. E.g., (Teacher utterance, Learner utterance) = (4, 6). The figure also shows that some combinations occurred less frequently (i.e., (1, 1), (4, 1), (7, 2)).

One captivating phenomenon is that the teacher started to frequently use "reframe response" from the second class. One reason might be related to the fact that the learning environment of the first class was more conventional than the other classes in that the teacher had to explain the purpose and structure of the course and had to offer theoretical instructions so that the learners can deepen the discussion in the succeeding classes.

Discussion

The characteristics of combinations of utterances identified by this study offer rich information on the dynamic nature of the teacher-learner interaction. If we focused only on either a teacher or learners, we would not detect such a dynamic process of interaction. In sum, this study suggests researchers that a study on dynamic interaction processes should not examine variables separately but investigate combination of variables that characterize the interaction. Also, SSG enables us to explore the trajectories of change of interaction patterns.

References

Glaser, B. G., & Strauss, A. L. (1967). *The discovery of grounded theory: Strategies for qualitative research.* Hawthorne, NY: Aldine de Gruyter.

Granic, I., & Lamey, A. V. (2002). Combining dynamic systems and multivariate analyses to compare the mother-child interactions of externalizing subtypes. *Journal of Abnormal Child Psychology, 30*(3).

Granic, I., Hollenstein, T., Dishion, T. J., & Patterson, G. R. (2003). Longitudinal analysis of flexibility and reorganization in early adolescence: A dynamic systems study of family interactions. *Developmental Psychology, 39*(3), 606-617.

Hollenstein, T. (2013). *State space grids: Depicting dynamics across-development.* New York: Springer.

Lewis, M. D., Lamey, A. V., & Douglas, L. (1999). A new dynamic systems model for the analysis of early socioemotional development. *Developmental Science, 2*(4), 457-475.

Secondary Students' Model-Based Reasoning about Earth Systems: Practice, Epistemology, and Conceptual Understanding

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Abstract: To become scientifically-literate, students must develop competence with the use of computer-based models to reason about Earth systems. In this poster presentation, we share early-stage work spanning multiple projects using technology-enabled modeling tools grounded in 'big data' with students in secondary science learning environments. The poster will showcase the modeling tools and design-based research approaches, as well as provide a context for discussion about theoretical, empirical, and design aspects of the projects.

Introduction

Today's most pressing global challenges span Earth systems at local, regional, and global scales. The problem-solvers and innovators who will be faced with addressing these challenges must develop scientific literacy. Models are a critical tool with which scientists study and seek to solve these challenges. Scientists use computer-based modeling tools grounded in 'big data' to both explain and predict systems-level phenomena. While technology-enabled tools have been a core focus for learning scientists for many years, there remains a great deal to learn about how to make these modeling tools available to students in meaningful ways and support their productive by students to reason about Earth systems. We are engaged in early-stage design-based research across multiple grant-funded projects to implement computer-based modeling tools in secondary (high school) classrooms. This work is grounded in a theoretically- and empirically-grounded learning performances framework for model-based reasoning about Earth systems. The purpose of this poster presentation is to a) share preliminary findings from project research and b) interrogate and revisit this framework as both a theoretical and analytical tool for understanding and studying secondary students' model-based reasoning.

Computer-based modeling tools

Our current work involves two computer-based modeling tools: The Hydrogeology Challenge (HGC) and Easy Global Climate Model (EzGCM). Both provide technology-enabled interfaces that allow students to 'shortcut' the complex computations that commonly underlie numerical models. The HGC (Fig. 1) is an online, computer-based learning tool used to explore hydrologic concepts associated with subsurface water. Developed by a U.S.-based non-profit organization, the HGC makes national geologic and hydrologic datasets accessible to students. Within the HGC interface, students conduct simulation-based experiments to investigate how groundwater flows, factors affecting flow rates, including gradient, porosity, and substrate. These experiments are embedded within both real and hypothetical real-world scenarios involving water issues.
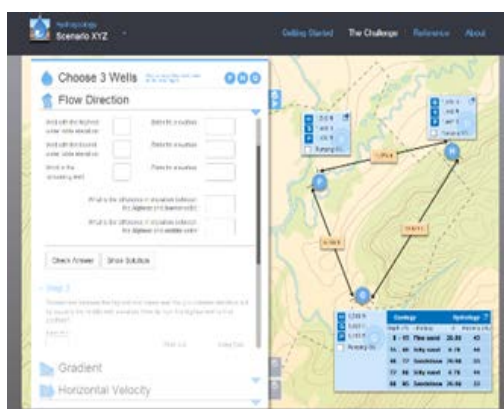
Figure 1: Hydrogeology Challenge Screenshot.
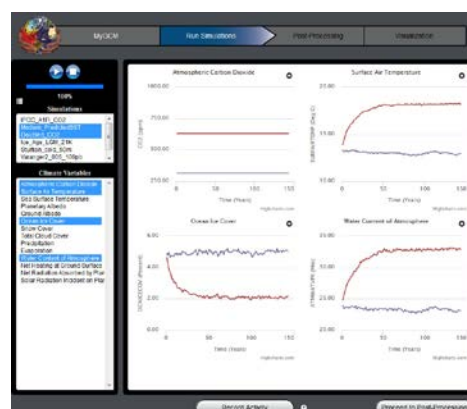
Figure 2: EZ Global Climate Model Screenshot.

EzGCM (Fig. 2), developed at Columbia University in cooperation with the NASA Goddard Institute for Space Studies, is a web-based global climate modeling suite designed to provide non-scientists with authentic climate modeling experiences. Drawing from NASA's GCM development program and using actual data from U.S. global climate modeling efforts, EzGCM streamlines and makes transparent the key features of climate models that help scientists simulate and analyze Earth's climate system. Through EzGCM, students are able to

participate in the science of climate modeling, including running simulations, post-processing model output, analyzing model results by creating scientific visualizations, and communicating results, all crucial epistemic practices through which students engage in model-based reasoning about Earth's climate.

A learning performance framework for scientific modeling

Competency with scientific modeling requires students develop abilities to use models in ways that mirror the practices of science to reason about natural phenomena. Modeling competence is developed through interactions between the learner, the model, and the real-world phenomenon. We draw upon Harré's (1970) concept of 'projective convention', situated and activity-based perspectives on learning and expertise (e.g., Engeström, 2008), and scientific modeling in educational contexts (e.g., Schwarz et al., 2009) to foreground the practice-based and integrated nature of scientific modeling. Competence is defined by 'knowledge of' scientific models and modeling, as well as how users apply models to make sense of natural phenomena. These assumptions are captured in student *learning performances* (Krajcik, McNeill, & Reiser, 2007), which define practice-based evidence of learning. The learning performances framework we articulate for scientific modeling is comprised of three dimensions: modeling practices, epistemic dimensions of modeling, and disciplinary concepts.

Research methods

Both projects involve design-based research (Collins, Joseph, & Bielaczyc, 2004) to engage in iterative development of curriculum, refinement of the modeling tools, creation of research measures that embody theoretical constructs, and data collection and analysis. Curriculum development involves a process of construct-centered design (Shin et al., 2010), through which the modeling tools are being piloted in eight secondary science classrooms in the United States. We are collecting a diverse set of data in these classrooms, including student assessments and artifacts, clinical interviews, observational data, and implementation logs.

Preliminary findings and points of discussion

Preliminary analyses of project data point to key aspects that will lead to productive discussions with conference participants. First, even though the learning tasks in the curriculum modules are designed to target all theoretical learning performances, evidence for some performances is far more robust than others. Is this reflective of students' model-based reasoning within these domains, or perhaps reflective of limitations in learning environments design and/or measurement of anticipated student outcomes? Second, what are core epistemic elements of scientific modeling, and perhaps scientific practice more generally? While the learning performances framework embodies contemporary perspectives on epistemological dimensions of modeling in science, not all have proven to be equally useful and/or applicable as educational design heuristics or research constructs. What are key aspects of models and modeling that make them scientific? What levels of conceptual understanding do students exhibit and what levels should they be expected to attain? How do they manifest themselves in certain modeling practices in which students engage to investigate natural phenomena? Conversations about the nature of epistemology as it applies to Earth systems modeling using technology-enabled tools will help clarify epistemic dimensions of students' model-based reasoning about Earth systems.

References

Collins, A., Joseph, D., & Bielaczyc, K. (2004). Design research: theoretical and methodological issues. *The Journal of the Learning Sciences*, *13*(1), 15-42.

Engeström, Y. (2008). *From design experiments to formative interventions*. In G. Kanselaar, V. Jonker, P. Kirschner, & F. Prins (Eds.) *Proceedings of the 8th International Conference of the Learning Sciences*, (pp. 3-24). Utrecht, The Netherlands.

Harré, R. (1970). Constraints and restraints. *Metaphilosophy, 1*(4), 279-299.

Krajcik, J., McNeill, K. L., & Reiser, B. (2007). Learning-goals-driven design model: Developing curriculum materials that align with national standards and incorporate project-based pedagogy. *Science Education*, *92*(1), 1-32.

Schwarz, C., Reiser, B., Davis, E. A., Kenyon, L., Acher, A., Fortus, D., Krajcik, J. (2009). Developing a learning progression for scientific modeling: Making scientific modeling accessible and meaningful for learners. *Journal of Research in Science Teaching*, *46*(6), 632-654.

Shin, N., Stevens, S. Y., & Krajcik, J. (2010). Tracking student learning over time using construct-centered design. In S. Rodrigues (Ed.), *Using analytical frameworks for classroom research: Collecting data and analyzing narrative* (pp. 38-58). London, England: Taylor & Francis.

Acknowledgments

Exploring Novice Approach to Conceptual Design of Software

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Abstract: Engineering graduates are expected to design solutions to solve real world problems. While experts have body of knowledge and heuristics to arrive at solutions, novices do not have such knowledge and hence find it difficult to design solutions. In order to determine the nature of difficulties faced by novices, we conducted a study where novices were required to come up with a conceptual design for a given software design problem. We used the Function-Structure-Behaviour (FSB) lens to analyze the artefacts and the processes. Results from the analysis show that novices were unsuccessful when they fixate to either one or all FSB elements initially. These results inform the pedagogical strategies for teaching learning of conceptual design in the context of software.

Keywords: software, conceptual design, novices, function-structure-behaviour

Introduction

Conceptual design is one of the critical steps in engineering design (Pahl & Beitz, 2013). Conceptual design activity is described as a process in which the functional requirements of the design problem are transformed into descriptions of solution concepts (Chakrabarti & Bligh, 2001). Software design even though has a lot of common activities with other design domains (Cross et al, 1996); the dynamic and intangible nature of software however, poses a lot of challenges. Novices often have limited knowledge structures and experience that professional software designers have gained by experience. Novices might find designing solutions for open-ended problems daunting. Novices' difficulties can drive design of interventions and pedagogic strategies. In this paper we report a study conducted to understand novice's difficulties during the conceptual design activity in the context of software design.

Theoretical lens

The overarching theoretical lens that we chose to understand the novice conceptual design processes is Function-Structure-Behavior (Gero, 1990; Goel et al 2009). Function-Structure-Behaviour (FSB) answers – what the system does (F), what are all required to achieve the function (S), how is the function achieved (B). We used the FSB framework to analyze artefacts and identify absence of cognitive strategies/mechanisms in novices such as mental simulation, abstraction, association. These cognitive strategies have been reported to be utilized by expert software designers (Ball et al, 2010).

Methodology

The broad research question guiding this study was, 'What are the difficulties novices face while creating a conceptual design? '.

Participants and problems

The study spanned over two days and had five final year computer-engineering under-graduates as participants. The participants (par1-5) were exposed to software design courses as a part of their curriculum. So they had pre-requisite knowledge for the task. The participants were given a choice of problems: (i) Design a finger print ATM system (par2), (ii) Design a mood based automatic player (par1 & par3), (iii) Design a finger print based payment system (par4 & par5) and (iv) Design a cooking recipe recommender system. All the problems are equivalent in terms of complexity of time and cognitive skills.

Data source and analysis

Each participant was required to select one of the above problems and create a conceptual design. To accomplish the task the participants were provided with laptops with internet connection, paper and pen. While the participant was on the task, video recording of the activity and screen capture of their interaction with laptop was captured. Post task the participant was also interviewed. The data source included the video recording of the activity, screen captures, participant generated artifacts and the interview transcripts.

To analyze the video recording the protocol analysis by Mc Neill et al, (Mc Neill et al, 1998) was adapted. We looked for the FSB elements and tagged the video with the timestamp and details. The unit of analysis for

function (F) was words/sentences, for structure (S) words and for behaviour (B) it was sentences. The coded video and the artifacts were used to extract the frequency of the FSB elements. The frequency and uniqueness would indicate the breadth and depth of conceptual design. A csv file was created with the FSB codes, details and timestamps. Process Mining Tool (PROM) was used to present in the data in the form of an event stream where the transitions across timelines was generated. The event stream provided the timeline and transitions of FSB elements indicating the cognitive processes

Results

Among the five participants two of them (par2 & par4) completed the task successfully. They both generated artefacts ranging from most basic formal representations like component diagram, use case diagram to the complex formal representations like sequence diagram and process diagram. These participants also had the higher frequency of unique function (F) elements. They also identified appropriate structures and generated behaviours, which lead to the solution design to have sufficient details. The event stream for these two participants indicate a cyclic process of simulating end user interactions (B), abstract them to features of solution (F) and associating it to components (S) in the system.

Par1 and par3 had higher frequency of function (F) elements, however the unique functions were very less. They both simulated behaviours (B) however kept going back to the same behaviour. They were unable to identify structures (S), which indicate the absence of association/abstraction process. Par5 on the other hand kept going back to the same function (F). The unsuccessful candidates were fixated to one of the FSB elements during conceptual design. The FSB framework helped to identify that fixation can happen at absence of certain cognitive processes like mental simulation, abstraction and association. All three unsuccessful participants were unable to utilize formal representation mechanism naturally even though they had the pre-requisite knowledge.

Conclusions and implications

The study task was time bound and we are unsure about the effect of additional time in hand on the participants' conceptual design. We would need to repeat the study for more novices to ascertain if there are any more cognitive processes that we could have missed.

This paper identifies the role of mental simulation, abstraction, association and representation in novices to create conceptual design in the context of software design. The study also identified that fixation can happen across function, structure and behaviour. Fixation could mean that novice couldn't simulate/associate/abstract. We need to explore mechanisms to trigger such processes and also observe experts' process. For teaching learning of conceptual design pedagogical strategies need to be developed which would avoid fixation.

References

Ball, L. J., Onarheim, B., & Christensen, B. T. (2010). Design requirements, epistemic uncertainty and solution development strategies in software design. *Design Studies*, 31(6), 567-589.

Chakrabarti, A., & Bligh, T. P. (2001). A scheme for functional reasoning in conceptual design. *Design Studies*, 22(6), 493-517

Cross, N., Christiaans, H., & Dorst, K. (Eds.). (1996). *Analysing design activity* (Vol. 11, p. 463). Chichester: Wiley.

Gero, J. S. (1990). Design prototypes: a knowledge representation schema for design. *AI magazine*, 11(4), 26.

Goel, A. K., Rugaber, S., & Vattam, S. (2009). Structure, behavior, and function of complex systems: The structure, behavior, and function modeling language. *Ai Edam*, 23(1), 23-35

Mc Neill, T., Gero, J. S., & Warren, J. (1998). Understanding conceptual electronic design using protocol analysis. *Research in Engineering Design*, 10(3), 129-140.

Pahl, G., & Beitz, W. (2013). *Engineering design: a systematic approach*. Springer Science & Business Media.

What's the Difference? A Closer Look at Idea-Centric Analysis of Online Discourse in K12 and Higher Education Settings

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Abstract: This study investigated the differences between two online discourses in the eighth grade and post-graduate settings, in an initial effort to understand how students deepen their understanding by improving their ideas through knowledge building discourse. Using an idea-centric approach for discourse analysis, preliminary findings show a diverse and larger number of ideas in the eighth-grade discourse when compared to a smaller variety but more promising ideas in the post-graduate discourse. The findings provided information about strategies to guide and scaffold students of different levels in their improvement of ideas and understanding through knowledge building discourse.

Keywords: Discourse analysis, idea analysis, knowledge building, K12, higher education

Introduction

The approach of framing and co-constructing knowledge through technology (Scardamalia & Bereiter, 1994; Cohen & Scardamalia, 1998) has been established for some time, with discourse increasingly taking place in online spaces. Knowledge building (Scardamalia & Bereiter, 2003) was developed as a pedagogical approach to leverage learners' natural capability of idea generation for collaborative improvement of ideas through discourse. For students to achieve a deeper approach to learning (Biggs, 1987) and use the most appropriate cognitive activities for handling learning tasks, there is a need for analyzing ideas in the discourse so that users are able to recognize ideas that are potentially interesting to the community and continue improving these ideas to enhance their learning and understanding. The productive use of the "improvable ideas" principle (Scardamalia, 2002) through inquiries and productive discourse could encourage students to value every contribution and idea in discourse as being potentially improvable. K12 students are assumed to be still developing their knowledge-building capacity, whereas higher education students are considered to be more mature in such an approach, but is this assumption always valid? The findings in this study could shed some light on this assumption and provide valuable information about strategies to guide and scaffold students at different levels, to improve their ideas and understanding through knowledge building discourse.

Method and plan of analysis

Dataset

The dataset contains a week of discourse data selected from two discourse communities, namely a middle school class in the K12 setting and a graduate course in the higher education setting. There were 20 eighth-graders in the middle school class discussing the scientific topic of "Human Transport System", with 101 notes being contributed and shared among the community on the Knowledge Forum – a knowledge building environment built specifically to support collaborative production and refinement of communal knowledge. Similarly, a total of 13 in-service teacher participants discussed the "basic principles of Computer-Supported Collaborative Learning (CSCL)" and contributed 162 notes to the Knowledge Forum.

Method and analysis

This study employed the methodology Idea Identification and Analysis (I^2A; Lee, Tan, & Chee, 2016) to conduct an idea analysis and compare the knowledge building discourses from K12 and higher education settings. This methodology was primarily developed and used as a tool to identify ideas promising to the students or the teachers. I^2A aided in the analysis of knowledge building discourse using network measures such as betweenness centrality to identify ideas that have a subsequent impact on community discourse. As a result, *promising* and *potential* ideas from discourse were classified as part of the process that measured the progress of idea development in knowledge building discourse. *Promising ideas* are defined to be of great relevance to the community and are able to sustain the community's interests and therefore, are worth pursuing and likely to affect the communal discourse. *Potential ideas* exhibit lesser communal relevance to some extent and the community's interest in these ideas are difficult to be triggered or sustained. Therefore, in order for these ideas to have some form of impact or

influence on communal discourse, scaffolds and interventions are required to elevate and maintain the community's interests in the ideas within the discourse. The discovery of promising ideas and their effects through network analysis were subsequently validated using a qualitative analysis.

Preliminary results

Preliminary results computed from the network analysis in the I^{2}A methodology show that a total of 10 ideas (including both promising and potential ideas) were identified from the eighth-grade discourse, but only one idea was considered promising; whereas 8 ideas were identified in the post-graduate discourse, of which half were considered promising to the discourse community. The categorization of ideas was qualitatively assessed and 88.9% of the identified ideas were recognized to be correctly classified by two raters, consisting of teachers and instructors participating in the discourses. Together with a visualization of notes that were created on the Knowledge Forum, these results offered a new perspective on the development of ideas in knowledge building discourse from different settings. The post-graduate students were able to produce an equal split of potential and promising ideas from their communal discourse, signifying the focus on idea quality and promisingness. Comparatively, the student community from the K12 setting was keen to contribute more ideas, with a majority of them being potential rather than promising ideas. The students in the eighth grade were generally able to contribute notes with ideas that were potentially promising and broadly interesting to the discourse community, but these ideas lack a convincing attribute to encourage uptake by other students or impact subsequent discourse. Contrarily, from the post-graduate discourse, the group of promising and potential ideas acted as key mediators between different groups of students and became triggers that stimulated student interests in relevant and supplementary content.

Conclusion and future work

In conclusion, the differences of knowledge building discourse from a K12 and higher education setting were investigated, in an effort to understand how students in different settings deepen their understanding using ideas in knowledge building discourse. Based on an idea analysis and comparison of two discourses, more ideas were generated but were less promising in the eighth-grade discourse, while fewer ideas were generated but were more promising to the post-graduate community. K12 students had difficulty in harmonizing with the community's goals, while students in higher education were able to organize their ideas and thoughts to improve the coherence of ideas and their level of understanding, with the contrast possibly attributed to the different cognitive ability of students. For future work, this preliminary study presented the possible role of a computational-based methodology for idea analysis in discourse. The technological affordance of Knowledge Forum and findings from this study were instrumental in aiding the construction of strategies to guide and scaffold students in their improvement of ideas and maintaining the support and interest of the community in generating more promising ideas, deeper understanding, and attainment of knowledge creation goals.

References

Biggs, J. B. (1987). *Student Approaches to Learning and Studying. Research Monograph*. Australian Council for Educational Research Ltd., Radford House, Frederick St., Hawthorn 3122, Australia.

Cohen, A., & Scardamalia, M. (1998). Discourse about ideas: Monitoring and regulation in face-to-face and computer-mediated environments. *Interactive Learning Environments*, *6*(1-2), 93-113.

Lee, A. V. Y., Tan, S. C., & Chee, K. J. K. (2016). Idea Identification and Analysis (I2A): A search for sustainable promising ideas within knowledge-building discourse. In C. K. Looi, J. Polman, U. Cress, & P. Reimann (Eds.), *Transforming Learning, Empowering Learners: Proceedings of the 12th International Conference of the Learning Sciences* (ICLS '16), 20-24 June 2016, Singapore (Vol. 1, pp. 90-97). International Society of the Learning Sciences.

Scardamalia, M. (2002). Collective cognitive responsibility for the advancement of knowledge. In B. Smith (Ed.), *Liberal Education in a Knowledge Society*, *97*, 67-98.

Scardamalia, M., & Bereiter, C. (1994). Computer support for knowledge-building communities. *The Journal of the Learning Sciences, 3*(3), 265-283.

Scardamalia, M., & Bereiter, C. (2003). Knowledge building. *Encyclopedia of Education* (pp.1370-1373). New York: Macmillan Reference.

Acknowledgments

Enhancing Online Structured Dialogue During Teaching Internships Through Digital Storytelling to Promote Professional Socialization

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Abstract: We conducted a five-year design-based research that aimed to investigate the conditions necessary to create a weblog community where the student teachers could discuss the variety of work-related experiences they encountered during their internships with the goal of fostering teachers' professional socialization and identity development. We introduced digital storytelling so that student teachers could visualize their prospective internships and could then engage in a dialogue related to teachers' professional socialization and identity development. A social network analysis (SNA) showed a relatively stable impact of prospective storytelling on the online dialogue that structurally demonstrated teachers' professional values and social behaviors, rather than focusing solely on their teaching.

Introduction

A student teacher's experience with a particular school's institutional and ecological aspects is the strongest determinant of one's teaching outlook (Fenstermacher 1980). Practicum can function as a factor in developing professional identities and increasing socialization through an intensive working experience. Sharing and examining such working experience in schools is essential for student teachers to effectively develop their professional identity and increase professional socialization. Our research indicated that a weblog community with an experienced teacher during the practicum could be an excellent resource for professional socialization by allowing the student teachers to exchange practical knowledge, impressions of their respective working environments, and solutions to various problems.

The purpose of the current study is to investigate the conditions necessary to create a weblog community where the student teachers could discuss the variety of work-related experiences they encountered during their internships with the goal of increasing teachers' professional socialization and building their professional identity. Storytelling can be another means to represent the teachers' professional identity and socialization, that is constructed in their life stories as workers in the school (Atkinson and Delamont 1985). This study examines the potential benefits of digital story telling (DST) wherein the student teachers share their prospective experiences to obtain a broader understanding of schools as workplaces, with improvement in the quality of online dialogue in the weblog community from the viewpoint of professional socialization.

Research design

A design-based research methodology was applied for five years in an on-campus course as a part of a Japanese undergraduate teacher training program requiring a two to three-week practice teaching internship at a school (Table 1). The student teachers were asked to access the weblog community and post a weblog on their working experience every 2 or 3 days throughout the internship, as well as to comment on weblog entries of other student teachers. DST was implemented from the 3rd year, just before the practicum began. Each student teacher made a presentation using their prospective working stories created with a cartooning application before their practicum. The student teachers could foster their professional socialization and identity development by imagining potential scenarios (including relationships with key individuals and cultural artifacts).

Table 1: Overview of the participants, weblog activities, and interventions.

Year	# of Student Teachers	# of Weblogs	# of Comments	An Experienced Teacher's Participation as a Facilitator on the Weblog Community	DST
1	15	102	155 (355)	Online only, actively providing comments	No
2	9	82	366 (430)	Online (inactive) and face-to-face (with insightful comments)	No
3	7	82	180 (221)	Providing comments and asking questions both online and face-to-face from a professional teacher's perspective	Yes
4	16	118	125 (326)		
5	8	41	51 (93)		

Note: Numbers in parentheses include the professional's facilitations and comments.

Weblogs and comments were coded for ascertaining to what extent the student teachers wrote about working as schoolteachers, and whether they took the school's institutional characteristics into consideration. The coding scheme was based on Hong (2010), including (1) Commitment Towards Work, (2) Value and Standpoint as Teachers, (3) Emotion, (4) Micropolitics, (5) Efficacy, and (6) Knowledge and Beliefs of Teaching, as well as (7) Expectations and the Reality of Schools, (8) Social Behavior as Professionals, and (9) miscellaneous category. When a weblog or a comment entry had multiple categories, each category was counted; coding discrepancies were resolved through discussion. Furthermore, to evaluate the quality of online dialogue during each academic year regarding discourse structure, a social network analysis was conducted using Knowledge Building Discourse Explorer (Oshima, Oshima, and Matsuzawa 2012). We focused on degree centralities of each coded category related to teacher socialization and professional identity development to assess temporal structural qualities indicating the linkage of the categories pertaining to such development.

Results and discussion

Figure 1 shows differences in transitional changes of the sum of degree centralities and each category's degree centrality related to teacher socialization and identity development, focusing on values and standpoints, and on social behavior as professionals. The graphs showed a tendency for transitions in the 3rd, 4th, and 5th years to have a relatively higher stable value when compared to the 1st and 2nd years, indicating that the student teachers' discourse concentrated densely on teacher professional socialization. One-way ANOVA with Bonferroni post hoc analysis for 5 factors (years) with the sum of degree centrality as the dependent variable revealed that each sum of degree centralities for the 3rd ($n = 303$, $M = 5.02$, $SD = .995$), 4th ($n = 446$, $M = 4.69$, $SD = 1.15$), and 5th ($n = 136$, $M = 4.68$, $SD = 1.12$) years was significantly higher than those for the 1st ($n = 457$, $M = 2.89$, $SD = .947$) and 2nd ($n = 512$, $M = 3.63$, $SD = 1.52$) years; $F (4, 1849) = 214.103$, $\eta_p^2 = .317$, $p < .001$.

Similar one-way ANOVAs with Bonferroni post hoc analyses using the degree centrality for each category as the dependent variable revealed that the indicators of "Value and Standpoint" for the 3rd ($M = .595$, $SD = .258$), 4th ($M = .576$, $SD = .214$), and 5th ($M = .562$, $SD = .274$) years were significantly higher than those for the 1st ($M = .270$, $SD = .235$) and 2nd ($M = .364$, $SD = .297$) years; $F (4, 1849) = 129.316$, $\eta_p^2 = .219$, $p < .001$, with Bonferroni post hoc analysis. Moreover, the indicators of "Social Behavior" for the 3rd ($M = .762$, $SD = .121$), 4th ($M = .691$, $SD = .175$), and 5th ($M = .756$, $SD = .189$) years were significantly higher than those of the 1st ($M = .512$, $SD = .209$) and 2nd ($M = .554$, $SD = .265$), even though there were significant differences between the 4th and 3rd/5th years; $F (4, 1849) = 107.387$, $\eta_p^2 = .189$, $p < .001$.

This indicates that the third-year design comprising storytelling about the student teachers' prospective work experiences fostered structured dialogue from the viewpoint of teachers' professional socialization.
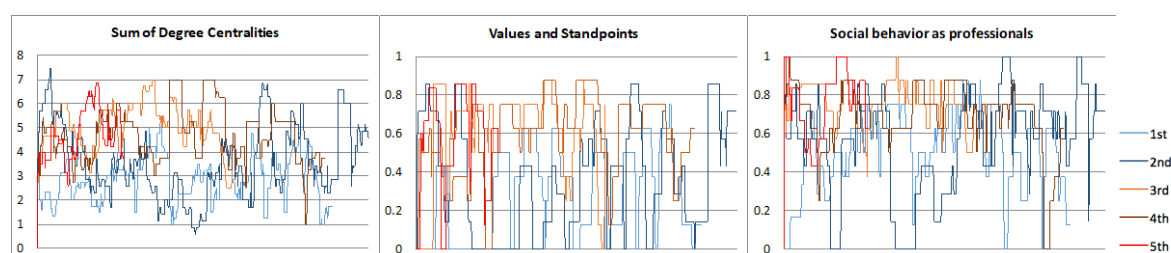
Figure 1. Changes in degree centralities in each year (horizontal axes: conversational turns of posts).

References

Atkinson, P., & Delamont, S. (1985). Socialization into teaching: The research which lost its way. *British Journal of Sociology of Education*, 6(3), 307–322.

Fenstermacher, G. (1980). On learning to teach from research on teacher effectiveness. In C. Denham & A. Lieberman (Eds.), *Time to learn* (pp. 127-137). Washington, DC: U.S. Dept. of Education.

Hong Y. (2010). Pre-service and beginning teachers' professional identity and its relation to dropping out of the profession. *Teaching and Teacher Education*, 26, 1530-1543.

Oshima, J., Oshima, R., & Matsuzawa, Y. (2012). Knowledge Building Discourse Explorer: a social network analysis application for knowledge building discourse. *Educational Technology Research and Development*, 60(5), 903–921

Acknowledgments

Enskilment in the Digital Age:
The Interactional Work of Learning to Debug

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Abstract: We present a detailed account of the interactional work between a programming instructor and a middle school student that leads to the resolution of an elusive error in the student's code. By tracing the fine details of how this resolution came to be, we demonstrate how learning to debug in face-to-face interactions resembles a process of enskilment.

One of the most fundamental and difficult aspects of mastering computer programming is learning to *debug*—to detect and resolve hidden errors (*bugs*) in programs (Papert, 1980). Here, we contribute a close examination of a productive debugging encounter between a programming instructor and a fifth-grade student to better understand how face-to-face interactions can support students' search for and resolution of errors.

In the episode we examine, the student is able to locate and resolve a bug in her program without being explicitly told where or what it is. Following Suchman (1987), we approach debugging as an event-driven form of *situated inquiry* that cannot be reduced to pre-specified plans or generalizable procedures. Inspired by ethnomethodological conversation analysis, our fine-grained approach reconstructs the practical interactional work between student and instructor that leads to the error's resolution. We find that the process resembles one of *enskilment* (Ingold, 2000): A newcomer is supported in appreciating and using the affordances of their environment (Figure 1) for *work-relevant perception and action* (Goodwin, 2018).

Figure 1. ComputerCraft's integrated development environment (IDE) is a complex, dynamic perceptual field with an array of specialized tools and possibilities for action.

In particular, we find two key interactional mechanisms that contribute to the productive resolution of the bug: (1) The use of *vague references* to occasion the search for the error; and (2) the use of *contracting question agendas* to structure participation in specific forms of perception and action for debugging.

Figure 2. Excerpt 1: Formulating the bug as a witnessable event that can be further specified.

Student Ana writes a program in ComputerCraft to make her turtle robot move one grid square to the right, but the program outcome is not as expected. While Teo, the instructor, could easily spot the problem by watching the program's behavior in the virtual world or inspecting the code in the program window, the nature of the problem is opaque to Ana in both of these domains (Figure 1). Teo could simply tell her from his experience that the error message "attempt to call nil" likely means she is calling a function that has not been defined. However, this would not support Ana in productively engaging in her own search for the bug. Encountering an error without knowing where or what it is and being presented with an ambiguous error message is a pervasive experience in programming. Knowing how to use the IDE to narrow the search to locate the bug is paramount.

Instead, Teo uses evidently-vague (Garfinkel & Sacks, 1970) indexical references ("something happened," and "an error;" Figure 2, E1.5), occasioning further analysis of the issue. Evidently-vague references

are *prospective indexicals* that make presently-unknown, yet-to-be-determined entities phenomenally present in the ongoing interaction. This allows participants to orient to their prospective elaboration and subsequent specification (Goodwin, 2018). Thus, Teo's description creates the need to continue the search.
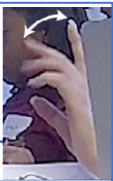

```
1  Teo:  So::o, [let's go to stop
2             [((Teo points toward screen))
3  ((Ana clicks stop then goes to the code window))
4  Teo:  Soo, [turn right and forward,
5             [((Teo points to screen twice, rhythmically timed with "right" and forward"))
6        [are they working right now? Yes or no, what do you think?
7        [((Teo holds up middle and index finger and alternates them back and forth))——
8  Ana:  No, because I didn't put double
```

Figure 3. Excerpt 5: Using question agendas to narrow the search: Eliminating properly functioning code.

After a few minutes, Ana has still not discerned which portions of her code are functioning properly. Removing functional lines of code from consideration would significantly simplify the search for the bug. Teo directs Ana to stop the program (Figure 3, E5.1) and calls her attention to two working lines of code: `turtle.turnRight()` and `turtle.forward()` (E5.4), using a rhythmic pointing gesture to highlight each discrete step (E5.5). Then, Teo asks, "Are they working right now?" (E5.6). This polar question projects a restricted, binary yes or no response as the relevant action agenda (Heritage, 2003). Teo *upgrades* this action agenda with the tag question, "Yes or no, what do you think?" (E5.6) By alternating his left index and middle fingers (E5.7), he further amplifies the binary choice for Ana. Goodwin (2000) showed that when gestures appear redundant, they can actually function to *insist* that the recipient address the projected agenda of the talk. By making the required response explicit, Teo makes it difficult for Ana to avoid answering by claiming a misunderstanding of the kind of response Teo is projecting. Designing questions that force recipients to take a binary yes-or-no stand on delicate issues is frequently observed in news interviews. Such questions often take the form of "splits" or "forks," where the interviewee is left to select between two choices the interviewer has given, though neither of them may be appealing (Heritage, 2003). While often seen as an aggressive tactic, Teo's use of his question with its highly constrained action agenda is not hostile or argumentative. Instead, it limits Ana's possibilities for action, creating an opportunity for her to participate in a productive strategy for debugging: Eliminating properly functioning code from the search (Gould, 1975). However, because Ana doesn't realize that these lines work (E5.8), they next move on to examining and testing each statement line by line, until Ana finally finds success.

At the end of this 4-minute episode, Ana was able to fix the bug in her program without ever being explicitly told where it was, what it was, or how to fix it. Ana's path to finding and fixing the bug was not the most efficient or elegant one. However, each strategy Ana was led to participate in along the way was an authentic approach an experienced programmer might choose to locate a bug. Ana's engagement in each approach was emergent from and contingent on her instructor's ongoing efforts to position the digital world in front of her for work-relevant kinds of perception and action. In turn, each of Teo's efforts to position the IDE was finely calibrated to Ana's public exhibits of how she was currently attuned to what she saw in front of her. While taking place in the digital arena of a programming classroom, we find that this process closely resembles the forms of enskilment observed in what are traditionally thought of as more "physical" domains of human practice such as hunting, surgery, cooking, and scientific fieldwork (Goodwin, 2018; Ingold, 2000).

References

Garfinkel, H., & Sacks, H. (1970). On formal structures of practical actions. In J. C. McKinney & E. Tiryakian (Eds.), *Theoretical sociology: Perspectives and developments* (pp. 337–366). New York: APC

Goodwin, C. (2000). Action and embodiment within situated human interaction. *Journal of Pragmatics*, *32*(10), 1489–1522.

Goodwin, C. (2018). *Co-operative action*. Cambridge: Cambridge University Press.

Gould, J. D. (1975). Some psychological evidence on how people debug computer programs. *International Journal of Man-Machine Studies*, *7*(2), 171–182.

Heritage, J. (2003). Designing questions and setting agendas in news interviews. In P. J. Glenn, C. LeBaron, & J. Mandelbaum (Eds.), *Studies in language and social interaction*. Mahwah: Lawrence.

Ingold, T. (2000). *The perception of the environment*. London: Routledge.

Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas*. New York: Basic Books.

Suchman, L. A. (1987). *Plans and situated actions*. New York, NY: Cambridge University Press.

Acknowledgements

Robots That Help: Moving Toward Human-Centered Designs

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Abstract: Secondary school students following a problem-based human-centered robotics (HCR) curriculum designed and built robots as a way of engaging with engineering design practices. In this preliminary analysis, we identified a shift in a focal classroom from technically to socially focused robot designs across two semesters. This poster considers how teacher framing and scaffolding supported a social orientation in student designs.

Keywords: problem-based learning, STEM learning, human-centered robotics

Robotics has been a popular approach for engaging learners in Science, Technology, Engineering and Mathematics (STEM), as it enables students to co-construct tangible artifacts based on personal interests and values (Blikstein & Krannich, 2013). Human-centered robotics (HCR) can help students understand how robots can help humans in their everyday lives and, by using social aspects of engineering, it can engage learners who may not otherwise display interest in STEM (Rusk et al., 2008). Here, a problem-based learning (PBL) curriculum was adapted to different school contexts. In PBL, students are presented with an authentic, ill-structured problem (Hmelo-Silver, 2004). Teachers scaffold student learning and inquiry by directing them toward resources, providing just-in-time information, and helping them evaluate what they have learned (Puntambekar, 2015). In this HCR unit, students were presented with a design challenge to create robots that both served a need in their local community and could be used to communicate telepresently with other geographically distant classrooms (Gomoll et al., 2016). One of the challenges in this unit is the tension between the technical and social aspects of design. Here, we compare the final robots created in different implementations of the unit as the teacher introduced designing for clients and emphasized the social aspects of STEM. Thus, we seek to understand what aspects of the design challenge were taken up in the students' final designs and how teacher framing may have influenced that uptake.

Methods

Using a qualitative coding scheme, we analyzed the students' final robot artifacts (n=42), which were created in small collaborative groups composed of 2-4 students at three middle schools, one high school, and an afterschool club. Two researchers used images and descriptions of the final robots to code for visibly obvious function, social need, telepresence function, advanced components (e.g., laser-cut or 3D printed pieces), sensors and actuators (e.g., moving limbs, LED lights), embellishment, safety features, and client personalization. After achieving 92% agreement on a 20% sample of the artifacts, the researchers coded the remaining artifacts and resolved all disagreements. Descriptive statistics of artifact codes highlighted differences across school contexts and semesters. This preliminary analysis centers on the work of 12-14 year old students from Rose Stem Middle School (RSMS) (pseudonym), as this context showed the most dramatic change across two semesters, with five groups of 2-3 students each per semester. Teacher interviews were used to understand how the RSMS teacher conceptualized the unit, the changes between the two semesters, and if and how the teacher's framing affected student designs.

Results and discussion

Descriptive statistics on the coded artifacts are shown in Figure 1. The obvious function, advanced components, sensors, and actuators categories remained relatively constant across these two semesters. Other categories changed dramatically. For example, social need increased from 0% in 2016 to 100% in 2017, embellishment dropped from 100% to 40%, and client personalization increased from 0% to 100%. Telepresence also increased from 20% to 80%. We conjecture that these changes reflect an increased focus on the social aspects of STEM and client-oriented design from 2016 to 2017. Multiple codes that decreased (e.g., safety features, sensors) were technical features, allowing more balanced attention to social and technical aspects of design overall.
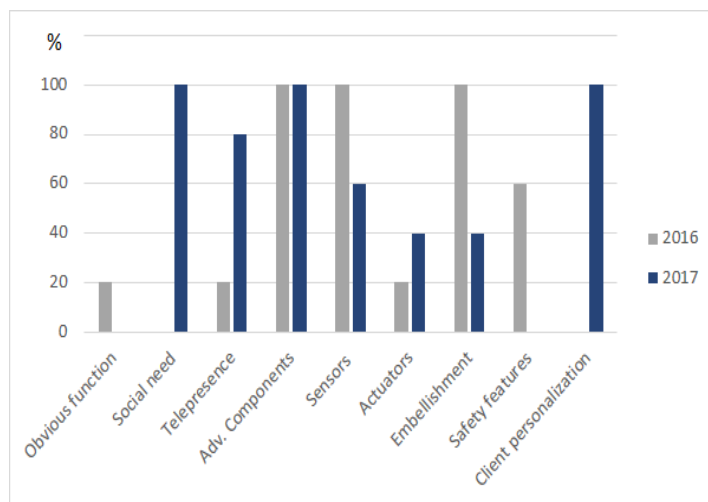
Figure 1. RSMS artifact design features.

Figure 2. RSMS 2017 artifact.

Given this shift from technically to socially-oriented robot designs, we sought to understand what role teacher framing of the unit played in these changes. A post interview with the RSMS teacher showed increased attention to the social aspects of design in the 2017 iteration. She pointed out that it was important to frame the unit in a way that would "get kids to think about how the social interaction comes in, not just the programming."

Students in 2017 selected clients in their school and designed their robots to meet the client needs. For example, in Figure 2, the students added animals to their design to appeal to their clients (students with special needs) after receiving feedback that the robot did not look friendly enough, showing increased attention to social need. The teacher demonstrated her own orientation toward client-centered design when she suggested telling future facilitators "not to worry too much about the programming…but to focus on the creativity and the design for clients." She emphasized that the most important things the students learned were "teamwork, working together, the programming, and just the whole idea of design and build and test," which showed her commitment to both the social and technical aspects of the HCR unit, and her foregrounding of the engineering design cycle.

Conclusion

These preliminary results suggest that we need to better understand how teachers can frame engineering design units in ways that make the social aspects of STEM more salient in order to engage more diverse learners. After noting substantial differences in RSMS, further analysis is needed across all contexts to see if similar patterns of movement from technical to social focus occurred, and ways that framing may have supported or hindered this shift. The adaptability of this PBL curriculum shows promise for supporting students as they design robots that meet local needs. As instructors incorporated the voices of familiar community stakeholders into the PBL problem, students moved from designing for themselves toward designing for others—a key aspect of the engineering design cycle. The emphasis on the social and human-centered aspects of engineering design shows promise for empowering student voices, sparking student interest, and diversifying involvement in STEM.

References

Blikstein, P., & Krannich, D. (2013, June). The makers' movement and FabLabs in education: Experiences, technologies, and research. In *Proceedings of the 12th international conference on interaction design and children* (pp. 613-616). ACM Digital Library.

Gomoll, A., Hmelo-Silver, C. E., Šabanović, S., & Francisco, M. (2016). Dragons, ladybugs, and softballs: Girls' STEM engagement with human-centered robotics. *Journal of Science Education and Technology, 25*(6), 899-914.

Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn?. *Educational Psychology Review, 16*(3), 235-266.

Puntambekar, S. (2015). Distributing scaffolding across multiple levels: Individuals, small groups and a class of students. In A. Walker, H. Leary, C. E. Hmelo-Silver, & P. A. Ertmer (Eds.), *Essential readings in problem-based learning* (pp. 207-221). West Lafayette, IN: Purdue University Press.

Rusk, N., Resnick, M., Berg, R., & Pezalla-Granlund, M. (2008). New pathways into robotics: Strategies for broadening participation. *Journal of Science Education and Technology*, *17*(1), 59-69.

Child-Coach-Parent Network for Early Literacy Learning

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Abstract: Literacy is an inherently social experience. Yet, many literacy learning apps have no collaborative dimension. In response, we propose a learning network centered around children's play on open-ended literacy apps that engages three stakeholders—child, parent, and family learning coach—in the experience. Findings from our pilot show that coaches' messages increased parent visibility into and understanding of children's play. This work has implications for how digitally-mediated networks could facilitate family engagement in children's learning.

Introduction

When well-designed to be open-ended, child-driven, provide support, and encourage co-creation, learning technologies can offer unique affordances (Hirsh-Pasek et al., 2015). Educational apps designed for parent-child dyads have the potential to empower parents to engage in their child's learning process (Takeuchi & Stevens, 2011). Despite the well-documented importance of family involvement in learning, few literacy technologies are designed with parents and families in mind. Many learning apps are opaque, offering no way for children's learning moments to be shared with parents (Vaala et al., 2015). With existing open-ended literacy apps, the nature of free-play and the customizability of child-directed learning goals makes it difficult to automate feedback for parents. Since a fully automated solution is neither practicable nor desirable, a human element must be incorporated into the system.

Therefore, we propose a family learning network with new human-in-the-loop features, augmented by data analysis tools to help an adult collaborator support the child's learning in a time-efficient manner. This person, whom we call a *family learning coach,* has a background in learning. The coach analyzes children's play on open-ended apps in order to: track a child's progress through play, send brief individualized updates to parents, and suggest short, contextualized activities for family co-engagement based on a child's play patterns.

The goal of this pilot was to explore how to design a sociotechnical system—or family learning network—that could engage children and parents in literacy-related play, and lead to new knowledge, skills, and attitudes about literacy.

Methodology

Our learning network involves three stakeholders: child, parent, and coach. The child plays with SpeechBlocks (SB), an open-ended literacy learning app that focuses on helping children with grapheme-to-phoneme correspondence (Sysoev et al., 2017). Using SB, children can tinker with letters and sounds, make nonsense words, and create and save personally meaningful words. When letters are pulled apart, put together, or tapped, a speech synthesizer pronounces the letter sequence. All in-app play is captured and streamed to the coach.

Nine families in the Greater Boston Area with children ages 4 to 10 (12 female and 4 male) participated in our 10-week exploratory pilot. All families were given Android mobile phones with the SB app installed. Families attended a pre-workshop where they learned about the coaching system, filled out a background survey, and met coaches to start building a relationship.

Three of the researchers with backgrounds in education served as the coaches for this study. Each coach served approximately 5 parent-child dyads. Three times a week, the coaches analyzed children's play data and translated key insights into short updates that were sent to the child's parent via SMS or email (per parent preference). Once a week, these updates included a 2-minute activity, based on the child's in-app play, that the parent and child could do together. For example, a coach might say, "Sofia made the word BATMAN. She then created the words BATMOM and BATDAD. For a fun activity, you and Sofia could brainstorm new characters that have 'bat' in them and Sofia can write her favorites in SpeechBlocks."

At the end of the pilot, families attended a post-workshop in which they filled out a survey on their experience with the coaching system.

Initial findings

To investigate how parents felt about the coaches' updates, we used qualitative analysis methods to identify emergent themes in parents' free-response answers in the post-workshop survey. The two emergent themes were: parents felt the updates helped them (a) increase their visibility into their children's in-app play and (b) understand what their children learned through their in-app play.

Multiple parents reported that they liked the updates because they increased their visibility into what their child was doing when they played with SB. For example, one parent said, "I wasn't always watching what they were doing… I liked getting the text messages [so] I know what they were doing." In fact, a couple of parents reported not knowing where the SB device was during the study because it was in the child's possession, and therefore the increased visibility afforded by the updates was helpful to them.

Parents reported feeling that they learned about their children's literacy learning process through the parent updates. One mother said that she liked it when the coaches explained "*why* we [coaches] think [her son] did something," and another stated that the updates "help [her] understand what her daughter needs." One parent reported that she liked it when the coaches' sent her an update on *how* her daughter tried to construct the word TOASTER by spelling TOAST and adding the letter R to make TOASTR. She explained, "What I found interesting was Ella trying to make TOASTER… [it shows] that she's trying to think on her own." When reflecting on the coach updates about her child's play, one parent stated that her child "always refused to read or learn to read" but through seeing her child's progress, she realized the app had "really helped [her child] become more confident."

Conclusions and implications

The results of our pilot show that our family learning network was feasible and well received by the families. Reflecting on the coaches' actions and the family feedback, we better understand the coach's role: supporting the family in understanding and contextualizing their children's learning process on open-ended learning apps in order to empower the parents to co-engage with their children.

This exploratory pilot also helped us understand what types of skills a coach might need, and who would be best suited to fill this role. The amount of time a coach spent (approximately 40 minutes per week) is a relatively low time commitment in comparison to that required for in-person literacy coaching, yet enough to sustain a high frequency of communication. An ideal coach is someone who has both empirical skills and knowledge of literacy processes, in order to identify emerging patterns related to literacy development; and who is relationship-focused and interested in family and community engagement. One group with these skills that might be well-suited to be coaches are speech language pathologists (SLPs). Our next step is to run a comparison study in which SLP students will be trained as coaches and separate researchers compare the SB program with and without coaches to better examine the effectiveness of the coaching system.

Overall, our family learning network was shown to be promising. Many parents perceived that the coach's updates increased their visibility into their children's play and understanding of their children's learning process. We hope that this work will be the first of many iterations on the role of the family learning coach, as new apps are added to the repertoire and new coaches mold the role to fit their communities' contexts and needs.

References

Hirsh-Pasek, K., Zosh, J. M., Golinkoff, R. M., Gray, J. H., Robb, M. B., & Kaufman, J. (2015). Putting education in "educational" apps: lessons from the science of learning. Psychological Science in the Public Interest, 16(1), 3-34.

Sysoev, I., Hershman, A., Fine, S., Traweek, C., & Roy, D. (2017). SpeechBlocks: A Constructionist Early Literacy App. In Proceedings of the 2017 Conference on Interaction Design and Children (pp. 248-257). ACM.

Takeuchi, L., Stevens, R., et al. (2011). The new coviewing: Designing for learning through joint media engagement. In *The Joan Ganz Cooney Center at Sesame Workshop*.

Vaala, S., Ly, A., and Levine, M. H. (2015). Getting a read on the app stores: A market scan and analysis of children's literacy apps. full report. In *The Joan Ganz Cooney Center at Sesame Workshop*.

Acknowledgments

Learner Expertise and Emotional Design in Multimedia Learning

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Abstract: Literature shows that learners' emotions affect the effectiveness of multimedia learning, which is explained by Cognitive-Affective Theory of Learning with Media (CATLM). An emotional design that changes learners' emotional status can facilitate or suppress multimedia learning. In CATLM individual difference is an assumption. How learner expertise affects the effectiveness of emotional designs remains unclear. This study comprising 122 K12 students aims to investigate the effect of learner expertise (novice vs advanced) and emotional design– face-shape like and warm colors – (with vs without) on developing remembering and understanding. These results showed that (1) in remembering the emotional design group performed better, and (2) in understanding the design benefited the advanced group, but not the novice group. A plausible explanation is the benefits of the emotional design do not overweigh its drawback in the novice group when developing understanding. Further analysis reveals that learner expertise and learning outcomes aid to determine the designs' effects.
Keywords: emotional design, learner expertise, CATLM, multimedia learning

Introduction

Recent research on multimedia learning has been focusing on the influence of affective processes such as emotions and motivations (Ng & Chiu, 2017; Park, Knörzer, Plass, & Brünken, 2015). Multimedia design elements that can change learners emotional status (Heidig, Müller, & Reichelt, 2015) may affect working memory capacities during learning, which is supported by many empirical studies (Knörzer, Brünken, & Park, 2016). These studies showed that learners emotions can facilitate or suppress their learning processes, for examples, Knörzer and colleagues (2016) provided evidences that there are differential effects of diverse emotional status on multimedia learning - a facilitating effect of induced positive emotions and a suppressive effect of induced negative emotions occurred on learning outcomes. These empirical evidences can be explained by Moreno's Cognitive-Affective Theory of Learning with Media (CATLM) (Moreno, 2009). CATLM suggests that individual difference includes learner expertise affects multimedia learning, which is supported by studies of Chiu and Mok (2017), Kalyuga (2007, 2014) and his colleagues (2012). However, how learner expertise affects the effectiveness of emotional design remains unclear. The present study aims to investigate the effects of learner expertise and emotional design on learning outcomes - remembering and understanding. The rest of the paper is organised as follows: we first present the theoretical framework of this studies, and previous studies on emotional design in multimedia learning, followed by the purpose and methodology of the study. Then we describe the results of our analyses, followed by discussing the results and concluding the study.

The present study

This study investigates how different learner expertise levels affect an emotional design on multimedia learning and attempts to understand how the design affect cognitive capacities available for learning. We expected that the design would place extraneous cognitive load on both learners, but have larger facilitating effects on novice learners in developing understanding due to the expertise reversal effect (Kalyuga, 2007, 2014)

The participants comprised 122 primary 1 and 2 students, (5-9 years old, around 52% is boy), and an experienced mathematics teacher in Hong Kong. A 2 x 2 between subjects factorial design with the factors learner expertise (primary 1, P1 vs primary 2, P2) and emotional design (with an emotional deign, ED vs without, ND) was used. This resulted in the four experimental conditions. Materials were written in Chinese (Cantonese style) included learning materials, a post-test and a questionnaire. The learning materials were 5-minute videos; the topic was understanding geometrical patterns. In the experimental group, face-like shape and warm colors were used in the design. The post-test was in form of multiple choice questions with 4 answers assessed remembering and understanding. The questions were used in the experiments of Ng and Chiu (2017) and modified from the studies of Chiu (2016, 2017), Chiu and Mok (2017), and Chiu and Churchill (2015). The remembering measured learning outcomes by means of recall questions, as same as that presented in the videos from the control group; that of understanding were new. Each measure had 10 questions and scored 1. The questionnaire includes a 5-scale likert question measuring intrinsic motivation - I find learning the material is fun. This question was used in the study of Plass and colleagues (2014).

Discussions and conclusions

There are three major empirical implications. First, the emotional design "face-shape like and warm colors" had main effects when developing remembering. Second, the design benefited the advanced group, but not the novice group when developing understanding. Final the emotional design derived more fun (instinct motivation) from the learning process. In term of theoretical contribution, the results contribute to CATLM, more specifically, how the emotional design affects cognitive processes through emotion, motivation and attention in multimedia learning. Most previous relevant studies did not take learner expertise / order thinking skill into account when studying the emotional designs (see Park et al., 2015, Plass et al., 2014; Knörzer, et al., 2016; Schneider et al., 2016; Um et al., 2012). In their studies, the authors advocated that an appropriate emotional design can facilitate cognitive processing during learning even though it may place extraneous cognitive load on the learners. The learners would invest more effort in their cognitive processing to integrate their prior knowledge from long term memory and organized knowledge from the multimedia presentations into new knowledge. Moreover, this study affords two practical suggestions. First, it is more effective to use the face-shape like and warm colors for all learners in developing lower order thinking skills. The human-like pictures are recommended to be included in multimedia presentations when the learning tasks are not too complicated. Second, we suggest that teachers should be very careful when they design activities for drawing interests and fostering motivation because those activities may not lead to better learning outcomes. Multimedia presentation designers are suggested to use learner expertise and learning outcomes to determine whether to include emotional design offered to learners. Overall, future research on adaptive learning environments should focus on cognitive processing, and interactions among learner prerequisites, emotions and multimedia presentations.

References

Chiu, T.K.F. (2016). Prior knowledge and mathematics order thinking skill in multimedia learning. In *Proceedings of The International Conference of Learning Sciences*, June 20-24, 2016, Singapore.

Chiu, T.K.F. (2017). Effects and Contributions of External Presentation Comprising Prior Knowledge during Multimedia Learning. *AERA Annual Meeting*, April 27-May 1, 2017, San Antonio, Texas.

Chiu, T.K.F., & Churchill, D. (2015). Exploring the characteristics of an optimal design of digital materials for concept learning in mathematics: Multimedia learning and variation theory. *Computers & Education, 82*, 280-291. https://doi.org/10.1016/j.compedu.2014.12.001

Chiu, T.K.F., & Mok, I.A.C. (2017). Learner expertise and mathematics different order thinking skills in multimedia learning. *Computers & Education, 107*, 147-164. https://doi.org/10.1016/j.compedu.2017.01.008

Heidig, S., Müller, J., & Reichelt, M. (2015). Emotional design in multimedia learning: Differentiation on relevant design features and their effects on emotions and learning. *Computers in Human Behavior, 44*, 81-95.

Kalyuga, S. (2007). Expertise reversal effect and its implications for learner-tailored instruction. *Educational Psychology Review, 19*(4), 509-539. DOI:10.1007/s10648-007-9054-3

Kalyuga, S. (2014). The expertise reversal principle in multimedia learning. In R.E. Mayer (Ed.), *The cambridge handbook of multimedia learning*, (pp. 576-597). New York, NY: Cambridge university press.

Knörzer, L., Brünken, R., & Park, B. (2016). Facilitators or suppressors: Effects of experimentally induced emotions on multimedia learning. *Learning and Instruction, 44*, 97-107.

Moreno, R. (2009). Learning from animated classroom exemplars: the case for guiding student teachers' observations with metacognitive prompts. *Journal of Educational Research and Evaluation, 15*, 487-501.

Ng, K.H, & Chiu, T.K.F. (2017). Emotional Multimedia design for Developing Mathematical Problem solving Skills. *HKAECT x AECT 2017 Summer International Research Symposium*, June 15-17, 2017, Hong Kong.

Park, B., Knörzer, L., Plass, J. L., & Brünken, R. (2015). Emotional design and positive emotions in multimedia learning: An eyetracking study on the use of anthropomorphisms. *Computers & Education, 86*, 30-42.

Plass, J. L., Heidig, S., Hayward, E. O., Homer, B. D., & Um, E. (2014). Emotional design in multimedia learning: Effects of shape and color on affect and learning. *Learning and Instruction, 29*, 128-140.

Acknowledgements

Problem Scoping in Designing Biomimetic Robots

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Abstract: We examine problem scoping in our interdisciplinary curriculum where students build biomimetic robots. Biomimicry is a context for learning biology, computational thinking, and engineering design. In the *solution space,* students narrow the scope of their robot designs, informed by animal structure-function relationships. In the *challenge space*, they narrow the scope of real-world disasters by modeling them in the classroom. This dual problem scoping enables students to be active participants shaping the content of their learning.

Keywords: problem scoping, interdisciplinary curriculum design, design-based research

Introduction

Robotics design over the past two decades has drawn heavily from the study of biological systems (Cho & Wood, 2016), and biomimetics is beginning to make its way into K-12 classrooms (e.g., Gardner, 2012; glbiomimicry.org; teachengineering.org). Biomimetics provides an ideal context for both fostering and investigating interdisciplinary STEM learning, as it invites the study of biological structures, functions, and processes to inform engineered solutions to problems. In our work, middle school students build biomimetic robots from available classroom materials to solve a search and rescue challenge. This poster focuses on an early stage of a multi-year project and explores the research question: *How do middle school students engage with problem scoping in the development of a biomimetic robotics design challenge?*

Theoretical and methodological approach

Participatory learning spaces emphasize the intellectual resources of students as knowledge producers (Tucker-Raymond et al., 2012), draw on the values, practices, and histories of learners and their communities (Bell et al., 2009), value distributed expertise, and flatten traditional knowledge structures (Jenkins, 2009). Our project's *participatory* approach allows young people to shape content, collaboratively solve problems, and develop self-efficacy as learners and technology creators (Jenkins, 2009; Tucker-Raymond et al., 2012). The study uses a design-based research (DBR) approach, driven by our design conjectures about the tools, task structures, participant structures, and discursive practices that support learning in a classroom environment. The DBR framework allows us to contribute to theory about participatory pedagogy as a strategy for improving learning and efficacy in STEM, and contribute design principles for effective interdisciplinary learning environments that integrate science, engineering, and computing. Here, we report on our investigation of problem scoping in three middle school classrooms that implement the pilot version of our biomimetic robotics curriculum.

Problem scoping

We focus on problem scoping because it is an engineering practice aligned with participatory pedagogy. We define problem scoping as determining the boundaries of a complex problem space (Watkins et al., 2014). Much of the research on problem scoping has been done at the university level (Atman et al., 2008); we build on the work that has been done with young learners (Watkins et al., 2014). As we have designed the curriculum and explored scaffolding needed, we have observed that problem scoping both narrows the *challenge space* of search and rescue (Figure 1, left, green), and the *solution space* of biomimetic robot design (Figure 1, right, orange). Students employ *reflective decision-making* (Wendell et al., 2017) as they decide how to represent real-world disaster scenarios and robotic solutions. Throughout the curriculum, students examine structure-function relationships from an organism to design a human-created system.
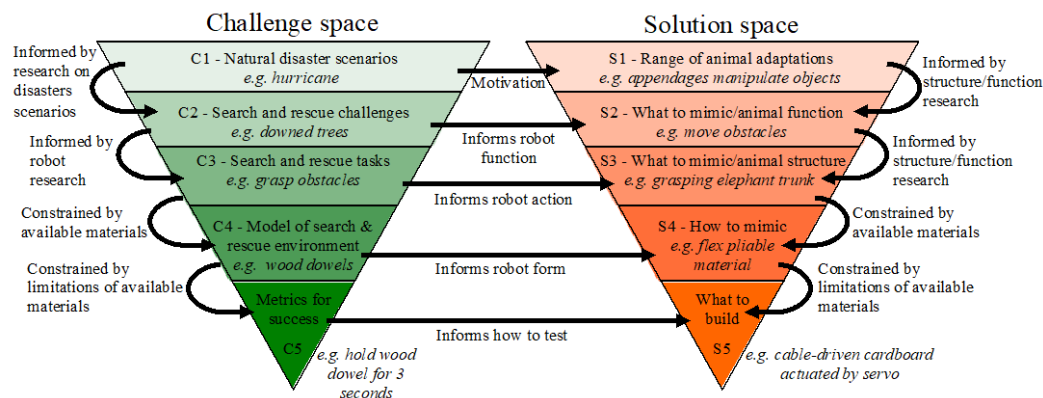
Figure 1. Problem scoping in the challenge space (left, green) and solution space (right, orange).
We highlight a hurricane disaster example in italics.

We first examine the challenge space to include a wide range of natural disaster scenarios (C1). In these scenarios, the terrain may be impassable by wheeled vehicles, making animal adaptions applicable. Animals are able to burrow under, jump over, cut through, and manipulate obstacles (S1). In this example, we describe a hurricane scenario (C1) where large obstacles are downed trees (C2). Students study animals that can manipulate objects (S1) and move them out of the way (S2). They then examine potential robot tasks and they choose to grasp objects (C3) as inspired by an elephant trunk (S3). The students model their environment and wood dowels can represent downed trees (C4). Mimicking an elephant's trunk, students design a pliable robot to pick up a dowel (S4) and hold it for 3 seconds (C5). One solution is to construct a cable-driven mechanism actuated by a servo (S5). Biomimicry provides a rich context for students to develop a wide variety of solutions to problems they identify, define. Students do repeated reflective decision-making as they narrow scope to build a representation of a disaster scenario and a robot that can negotiate it. The students are empowered as active learners as they define their own criteria for success.

References

Atman, C. J., Yasuhara, K., Adams, R. S., Barker, T. J., Turns, J., & Rhone, E. (2008). Breadth in problem scoping: A comparison of freshman and senior engineering students. *International Journal of Engineering Education*, *24*(2), 234.

Cho, K. J., & Wood, R. (2016). Biomimetic Robots. In: Siciliano B., Khatib O. (eds) *Springer Handbook of Robotics*. Springer. https://doi.org/10.1007/978-3-319-32552-1_23

Bell, P., Lewenstein, B., Shouse, A., & Feder, M. (2009). *Learning Science in Informal Environments: People, Places, and Pursuits.* National Academies Press.

Gardner, G.E. (2012). Using Biomimicry to Engage Students in a Design-Based Learning Activity. American Biology Teacher, 74, 182-184.

Jenkins, H., Purushotma, R., Weigel, M., Clinton, K., & Robison, A. J. (2009). *Confronting the challenges of participatory culture: Media education for the 21st century*. MIT Press.

Tucker-Raymond, E., Torres-Petrovich, D., Dumbleton, K., & Damlich, E. (2012). Reconceptualizing together: Exploring participatory and productive media literacies in a collaborative teacher research group. In D. Alvermann & K. Hinchman (Eds.). Reconceptualizing literacies in adolescents' lives. New York: Routledge. pp., 224-243.

Watkins, J., Spencer, K., & Hammer, D. (2014). Examining young students' problem scoping in engineering design. Journal of Pre-College Engineering Education Research, 4(1), Article 5. https://doi.org/10.7771/2157-9288.1082

Wendell, K. B., Wright, C. G., & Paugh, P. (2017). Reflective Decision-Making in Elementary Students' Engineering Design. *Journal of Engineering Education*, *106*(3), 356-397.

Acknowledgments

Mentor Academy: Engaging Global Learners in the Creation of Data Science Problems for MOOCs

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Abstract: We engaged MOOC learners (mentors; n=120) as collaborators in the design and improvement of an online course through an activity called the Mentor Academy; an online instructional program where mentors create original problem sets for future iterations of a course. Following a design research methodology, we trace the development of the program's design and report on the features of a learning design that effectively support mentors in the problem creation process. Our analysis shows that mentors were offered three kinds of support: community building, logistical, and pedagogical. The following kinds of changes and additions were made to the design: expanded project requirements, improved technical infrastructure, and increased opportunities for interaction in discussion forums and live peer chat sessions. We present an analysis of problem sets for quality, diversity of subject area, and usability.

Introduction and theoretical foundations

Instructors and designers of Massive Open Online Courses (MOOCs) face a two-fold challenge in creating content for a *global* audience of learners: (1) it is time consuming to develop robust problems for learners who require multiple opportunities to practice emerging skills; (2) problems should be representative of learners who are situated in diverse contexts. The first challenge is a logistical and pedagogical one; the second challenge relates to the growing worry that MOOCs currently promote a version of cultural hegemony (Head, 2017).

To address both of these challenges we designed the Mentor Academy, a two-week instructional program that invited learners who successfully completed the University of Michigan's Introduction to Data Science in Python MOOC to be *mentors* and engage in the creation of problems for use by new learners in the next iteration of the MOOC. Our work builds on the concept of *learnersourcing* as a method of engaging with learners to create new learning experiences (Kim, 2015). Learnersourcing "is a form of crowdsourcing in which learners collectively contribute novel content for future learners, while engaging in meaningful learning experiences themselves" (Kim, 2015, p 3). We asked mentors to identify and then use subject matter and datasets that they felt would be compelling and relevant for learners who live and work in the same local context (i.e., country). Our program resulted in both a more *plentiful* and a more *diverse* set of problems than the instructional team would be able to provide on their own.

Our approach also shares common ideas with *communities of practice*, where members are mutually engaged in a joint enterprise, and work with a shared repertoire while actively negotiating the nature of the enterprise (Lave & Wenger, 1998). It also shares commonalities associated with *cognitive apprenticeship*, a model that adapts apprenticeship methods for the teaching and learning of cognitive skills (Collins, 2006). Tasks are situated in authentic contexts, and are "tightly coupled to the underlying competencies needed to carry out the tasks" (Collins, 2006, p. 54). In the Mentor Academy, mentors were apprentice instructors, acquiring the skills and competencies required to create problems suitable for use by novices in the domain of data science. These skills were modelled by the instructors of the program. The mentors' work was situated in an authentic context, that of an existing MOOC, and their contributions were seen as essential for the betterment of the MOOC. The following research questions guided our investigation:

1. What features of the learning design effectively support mentors in the creation of problem sets for use in the next-iteration of an online data science course?
2. What are the outcomes of the Mentor Academy program with respect to problem creation?

Methodology and research design

We recruited 120 mentors from the following countries: United States, India, Canada, China, Germany, and Brazil. We hosted Mentor Academy as four private courses on Coursera, one of the largest MOOC platforms. Instructors prepared video lectures that targeted pedagogical concepts such as constructivism, scaffolding, and writing effective problems. During each two-week session, approximately 30 mentors were asked to locate local data sets and write problems that leveraged those datasets. The problems were written in the Python programming

language, using the Jupyter notebook environment. Mentors shared their problems on discussion boards and in synchronous video conferences with instructors and other mentors. We used an iterative design research methodology in which two-week sessions overlapped by one week to allow for rapid iteration from one design cycle to the next. Transcriptions of design debrief sessions with course instructors and the research team and design documentation (e.g., annotated wireframes, digital spreadsheets) were analyzed to understand (1) effective program supports and (2) improvement strategies. We analyzed the 39 problems that resulted from the four Mentor Academy sessions with respect to quality, diversity of subject area, and usability.

Results and discussion

Features of learning design that were effective in supporting mentors

Our analysis revealed (a) three types of supports that were effective in supporting mentors and (b) five improvement strategies. Types of supports included: (i) community building (i.e., opportunities for mentors to interact with instructors and peers), (ii) logistical support (i.e., videos and documentation that explain the mechanics of the platform and organization of the program), and (iii) pedagogical support (i.e., instruction about pedagogy and feedback on problems). Improvement strategies included: (i) expanded project requirements, (ii) improved technical infrastructure, and (iii) increased opportunities for interaction with instructors in discussion forums and live peer chat sessions. Expanded project requirements and improved technical infrastructure led to increased diversity among problems; we allowed non-Wikipedia data sets to be used (e.g., local government data) and added technical capacity by allowing mentors to use URLs that contained accents. We gave mentors opportunities to share datasets and problems with instructors and peers in week one of the program, created additional opportunities for synchronous feedback, and provided mentors with improved scripts for video conferences with that included only mentors (not instructors).

Outcomes of the Mentor Academy program with respect to problem creation

Our analysis of problems with respect to *quality* revealed that generally problems stated a clear goal as well as details relating to product/performance that were required to solve the problem. However, problems often lacked supporting details and sufficient context that would motivate learners to solve the problem. Future versions of the Mentor Academy will consider how instructional resources can target this aspect of problem creation.

Our analysis of problems with respect to *diversity* uncovered four general topic areas: (1) society (e.g., immigration, population trends, child mortality reduction); (2) economics (e.g., government budget distribution, automobile industry); (3) individual in society (e.g., sports, healthcare, transportation); and (4) environment (e.g., air pollution, deforestation, and natural disasters). Some problems related to temporally relevant topics (e.g., hurricanes and California wildfires). We intend to perform a more nuanced analysis of these problems to understand the extent to which problems are relevant to learners from specific geographic regions.

Our analysis of problems with respect to *usability* uncovered four problem types, with respect to size:

- Micro (n=8): Small questions which could be completed quickly with one or two lines of code, suitable for use within an "in-video" quiz (i.e., embedded within a lecture, executable within the video player);

- Meso (n=11): The intended question size for the Mentor Academy program, which tended to be between 5-15 lines of code and practiced a single skill or topic;

- Macro (n=19): A series of questions which built on one another, suitable for use as an assignment;

- Tutorial (n=1): A form of worked example which provides a descriptive analysis, showing insights gleaned through data analysis in a narrative form, and which is intended to be read (and perhaps replicated) by the learner, but is not a problem to solve *per se*.

These problems will be integrated in the next iteration of the Introduction to Data Science in Python MOOC.

References

Collins, A. (2006). Cognitive apprenticeship. In R. K. Sawyer (Ed.), *The Cambridge Handbook of the Learning Sciences* (pp. 47-60). New York, NY: Cambridge University Press.

Head, K. (2015). The Single Canon: MOOCS and Academic Colonization. In *MOOCs and Open Education Around the World*, edited by Curtis J. Bonk, Mimi M. Lee, Thomas C. Reeves, and Thomas H. Reynolds, 190-202. New York: Routledge.

Kim, J. (2015). *Learnersourcing: improving learning with collective learner activity* (Doctoral dissertation, Massachusetts Institute of Technology).

Lave, J., & Wenger, E. (1998). Communities of practice: Learning, meaning, and identity. New York: Cambridge University Press.

The Student-Produced Electronic Portfolio in Craft Education

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Abstract: The authors studied primary school students' experiences of using an electronic portfolio in their craft education over four years. A stimulated recall interview was applied to collect user experiences and qualitative content analysis to analyse the collected data. The results indicate that the electronic portfolio was experienced as a multipurpose tool to support learning. It makes the learning process visible and in that way helps focus on and improves the quality of learning.

Introduction

The aim of this study is to research the use of an electronic portfolio (ePortfolio) in craft education at the primary school level and especially to develop its use as a method of documentation. The main research question focuses on the pupils' experiences of the functions and the benefits of using an ePortfolio.

The ePortfolio is a personalized tracking of learning with authentic evidence (e.g., Carmen and Christie, 2006; Lorenzo and Ittelson, 2005; Barrett, 2010). The ePortfolio´s role relatively often culminates in assessment and its main task is to bring forth the successes (Sherman, 2006). Sherman argues for more versatile use of the ePortfolio, such as reflection, goal setting and communication. Furthermore, Waltz (2006) defines university level students' definitions of the ePortfolio's role in their studies. Students described the ePortfolio as a means of storing their work, a way of collecting evidence of their development, a tool for information management and a tool for connecting and communicating with their teachers and other students. Parallel results were obtained with primary school students (Saarinen et al, 2016). Fundamentally ePortfolios should be studied as a means to increase pupils' own understanding of their learning (Barrett, 2003). The documentation of one's own learning process and its emphasis in assessment strongly emphasized in the renewed curriculum for craft education in Finland, which came into effect in 2016. The learner's active role, mastery of ICT tools and metacognitive skills are components of transversal competences, which are integrated across all school subjects in all grade levels (FNBE, 2014).

This longitudinal development study is based on data collected over four years, during which the students progressed from the beginning of the 3rd grade to the end of the 6th grade. The ePortfolio process was facilitated with one-hour starting session and general discussion of how to document, what to document and how often. The digital application starts portfolio with an empty white paper, which student fills with photos, writings and audio elements. The functionalities and instruction for using the ePortfolio were developed across the years: the minimum list of documentation was defined (the first year), video clips guidance was offered (the second year), peer-assessment was added (the third year) and optional video recording was permitted (the fourth year).

Method

A semi-structured stimulated recall interview was applied when the students were in the fifth grade to collect their experiences after three years of using the ePortfolio. Holding interviews provided an easier and more flexible means of gathering data than having the students write about their experiences. The students' own ePortfolios were used as stimuli during the interviews, as their use facilitated the students' recollection of past events. All the interviews (n=38) were video recorded, transcribed and analysed using data-driven content analysis. A qualitative content analysis program (ATLAS.ti) was used to analyse the data. The students' notes were organized according to the message of the notation. One notation could be divided into smaller units, but then again, the length of one unit could vary from one word to thirty words.

Results

The results indicate that an ePortfolio is a useful method for craft education. When students begin using it during the early school years, it is experienced as a natural part of the work process. The four key functions identified by students (see Figure 1.) were the storing and management of information, as well as communication and verification of development (inner circle). The experienced educational benefits were related to supporting the work process: for instance, the activities documented in the appeared to operate as stimuli to memory, eliciting the recollection of concepts in a way that deepened the understanding of past experiences (outer circle).
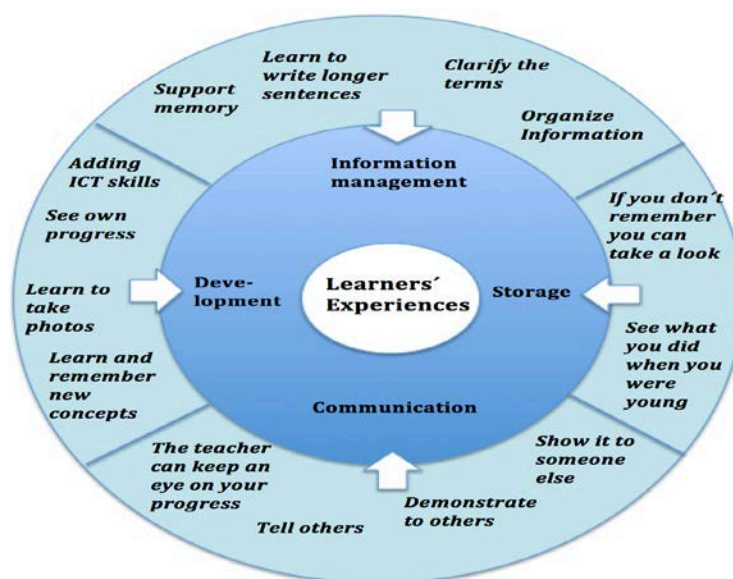
Figure 1. The student-identified functions of the ePortfolio are in the inner circle, and its benefits in the outer circle.

Discussion

The ePortfolio makes it easier to draw attention to the learning process. It offers a means of concretizing the steps of the learning process, which in turn enables the learner, or others, to monitor, reflect on and assess it afterwards. The method was considered to be positive and encouraging, and several benefits were pointed out. Each pupil learned to find their own individual style of using the method and had the opportunity to emphasize their own perspective. These results are in line with earlier research results (Walz, 2006), and relevant because they are useful to teachers both in developing their pedagogical practices and in expanding their understanding of the multiple possibilities of the ePortfolio.

References

Barrett, H. C. (2003). The research on portfolios in education. *Retrieved September*, *3*.

Barrett, H., 2010. Balancing the two faces of ePortfolios. *Educação, Formação & Tecnologias-ISSN 1646-933X,* 3(1), pp. 6-14.

Finnish National Board of Education, (2014). Perusopetuksen opetussuunnitelman perusteet 2014 [National Core Curriculum of Basic Education 2014].

Carmean, C. and Christie, A., 2006. EPortfolios: Constructing meaning across time, space, and curriculum. Handbook of research on ePortfolios, pp. 33-43.

Lorenzo, G. and Ittelson, J., 2005. An overview of e-portfolios. Educause learning initiative, 1, pp. 1-27.

Sherman, G., 2006. Instructional roles of electronic portfolios. *Handbook of research on ePortfolios,* pp. 1-14.

Saarinen, A., Seitamaa-Hakkarainen, P. and Hakkarainen, K. (2016). The Functions and Benefits of the ePortfolio in Craft Education at the Primary Level. Design and Technology Education. 21(3), pp. 29-40

Walz, P. (2006). An overview of student ePortfolio functions. Handbook of research on ePortfolios, pp. 194-205.

Acknowledgments

Designing Learning Environments to Facilitate Creativity

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Abstract: Creativity is often placed alongside collaboration as a 21st-century skill. However, research in collaborative learning has outpaced research in developing creativity skills. This design case study uses the Creativity Landscape conceptual framework as a conceptual lens through which to operationalize creativity in the design of learning environments, and proposes that constructionist learning principles, design thinking, designerly ways of knowing, and reflective practice are ideally suited to the development of various aspects of creativity.

The creativity landscape framework

Although creativity shares equal billing with collaboration as an essential 21st-century skill (Sawyer, 2014), the various conceptualizations of creativity found in the literature promote confusion and lack of systematic guidance for those who wish to design learning environments which facilitate creativity (Hanson, 2014). And yet the relationship between the design of learning environments and creativity is an area of great research potential (Diego & John, 2011). The Creativity Landscape conceptual framework has been applied to the analysis of creativity tools and techniques (Donaldson, 2016), and to analysis of instructional design projects (Donaldson, 2017). This paper describes the application of the framework as a guide to design for facilitation of creativity in a specific learning environment. This framework describes the rich landscape of creativity research through the use of four categories and prominent concepts within each:

- **Creative Environments:** Learning environments which facilitate creativity are highly collaborative, generative, playful, unregulated, and promote lowered inhibition.

- **Creative Mindsets:** The mindsets required for optimal creativity include perseverance, openness to experiences, tolerance of ambiguity, autonomy, creative self-efficacy, and mindfulness.

- **Creative Process:** The creative process has been conceptualized in various ways. Common features among different process models are stages including identification of problem, framing, preparation, idea generation, incubation, unconscious cognition, insight, and refining.

- **Creative Cognition:** Cognitive processes can be seen as falling somewhere along a continuum ranging from divergent to convergent thinking, including metaphor creation, perspective taking, analogical thinking, frame creation, conceptual combination, abductive reasoning, synthetic thinking, pattern recognition, and elaboration.

Optimal facilitation of creativity involves a balance among all four categories, as well as a strong mix of elements from within each category.

Design case

This design case study was on aspect a larger design-based research project which applied the Creativity Landscape conceptual framework to the design and delivery of a hybrid course on multimedia for teaching and learning. The 10-week course design included 3-hour weekly face-to-face classes accompanied by a robust online aspect in a learning management system organized in weekly modules which included weekly overviews, readings, videos, and online assignments. The course design was aligned as closely as possible to constructionist principles (Papert & Harel, 1991). The course design was structured around two group projects, four individual projects, and frequent reflective assignments. The first group project (weeks 2-4) used a design thinking process model, and the second group projects (weeks 5-10) allowed the students to decide on their own processes. The four individual projects (weeks 4-7) involved meaning-making through artifact construction. There were reflective assignments in both the face-to-face classes and online. After the course was designed and taught by the author, the Creativity Landscape conceptual framework was applied as a diagnostic tool to identify areas in which the facilitation of optimal learner creativity was strong, as well as areas in need of improvement in future iterations of the course design. The analysis was conducted according to a breakdown of course design elements: reflective assignments, individual projects, group projects, online atmosphere, and face-to-face atmosphere. Each course design element was then scored according to the percentage of creativity aspects specifically addressed according to the components in each of the four Creativity Landscape domains. Averages were then calculated for each assignment type and for each creativity domain.

First iteration findings

The reflective assignments were weak at facilitating development in the Creative Process Stages domain. The individual projects were strong in facilitating development in the Creative Context and Environment domain, and facilitated minimal development in the three other domains. The group projects addressed more aspects of all four creative domains than did any other type of work. These projects were strong in facilitating development in the Creative Context and Environment domain and facilitated moderate development in the Creative Process Stages and Creative Cognitive Processes domains. They facilitated minimal development in the Creative State of Mind domain. The online atmosphere was designed to focus on preparation (Creative Process Stages) and elaboration (Creative Cognitive Processes). However, it facilitated only minimal development in these domains, and was weak in facilitating development in the Creative State of Mind and Creative Process Stages domains. The face-to-face atmosphere was particularly strong in facilitating development in the domains of Creative Context and Environment and Creative Cognitive Processes. It facilitated only minimal development in the Creative State of Mind and Creative Process Stages domains. In-class instructor feedback emphasized tolerance of ambiguity (Creative State of Mind), playfulness (Creative Context and Environment), and metaphor creation (Creative Cognitive Processes).

Second iteration findings

The second iteration of this course was designed to leverage the strengths of the first iteration towards addressing the weaknesses. The reflective assignments originally only asked students to reflect on their processes and products, but were changed to include reflection upon emotional states, identity, and relevance to their current and future lives. This led to improvements across the four creativity domains. In the first iteration, the individual assignments were self-contained, but in the second iteration they were integrated into the group project so that each individual artifact would be woven into the group final project. This increased the creativity across the four domains, but there is still room for improvement in the Creative State of Mind and Creative Process Stages domains. In the first iteration, only the first group project used a design thinking process. In the second iteration the second group project was integrated with all the individual projects. This boosted the creativity levels in all four domains dramatically. The online aspects of the course were redesigned to include greater focus on creative self-efficacy, metacognitive practices, and a reflective state. As in the first iteration, the online atmosphere was the weakest of all design elements, but there were improvements in all four domains. However, a great deal of work will be needed in the next iteration to purposefully address the areas in which it was weakest, particularly in the Creative Process Stages and Creative Cognitive Processes domains.

Discussion

In the first iteration, the use of the Creativity Landscape conceptual framework was effective as a diagnostic tool in providing an easily-applied means of evaluating the degree to which course design features were weak or strong in facilitating development of creativity in general, as well as in particular creative domains. In the second iteration the Creativity Landscape conceptual framework was effective as an instructional design tool by suggesting concrete steps which could guide design moves towards increasing creativity. The Creativity Landscape conceptual framework provided a conceptual lens through which to explore design choices for facilitating greater creativity in the design of learning environments. This design study suggested that the principles of constructionist learning, design thinking, designerly ways of knowing, and reflective practice have potential in promoting creativity and warrant more investigation toward operationalizing creativity in learning environments in light of common placement of creativity on par with collaboration in 21st-century skills.

References

Diego, E. U. L., & John, F. C. (2011). The opportunities and challenges of technology driven creative collaborations *Technology for Creativity and Innovation: Tools, Techniques and Applications* (pp. 325-342). Hershey, PA, USA: IGI Global.

Donaldson, J. P. (2016). Alignment of creativity tools and techniques with theory and research. In F. Reisman (Ed.), *Creativity in arts, science and technology* (pp. 260-279). London: KIE Conference Publications.

Donaldson, J. P. (2017). *The creativity landscape framework and design of learning.* Paper presented at the 2017 American Educational Research Association Annual Meeting, San Antonio, TX.

Hanson, M. H. (2014). Converging paths: Creativity research and educational practice. *Knowledge Quest, 42*.

Papert, S., & Harel, I. (1991). Situating constructionism. In S. Papert & I. Harel (Eds.), *Constructionism* (pp. 1-11). New York, NY: Basic Books.

Sawyer, R. K. (2014). Conclusion. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (2nd ed., pp. 747-776). New York, New York: Cambridge University Press.

Social Comparison Theory as Applied to MOOC Student Writing: Constructs for Opinion and Ability

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Abstract: There has been limited research effort toward understanding how diversity attributes might influence peer feedback in Massive Open Online Courses (MOOCs). Using social comparison theory, we investigated the influence of socioeconomic status (SES) and agreement on peer feedback text in a data science MOOC. This study contributes to understanding how social comparison theory can be operationalized in online writing environments.

Introduction and literature review

Researchers have tried to maximize the benefits of peer feedback activity for MOOCs by focusing on features such as the large size of classes and diversity of students. Social comparison theory gives suggestions on how learner diversity might influence peer feedback in online classrooms. Social comparison theory proposes that people conduct comparisons through two mechanisms: opinions and abilities (Festinger 1954). Not only are attributes such as intensity of practice used, but socioeconomic status (SES) has been perceived as an ability-related attribute (Régner and Monteil 2007). Typical classrooms, even under low competitive and individualized atmospheres, give rich context for social comparison (Dijkstra et al. 2008). Considering MOOCS have students with larger diversity including SES and opinion, we believe they offer interesting context for social comparison. Thus, the question we explore is: *How does social comparison occur during peer feedback activities in MOOCs?*

We used psychological distance to explain reasons behind learner behaviors and how they influence the learning experience of feedback recipients. Emotional intensity and formality of textual response are measurable behavioral proxies during the feedback activity context in the MOOC. Tu and McIsaac (2002) found that farther psychological distance between a sender and a recipient causes more formal and less affective textual response which can discourage learning experience (Van Boven et al. 2010; Tu and McIsaac 2002).

We contextualize our inquiry in student writing and peer feedback activities, operationalizing social comparison theory through text analytic methods. In particular, we study how learners from countries which are generally considered as high SES countries (whose proportion is prevalent in most MOOCs) interact with peers showing similarity or difference in opinions and in performance during online feedback activity. Through experimentation we were able to measure how country and opinion diversity separately and together affect the way a learner responds to peers.

Methods

In all studies, learners read question prompts asking whether they agree with the non-technical issues related to data science and completed a short writing position. A controlled peer activity is where learners were randomly presented with one of two peer positions which were written by the instructor. Participants were recruited through an optional activity in the 'Introduction to Data Science in Python' MOOC taught by Christopher Brooks on Coursera. IRB oversight was sought under University of Michigan study id HUM00120884. The number of participants in preliminary study was 246 and participants in Study 1 was 138. Learners were classified as coming from high, medium, or low SES countries, based on whether they were in the first, second or third, or fourth quartiles of the UNDP Human Development Report 2016 respectively. In this work we focus on the actions of only those learners who were identified as coming from high SES countries. Then learners were randomly presented with one of two peer positions written by the instructor. The position text differed as to whether it was for or against a given argument outlined in the question prompt learners were shown. The country indicator was set either to a high SES country, or a low SES country. Thus, the study was a 2X2 factor design where each learner was to respond to a one of four types of an instructor response: (a) a high-SES peer with dissenting opinion, (b) a high-SES peer with agreeing opinion, (c) a low-SES peer with dissenting opinion, and (d) a low-SES peer with an agreeing opinion.

Findings

Preliminary study and study 1: Hypotheses tested on the different dataset

A two-way ANOVA was run on 246 learners. There was a significant difference between agreement and disagreement on affect (agreeing M (SD)=.21(1.15), disagreeing M(SD)=-.43(.26), F-value=21.90, p<.001) and formality (agreeing M (SD)=-.22(1.02), disagreeing M(SD)=.45(.78), F-value=24.31, p<.001). There was no significant difference between high peer SES and low peer SES either on affect (high M (SD)=.08(1.14), low M(SD)=-.10,.79, F-value=1.25) or formality (high M(SD)=-.03(.92), low M(SD)=-.04(1.10), F-value=.03). Yet, we observe a trend which gives evidence to build hypothesis on SES. There was no significant interaction between the two main independent variables. From results of the preliminary study and social comparison theory, we posed two hypotheses. First, learners from high SES countries will construct feedback that is more formal, with fewer emotional language when responding to cases of disagreement with peers, regardless of the country disclosure of the peer. Secondly, learners from high SES countries will write a less emotional and more formal feedback when responding to lower SES peers. We re-tested these hypotheses in Study 1 which used a different question prompt to see whether the agreement and SES factors are effective in a different context of a peer feedback activity.

Study 1 did not demonstrate supporting evidence to support H1; there was no significant difference between agreement and disagreement on affect (agreeing M (SD)=.04(1.01), disagreeing M(SD)=-.16(0.97), F-value=2.59) and formality (agreeing M (SD)=-.05(1.10), disagreeing M(SD)=.23(.66), F-value=.02, p<.00). For H2, evidence was found with respect to formality of responses towards learners in low SES countries (high M(SD)=-.19(1.06), low M(SD)=.23(0.97), F-value=5.04, p<.05), however there was no significant difference in affect between low peer and high peer groups (high M(SD)=-.08(1.02), low M(SD)=.09(0.99), F-value=3.33). There was no significant interaction between the two main effect variables, agreement and SES.

Conclusion and future work

Before concluding SES was not effective ability-related factor, through an analysis of learner responses, we realized that there was a gap in formality between the controlled instructor responses and the actual learner responses. In particular, learner responses ranged from a formality score of -.572 to 3.484 (M = .691, sd = .549), while the two instructor created positions which had formalities of .370 and .677 (M = .523). We were concerned that peer responses were impacted by the different level of formality which can influence persuasiveness of textual response (Graesser et al. 2014). Based on current understanding of formality, a hypothesis on peer formality should be posed in the future work.

References

Dijkstra, Pieternel, Hans Kuyper, Greetje van der Werf, Abraham P. Buunk, and Yvonne G. van der Zee. 2008. "Social Comparison in the Classroom: A Review." *Review of Educational Research* 78 (4). American Educational Research Association:828–79.

Festinger, Leon. 1954. "A Theory of Social Comparison Processes." *Human Relations; Studies towards the Integration of the Social Sciences* 7 (2). SAGE Publications:117–40.

Graesser, Arthur C., Danielle S. McNamara, Zhiqang Cai, Mark Conley, Haiying Li, and James Pennebaker. 2014. "Coh-Metrix Measures Text Characteristics at Multiple Levels of Language and Discourse." *The Elementary School Journal* 115 (2):210–29.

Régner, Isabelle, and Jean-Marc Monteil. 2007. "Low-and High-Socioeconomic Status Students Preference for Ingroup Comparisons and Their Underpinning Ability Expectations." *Revue Internationale de Psychologie Sociale* 20 (1). Presses univ. de Grenoble:87–104.

Tu, Chih-Hsiung, and Marina McIsaac. 2002. "The Relationship of Social Presence and Interaction in Online Classes." *The American Journal of Distance Education* 16 (3). Routledge:131–50.

Van Boven, Leaf, Joanne Kane, A. Peter McGraw, and Jeannette Dale. 2010. "Feeling Close: Emotional Intensity Reduces Perceived Psychological Distance." *Journal of Personality and Social Psychology* 98 (6). psycnet.apa.org:872–85.

Can Speaking Make Learning Easier? Verbal Rehearsal Effects on Cognitive Load, Learning Efficacy and Performance

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Abstract: In the study reported here, the effectiveness of verbal rehearsal as a learning strategy that could mediate extraneous load effects and increase learning was examined within the research area of Cognitive Load Theory. While the learning outcomes between the groups did not differ significantly, participants who verbally rehearsed the material found learning the new material less challenging and reported lower levels of cognitive load. Results imply verbal rehearsal may be an effective method to enhance learning.

Introduction

Understanding the cognitive processes of working memory capacity can enable us to make better educational decisions in the way instruction is delivered to students. The use of multimedia learning typically used in classrooms has the ability to impede learning by increasing the cognitive load demands on students. This is often due to substandard instructional design such as unnecessary irrelevant information or seductive details. Active learning strategies, on the other hand have been found to mediate extraneous load conditions, but can also risk adding to the load conditions. Well supported assumptions of Cognitive Load Theory (CLT) maintain that presentation approaches which reduce the amount of cognitive load caused by extraneous sources, such as added redundant information, will improve the learning performance of the student (Mayer & Moreno, 1998). In theory, these cognitive load effects are based on our understanding of human cognitive processing systems, primarily that we have a limited working memory capacity (Clark, Nguyen, & Sweller, 2011). Self-efficacy can also play an important role in predicting performance on learning and is considered an important component in learning achievement. Learning strategies that can enhance self-efficacy, could also increase learning. Therefore, in this study, the effect of the inclusion of seductive details and the possible mediating effect of a germane strategy (i.e. verbal rehearsal) on learning performance and perceived interest, confidence and challenge (as per Bandura, 1993) were explored.

The present study

Using a 2 x 2 x 2 repeated measures experimental design (see figure 1.), one hundred participants were randomly allocated to four learning conditions with varying cognitive load requirements (with vs. without seductive details), in a consistent low-load modality (visual + narration only) when learners were engaged in a germane load activity (with active verbal rehearsal vs. without active verbal rehearsal). Verbal rehearsal (Makita et al., 2013) that assists memory encoding, as the added germane load was used to explore the underlying question of whether verbal rehearsal as an instructional strategy would stimulate more elaborate cognitive processing and therefore result in better learning outcomes. Alternatively, the learner unnecessarily processes the additional cognitive load source in the act of verbal rehearsal, resulting in poorer learning.
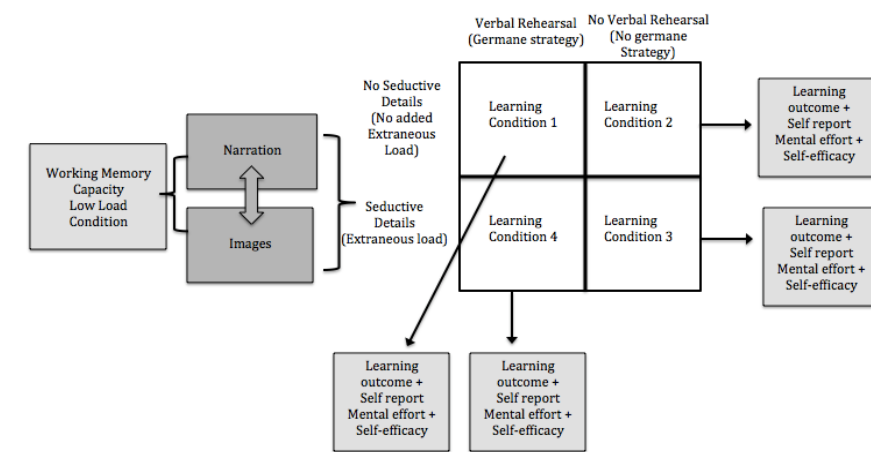
Figure 1. Study design of experimental paradigm.

Discussion and results

While learning performance did not differ significantly across the learning conditions, the difference in pre to post test scores did indicate some effect between the verbal and non-verbal groups. Differences in the pre and post mean scores between the reciting groups and the listening groups, showed a partial eta squared effect size of .04, approaching a medium effect. Results did show however that those who rehearsed, found learning the new material less challenging and reported lower levels of cognitive load (see figure 2.). We also found that ratings of self-perceived learning, were higher for those who had rehearsed the material, indicating the use of verbal rehearsal supported the participants in feeling more positive about their own learning. Combined with lower levels of cognitive load reported by this same group, averages for the rehearsal group ($M = 1.73$, $SD = 1.81$) were significantly lower than the non-rehearsal group ($M = 3.06$, $SD = 2.25$) with a main effect for rehearsal type yielding an F ratio of $F (1, 96) = 10.96$, $p = .001$, partial $\eta2 = .10$, a possible beneficial interaction with working memory demand constraints was revealed (Hoffman & Schraw, 2009). These low ratings of cognitive load were apparent even though participants were engaged in a germane load activity that could have added to the processing demands of working memory.
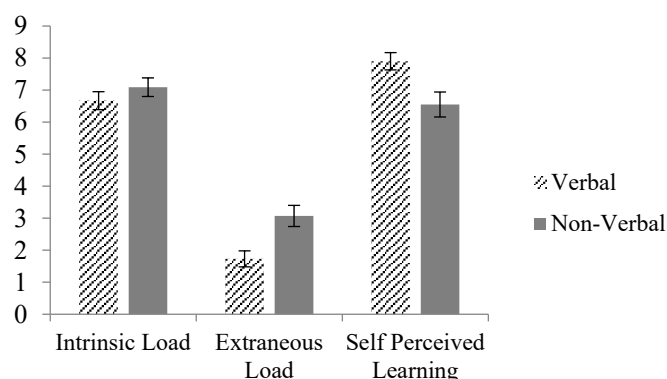
Figure 2. Cognitive load rating means, error bars denote standard error for verbal rehearsal.

Summary and conclusion

Research in educational and cognitive psychology continues to search for better ways to present new material in order to maximize learning and reduce cognitive load. Verbal rehearsal as an instructional strategy may stimulate more elaborate cognitive processing, and assist in successful encoding without overloading working memory capacity. Asking students to verbally rehearse the material they are learning, is a simple and cost-effective way for students to interact with the instruction. When the cognitive load demands are reduced to meet the needs of the student's working memory capabilities, the learning outcomes for individuals engaged in multimedia presentations could be improved. It is unresolved whether this was of any benefit to performance, however the results are promising and warrant further investigation.

References

Bandura, A. (1993). Perceived self-efficacy in cognitive development and functioning. *Educational Psychologist, 28(2)*, 117-148. doi: 10.1207/s15326985ep2802_3

Chandler, P., & Sweller, J. (1991). Cognitive load theory and the format of instruction. *Cognition and Instruction, 8*, 293–332. doi: 10.1207/s1532690xci0804_2

Clark, R. C., Nguyen, F., & Sweller, J. (2011). *Efficiency in learning: Evidence-based guidelines to manage cognitive load.* San Francisco: CA. John Wiley & Sons. doi: 10.1002/pfi.4930450920

Makita, K., Yamazaki, M., Tanabe, H. C., Koike, T., Kochiyama, T., Yokokawa, H., & Sadato, N. (2013). A Functional Magnetic Resonance Imaging Study of Foreign-Language Vocabulary Learning Enhanced by Phonological Rehearsal: The Role of the Right Cerebellum and Left Fusiform Gyrus. *Mind, Brain, and Education, 7(4)*, 213-224. doi: 10.1111/mbe.12029

Mayer, R. E., & Moreno, R. (1998). A split-attention effect in multimedia learning: evidence for dual processing systems in working memory. *Journal of Educational Psychology, 90*, doi: 10.1037/0022-0663.90.2.312

Hoffman, B., & Schraw, G. (2009). The influence of self-efficacy and working memory capacity on problem-solving efficiency. *Learning and Individual Differences, 19(1)*, 91-100. doi: 10.1016/j.lindif.2008.08.001

Visualizations of Community Knowledge for Supporting Middle School Students to Model Phenomena in Scientific Inquiry

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Abstract: In a design-based research study, 85 middle school students participated in a model-construction inquiry activity, where they contributed claims about species relationships. The relationships were modeled with a food web visualization that captured the classroom community's understandings. In Year 1, the visualization and knowledge base of claims were independent technologies. In Year 2 the visualization was automatically constructed from the database of claims. We examine the design implications of the visualizations for supporting whole-class discussions.

WallCology

Researchers have used a variety of technology solutions to support learners in collecting and sharing their observations with peers. This poster examines <u>community knowledge construction of food web models and whole-class discourse</u> around the food web representation in two iterations of an 8-week WallCology unit. As part of the Embedded Phenomena framework, WallCology is a digital simulation that situates students in a complex virtual ecosystem mapped onto their classroom walls (Moher et al., 2008). Groups of two to four students observe the species through WallScope portals (i.e., computer monitors) and perform investigations on local ecosystems. Since local ecosystems are designed to inhabit only a subset of the species, students must work together as a community to discover the complete set of relationships in WallCology. The "master food web" (MFW) serves as a public display of the classroom community's knowledge and is the focus of teacher-led whole-class discussions. Cycles of group work (making and justifying digital claims) and whole-class discussions (reporting on findings) drive community progress. In Year 1, claims about each species were saved onto tablets located in specific places within the classroom (11 species & tablets). The information was aggregated locally and accessed on these tablets. The MFW was ***constructed as a class***, as informed by the students' local group work. In Year 2, claims were about ***relationships***, describing the producer-consumer or competition relationship between a pair of species. The MFW was ***automatically constructed*** in real-time from the database of claims.

<u>Figure 1</u>. Y2 WallCology environment: WallScope (left), master food web (MFW; centre), claims dialog (right).

The design-based research study was implemented over two iterations with the same teacher participant. Three Grade 6 Science classes participated each year, with 44 students in Year 1 and 41 students in Year 2, aged 11-12. All sessions were video recorded and whole-class discussions reviewed.

Findings

Y1: Focus of whole-class discussions on procedural tasks in food web construction

In Year 1, whole-class discussions involving the MFW consisted of the teacher asking each group if they had anything to contribute to the representation (e.g., *"What do you have to add to our master food web?"*). Student

groups took turns describing what they found, with minimal discussion. Below we present an illustrative example that characterized the discourse in Year 1. The case began with one group (of two students) reporting their findings after an investigation (e.g., manipulation to their ecosystem): *"We decreased the population of Muk (species #4) to see what would happen to the population of others and to see if Dr. Finklesheetz (species #6) ate anything...and what we found out was that Muk went down [in population] after Dr. Finklesheetz also went down [in population]. So we think Dr. Finklesheetz ate Muk and also the population of Mitch (species #9) went completely down. Meaning since Dr. Finklesheetz didn't have Muk to eat he was completely focusing on Mitch."* The students concluded that Dr. Finklesheetz ate Muk and Mitch. The teacher then asked *"...are the arrows correct? If the population of Mitch increases, does that have a positive effect on the population of Dr. Finklesheetz?"* Several students confirmed this. The teacher added the new food web arrows while asking students which direction the arrows should face, and then moved on to the next group once the arrows were created.

Y2: Focus of whole-class discussions on the *quality* of claims that formed the master food web

In Year 2, the MFW was automatically generated through the claims submission process, off-loading the construction task from the teacher. She focused whole-class discussions about group claims in greater depth and the classroom community's emergent understanding about the entire WallCology ecosystem, as represented by the master food web. Below we describe an illustrative example in Year 2 (at a comparable point in the unit as the previous case). The discussion began in a similar fashion, with the same teacher asking each group to discuss their claims and what they learned from their manipulations. With their claim displayed on the MFW, the group began with: *"We think Maushy (species #0) eats Phogqu (species #5). In Figure 1 you see we decreased Phogqu and that Maushy went down...Maushy eats Phogque. In Figure 2, you can clearly see Maushy went down...Last, in Figure 3, you may think you see lots of Phogqu. But actually, that whole top part was filled with Phogqu, showing Maushy probably eats it. Also, you see that there are a lot more Maushy's than Pansirty's (species #7) in the picture."* The teacher then asked the class *"What do you think?"* and five students raised their hands. When called upon, a student said *"I think this claim is good but it's not promising because the word 'probably' shouldn't be in a claim...it's just kind of like (shrugs shoulders). Also, in Figure 3 I think there should have been a 'before' picture because it's not that believable."* The discussion continued with the teacher describing the positive qualities of the claim (e.g., use of two clear population graphs that connects to the reasoning). She then asked if a different group could contribute another claim, which would strengthen the relationship on the MFW (as a thicker line). The discussion continued for a total of six minutes and included engaged verbal participation from at least six students (of 15 in the class) before moving on to the next group due to time constraints. The teacher also frequently gestured towards the MFW, particularly when addressing the class about community progress: *"We're not just trying to figure out ecosystem 5, we're trying to figure out the whole thing. That's the goal."*

Discussion

In both iterations, WallCology was framed around modeling species relationships as a community of learners. In Year 1, our design had students intentionally distilling community knowledge from the set of claims in constructing the MFW during whole-class discussions. At the time, we believed the deliberate transfer of knowledge from the claims database to the MFW was consequential and would elicit more thoughtful reflections. However, we found that the discussions did not progress past a superficial level of discourse. There was also limited engagement between groups during discussions. Our findings in Year 2 suggested that the MFW, as an aggregate visualization, created from real-time student-generated claims accurately reflected the state of community knowledge and was used as a meaningful object of community discourse. Whole-class discussions were organized in a guided exploration context, which allowed the topic of discussion to be focused on the quality of student claims. This in turn allowed the visualization to be used as a resource for identifying community effort and progress towards completion. Engaged patterns of participation was seen across groups illustrating the MFW as a context for argumentation, and adoption or rejection of candidate relationships present in the ecosystem.

Reference

Moher, T., Uphoff, B., Bhatt, D., Silva, B. L., & Malcolm, P. (2008). WallCology: Designing interaction affordances for learner engagement in authentic science inquiry. Presented at the *Proceeding of the 26th Annual ACM SIGCHI Conference on Human Factors in Computing Systems* (pp. 163-172).

Acknowledgements

A New Facet: Building Multifaceted Engineering Identity

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Abstract: We redesigned a first-year course to support diverse students to develop a sense of belonging and professional identity in engineering. We collected student work (N=104) and interviewed a subset (n=8). Students cited altruism, family, camaraderie, work ethic, and enjoying science and mathematics. They positioned themselves as problem solvers capable of the hard work ahead. Students began to take up professional engineering identities without sacrificing prior identifies.

Major issues, significance, and theoretical framework

Without understanding students' perceptions and ways their past experiences might be relevant to engineering design, we remain limited in our ability to design learning experiences that entice them to take up engineering identities, *without sacrificing who they are.* This view of identity as multifaceted directs us to consider how we might jointly add new identities while preserving existing ones (Tracy & Trethewey, 2005). We argue that not explicitly supporting students to maintain their other identities risks homogenizing them. In line with arguments about culturally sustaining pedagogies (Paris & Alim, 2014), we argue that this diversity in identity is key to supporting students to become creative designers capable of tackling grand challenges. Building on students' funds of knowledge supports diverse student participation and development in engineering (Mejia, Drake, & Wilson-Lopez, 2015), positioning them as designers defining and solving problems in their communities. This positioning matters because identity and learning are intertwined, with changes in one altering opportunities in the other (Holland, Lachicotte, Skinner, & Cain, 1998).

Methods

We sought to investigate a research question: How might a first-year design course shape diverse students' perceptions of what it means to be an engineer and support such students to bridge or build new facets of their identities without sacrificing existing identities? The course was a first-year 1-credit chemical engineering course at a Hispanic-serving, very high research university. The students reflected the diversity of our state, with a majority of them from groups underrepresented in engineering. Many of them worked, supported families, and came from low-income communities. Across four design-based research iterations, we completely redesigned the course from its original format, which consisted primarily of faculty giving guest lectures. We developed design challenges that would build on students everyday experiences. For instance, the acid mine drainage challenge tasked students with developing a prevention or emergency response system and a community engagement strategy to aid a rural community whose water is contaminated by an abandoned mine, a topic made relevant by current events in our state. Students completed activities intended to engage them more deeply in the departmental culture and broader chemical engineering community. While this provided an experience many found interesting because they had so many choices, they did not connect this to their own past experiences. We therefore added a *professional engineering identity letter* to make this connection. Data included student work and interviews on students' perceptions of what an engineer does, how the first-year class was preparing them and how their groups functioned on design challenges. All questions were semi-structured and aimed to elicit information about their funds of knowledge, group dynamics and engineering design processes. We also collected student work in the form of *professional engineering identity letters*. We transcribed the interviews and used open coding.

Results and discussion

Broadly, students cited designing, problem solving, altruism, family, community, work ethic, and enjoying science and mathematics across both data sources. A majority of the students opted to address the letters to their future selves, at a time when they were considering leaving engineering. They reminded their future selves of their work ethic, and that "You are ok with making mistakes, fixing them, and trying again." Nearly 80% of students cited altruism, and approximately 70% cited a long-term passion for or ability in STEM.

Many students expressed a love of STEM and having STEM ability. They connected these to designing, problem solving, and being able to help people or the environment by creating "solutions for real world problems." Students reflected on their shift from pure science to engineering. Jill explained how a high

school job fostered a sense of altruism, which led her to a career pathway in medicine, which then because of her passion for STEM, led her to engineering. Similarly, Lamont explained that he loved science and math, and in our class he "found out that I could use [his] new love to help many people across the globe."

Students were aware that the path ahead would challenge them. Jill explained that the design challenges were "difficult, and it is much more of what an engineer actually does especially in the industry. […] I feel like this class—these design challenges are really representative of what you actually do in real life." Jill viewed the design challenges as providing an opportunity to not just learn about engineering, but to also experience it first hand. Some expressed surprise at finding such community within an engineering department. Easton explained that he initially expected engineering to be individualistic, and based on this, he wasn't sure that engineering would be a good fit; because he developed connections with other students, he came to see engineering as a good fit. By engaging students in the design challenges from the beginning, we were able to shift their perceptions of what it means to be an engineer.

While some students cited having family members who are engineers and how this shaped their motivation for pursuing engineering, many are the first in their families to attend college and have not had much interaction with engineers. Such students referenced family in complex ways. For instance, several students connected their experiences growing up in a community or family of limited means with their desire to help others as an engineer, a stance we reinforced in positioning students from rural communities as experts in the acid mine drainage challenge. Maya explained the acid mine challenge "impacted my life because our job not only creates new things but helps others. I was able to relate to the struggle of not having clean water since my parents would tell me stories that they too had to drink from dirty rivers. […] The aspiration of helping people and coming from a humble family will make you succeed." This helped Maya "realize that I do have a purpose in this career." We argue that students like Maya have great potential, particularly if they are supported to view their life experiences as not only permissible, but relevant in solving design problems.

Conclusions and implications

Students explained how their backgrounds, family and friends played an important role in choosing engineering as their degree program, but also the role it played in their desire to build camaraderie with engineering peers in the program. The students shared how these identities influenced their everyday learning. Our analysis revealed a pervasive reported belief that engineering would allow them to leverage their interests and abilities in STEM to solve problems. Unlike the stereotypical view of engineers motivated by money or pursuit of knowledge, our students commonly expressed a strong sense of altruism, and this was commonly connected to their experiences growing up in the face of struggles. By engaging diverse students in engineering design challenges and encouraging them to connect to the department, we are helping to correct misperceptions they bring about engineering. By also explicitly positioning them as having assets that are derived from their diverse experiences and that matter in solving design problems, we have helped them feel like they belong in engineering. As we continue to refine our curriculum, we will build on these findings, supporting our students to maintain multifaceted identities while adding new engineering facets.

References

Holland, D., Lachicotte, W., Skinner, D., & Cain, C. (1998). *Identity and agency in cultural worlds*. Cambridge, MA: Harvard University Press.

Mejia, J. A., Drake, D., & Wilson-Lopez, A. (2015). Changes in Latino/a Adolescents' Engineering Self-efficacy and Perceptions of Engineering After Addressing Authentic Engineering Design Challenges *Proceedings of American Society for Engineering Education Annual Conference* (pp. 1-14). Seattle, WA: ASEE.

Paris, D., & Alim, H. S. (2014). What are we seeking to sustain through culturally sustaining pedagogy? A loving critique forward. *Harvard Educational Review, 84*(1), 85-100. doi:10.17763/haer.84.1.982l873k2ht16m77

Tracy, S. J., & Trethewey, A. (2005). Fracturing the Real-Self↔ Fake-Self Dichotomy: Moving Toward "Crystallized" Organizational Discourses and Identities. *Communication Theory, 15*(2), 168-195.

Acknowledgments

Pre-Service Teachers' Perspectives on Computer Science Education Within an Equity-Oriented Teacher Education Program

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Abstract: This is a small-scale case study of pre-service teachers' perspectives on teaching and learning computer science (CS) after they participated in an equity-oriented teacher education program. We found that this program appeared to support pre-service teachers (PTs) in developing more expansive views on CS teaching and learning.

Introduction

In this paper, we consider pre-service teachers' views on computer science education in an after-school program for elementary students. As this was the first time incorporating new CS education tools into our program, we conducted an initial case study in order to understand: What were pre-service teachers' perspectives on teaching and learning CS after participating in this teacher education program? Our club, called EPIC, is focused on equity-oriented teacher education and providing culturally sustaining and disciplinarily-rich learning for elementary school children. The design of EPIC emphasizes working with children as partners and supports adults and children in working collaboratively on interest-driven and academically rigorous projects. We report findings from a small-scale case study, in which we analyzed interviews with participating pre-service teachers (PTs), focusing on their experiences teaching and learning CS and their ideas about CS education. Our analysis showed that PTs developed more expansive views on children's capabilities in CS and that their experience sparked new possibilities for CS pedagogies that can be more empowering for learners than approaches to CS education that are more often afforded to students from nondominant communities (Margolis et al., 2008).

Background

Researchers have made great strides in developing approaches to teaching CS through constructionist practices (Papert, 1980), including developing more interest-driven learning experiences that have the opportunity to better support culturally sustaining learning experiences for students from nondominant communities (e.g., Pinkard et al., 2017). Expansive learning opportunities around CS are not often afforded to students in equitable ways. In the US, white and/or wealthy students are more likely to be in schools that offer CS classes, even while students of color are more likely to be interested in learning CS (Google & Gallup, 2015). Even in schools that do offer CS, women and students of color are less likely to be perceived as capable in computing, and learning opportunities around CS education are often limited to "drill and kill" computing experiences (Margolis et al., 2008) or "Unplugged" experiences that do not involve actually programming computational technologies (Bell et al., 2009). Additionally, the question remains as to how computing can be integrated into elementary pre-service programs in line with practices that can advance equity.

Methods

This case study draws on interviews with four PTs who participated in EPIC. Of the fourteen university students who attended the club, we interviewed these four students because they intended to become teachers and were available for interviews. We understand that the small-scale nature of this research is a limitation, however in line with our social design experiment (Guitierrez & Jurow, 2016), we sought to understand PTs' experiences in our program as part of ongoing iterations of our program design to align with goals for more equitable and expansive learning. We analyzed data using an inductive approach (Strauss & Corbin, 1994).

Design and context

We incorporated CS education into an after-school club experience for pre-service elementary teachers and elementary students. Many of our university student participants intend to become teachers and generally tend to be white; the majority identify as women, coming from middle income backgrounds and being monolingual English speakers. Many elementary students (ages 8 to 11) who participate in the club identify as Mexican and speak varying levels of Spanish and English and many students come from families living in poverty. Our aims were to provide CS learning opportunities for children from historically underserved communities and to support PTs in approaching computing education with a focus on interest-driven learning and equity. We made

use of a new programmable technology called BBC micro:bit, a small programmable computer designed for young students with a block-based programming environment. The micro:bit is small, relatively inexpensive (USD $12), easy to integrate with the craft materials (e.g., paper, fabric, glue) that we already used at EPIC, and includes a variety of built-in sensors, a 5x5 pixel LED screen, and a built-in wireless (Bluetooth) radio.

Pre-service teacher perspectives on teaching and learning computing

Finding One. Pre-service teachers thought the children they engaged with at the club were capable, creative and talented in CS. Pre-service teachers made comments about their partners, such as: "they learned it pretty quickly," "they were so creative with their projects" and "they excelled at it." In the interviews, several of the PTs said they felt their elementary student partners often were the ones teaching them CS.

Finding Two. Pre-service teachers indicated that they felt the CS should be approached in a way that supports interest-driven and open-ended learning, and supports elementary students in participating in multiple, varied ways. For instance, one PT shared that she wanted her elementary partners to have creative freedom in their final CS project and her role was to support them in that endeavor. Another PT said that she wanted to keep the CS projects open-ended because students have different interests than one another and it is more meaningful for students to work on something that matters to them personally. One PT also commented, however, that she would have preferred more structure up front before diving into the open-ended projects.

Finding Three. Pre-service teachers had varying perspectives about the primary CS tool used at the club, the micro:bit. All of the PTs indicated that the micro:bit integrated well with the crafting and story-telling practices at the club, as with the goals of the club, including purpose-driven projects and relationship building. However, some PTs also shared that, by the end of the semester, some students lost interest in the micro:bit and that there was too much emphasis on this particular technology.

Discussion and tensions

Based on our small case study, we found that the PTs developed ideas for fostering more expansive CS learning opportunities with elementary students. Our data suggest that the PTs' asset-based views of children supported a move away from more hierarchical teacher-student relationships. PTs were grappling with the role of expertise in teaching CS, some simultaneously discussed a lack of expertise as an affordance for challenging such hierarchies *and* as a significant challenge for supporting their elementary partners in CS work. In future iterations, we have sought to help PTs develop greater expertise in CS while continuing to support them in seeing children as capable and creative with CS. Our interviews also helped us appreciate how these PTs were thinking about the potential educative value of children's ideas and experiences in relation to the disciplinary practices of CS. This perspective was in line with the design of our learning environment and our goals for supporting collaborative, interest-driven work. However, one PT's comment about wanting more structure early on raised a tension regarding what constitutes foundational CS learning for PTs, when to provide it and how. Relatedly, in regards to the use of the micro:bit, our intention was to support children and PTs in integrating the tool into their repertoire of tools for thinking and making. We did not want the tool to become the focal point of the program. As part of subsequent iterations of EPIC, we are working to offer a greater variety of tools to support CS work and position the micro:bit as one tool for supporting creative endeavors. As in any design work, we continue to reflect and revise our program to best meet our goals of supporting learning and equity.

References

Bell, T., Alexander, J., Freeman, I., & Grimley, M. (2009). Computer science unplugged: School students doing real computing without computers. *The New Zealand Journal of Applied Computing and Information Technology, 13*(1), 20-29.

Google & Gallup. (2015). Searching for Computer Science: Access and Barriers in U.S. K-12 Education. Accessed: https://services.google.com/fh/files/misc/searching-for-computer-science_report.pdf

Gutiérrez, K. D., & Jurow, A. S. (2016). Social design experiments: Toward equity by design. *Journal of the Learning Sciences*, *25*(4), 565-598.

Margolis, J., Estrella, R., Goode, J., Holme, J. J., & Nao, K. (2008). *Stuck in the shallow end: Education, race, and computing*. MIT Press.

Papert, S. (1980). Mindstorm. *Basic Book, New York*.

Pinkard, N., Erete, S., Martin, C. K., & McKinney de Royston, M. (2017). Digital Youth Divas: Exploring Narrative-Driven Curriculum to Spark Middle School Girls' Interest in Computational Activities. *Journal of the Learning Sciences*, *26*(3), 477-516.

Strauss, A., & Corbin, J. (1994). Grounded theory methodlology. *Handbook of qualitative research, 17*, 273-85.

Tracing Bodies Through Liminal Blends During Play-Based Inquiry in a Mixed-Reality Environment

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Abstract: We demonstrate how a Mixed Reality (MR) environment supported blending semiotic resources with embodied representations of water particle motion. Our analysis demonstrates the importance of a) providing a rich set of resources, b) the centrality of the body as a sensemaking resource, c) supporting students in iterative inquiry, and d) helping students to transition from unique classroom resources like MR into more normative accounts.

Introduction

We explore iterative cycles of inquiry within a Mixed Reality (MR) learning environment to examine how students used their bodies to develop an understanding of water particle behavior relating to states of matter. In progressive symbolization, learners iteratively refine and re-represent ideas to deepen understanding (Lehrer & Schauble, 2006) during which representations gather meaning through use and its relation to other representations (Hall, 1995). We traced students' evolving understanding by documenting how they leveraged multiple resources (the semiotic ecology; Enyedy, 2005). A blending framework was particularly powerful as it helps map lamination of virtual semiotic resources onto material structures like embodied activity to support unique forms of reasoning. We examined the (de)construction of these blends over time to examine the role of the body as representations are taken up and transformed over inquiry cycles. We claim a) students actively blend semiotic resources together to create meaning and b) throughout inquiry cycles and re-representing, material resources may go *underground* (become no longer materially present; Wertsch & Stone, 1999). However, c) resources that go underground are still implicated in practice and are recoverable when current representations and practice are not enough.

Methods

We analyze data from the Science through Technology Enhanced Play (STEP) project (Enyedy, Danish, & DeLiema, 2015). STEP is designed to privilege embodied inquiry by using OpenPTrack MR technology (Munaro, Horn, Illum, Burke, & Rusu, 2014) to follow students' movement and communicate it to a simulation that is projected (Figure 1, left). The visualization shows students as particles (yellow dots) with colored-rings determined by the state of matter students collectively make (red for gas, blue for liquid, white for solid).

We use interaction analysis (Jordan & Henderson, 1995) to analyze lessons from one first and second grade classroom. We identified a consistent pattern—iterative cycles of inquiry—in students' interactions as they explored out how particles behaved by noticing and proposing potential *recipes* to explore—verbal directions for how to move their bodies to produce a particular reaction in the MR visualization—and moved over time towards proposing the testing of rules (Figure 1, right). We examine *how students use bodies to create and refine liminal blends as they develop rules for states of matter during collaborative embodied inquiry?*
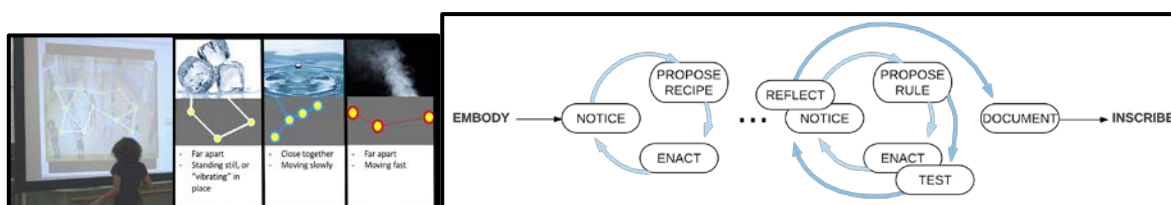
Figure 1. (Left) Student-particles observe the STEP visualization, small frame shows particle states of matter. (Right) Students' iterative cycles of inquiry.

Findings

Students embodied experience remained important throughout inquiry and after inquiry. Early cycles of inquiry consisted of proposing and enacting a recipe "move fast," followed by students' movement (students running), and students narrating "I'm red" illustrating the lamination of representational forms. During discussion, Cora, a

student, drew upon her own and classmates' bodies to re-enact related rules for red which Ms. Jones inscribed in documentation as "close to somebody + far from somebody else". The body no longer played a material role in this representation, but the phrasing nonetheless was based on prior embodied experience. Thus, while the body and the STEP visualization had gone underground, they remained representationally present. In later cycles of inquiry, students tested and confirmed rules for making gas, once again laminating the STEP visualization's representations (particle, color, attraction lines, state-meter) onto their movement with the explicit purpose of affirming their rule for making gas. Cycles of pushing semiotic resources underground (moving from embodied activity to gesture to written representation of embodied activity) and resurrecting resources (e.g., making sense of current embodied activity by drawing upon documentation) continued throughout inquiry, and afterwards. During her post-interview, Sarah, a student, struggled to accurately remember how water particles behaved in each state of matter until she was asked to embody particulate motion herself. Sarah explained her understanding to the researcher in reverse, to stand still to make gas. However, when Sarah was prompted to stand up and show a solid particle *with her own body* and explain her motion, Sarah quickly revised her response. She explained by describing what happened on the screen ("vibrating in place" but "staying in one place"). It was not until Sarah embodied being a particle again and was asked to explain her movement as a particle, that she recovered her understanding of solid and gas particles' motion.

Discussion

By combining students' embodiment and programmed-rules for making states, the STEP simulation provided feedback to students that allowed them to engage in iterative cycles of inquiry as they developed ideas or recipes for making states of matter. Each iterative cycle supported students to articulate rules for particle movements. Because students become particles themselves, they developed an understanding of the rules for states based on their own embodied experience. These representational forms, starting with the embodied experience and STEP visualization of student-particles, were progressively built upon and coordinated with new representational forms through inquiry, discussion, and documentation (Enyedy, Danish, & DeLiema 2015). These blends might re-appear across several sequential cycles of inquiry before the representational forms and semiotic resources were deconstructed and blended in new ways. However, the body was *central in forming these representational understandings.* Thus, even as students moved from embodied to inscribed representations of rules for making states of matter, the experience of *being* water particles and *moving* like water particles was codified in students' representations. Furthermore, the body was recoverable when words were not enough (Lindberg & Danish, in preparation); when students struggled to make sense of new ideas or prior experience, their bodies became resources for conveying understanding.

References

Enyedy, N. (2005). Inventing mapping: Creating cultural forms to solve collective problems. *Cognition and Instruction, 23*(4), 427-466.

Enyedy, N., Danish, J. A., & DeLiema, D. (2015). Constructing liminal blends in a collaborative augmented-reality learning environment. *International Journal of Computer-Supported Collaborative Learning*, *10*(1), 7-34.Goodwin, C. (2013). The co-operative, transformative organization of human action and knowledge. *Journal of pragmatics*, *46*(1), 8-23.

Hall, R. (1995). Exploring design oriented mathematical practices in school and work settings. *Communications of the ACM*, *38*(9), 62.

Lehrer, R., & Schauble, L. (2006). Scientific thinking and science literacy. In R. W. Damon, K. Lerner, A. Renninger, & I. E. Sigel (Eds.), Handbook of child psychology, 6th edition, (vol. 4). Hoboken, NJ: Wiley.

Lindberg, L., Enyedy, N., Danish, J. (in preparation). *When words are not enough: What students gestures and embodied responses tell us about understanding science through dance.*

Munaro, M., Horn, A., Illum, R., Burke, J., & Rusu, R. (2014). OpenPTrack: People tracking for heterogeneous networks of color-depth cameras. In IAS-13 Workshop Proceedings: 1st Intl. Workshop on 3D Robot Perception with Point Cloud Library, Padova, Italy.

Wertsch, J. V., & Stone, C. A. (1999). The concept of internalization in Vygotsky's account of the genesis of higher mental functions. *Lev Vygotsky: Critical assessments*, *1*, 363-380.

Acknowledgements

Curiosity Practice: A Powerful New Lever for Fostering Science Engagement

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Abstract: Curiosity is a perennial theme in science education policy documents and informal science education (ISE) mission statements. However, formal and informal science experiences often minimize curiosity by reinforcing an image of science as the territory of right and wrong. In this poster, we argue that this has negative implications for individual's participation in ISE. We then present *Curiosity Practices,* our approach to helping parents and children develop a sense of curiosity around natural phenomena.

Introduction

Imagine a parent driving the car when his child asks "Why do we put sand on the roads?" The parent might respond by stating the answer, suggesting they look it up, or calling an expert. All of these responses answer her question. But what if he treated the question as an opportunity to explore how the world works rather than explain? In this case, the parent might say "I notice they only put sand on the road after it snows," and the child might recall rough sand sticking to her skin at the beach. Here, parents and children would work together to check new ideas against what they know about other things and generate more questions.

This approach of exploring and making sense of the question is an example of *practicing curiosity* about science. Curiosity is something people *do*— "[it] is expressed through actions and attitudes that manifest themselves in wanting to know 'why'" (Hensley, 2004, p. 32). Many of us practice curiosity throughout our lives – from unpacking why a friend is angry with us to investigating the latest political turmoil. However, many of us do not experience curiosity around science related topics. Instead, we tend to think of science as a collection of final form facts to memorize, and this lack of curiosity can have negative implications for *whether* and *how* we participate in science, and science adjacent, activities. In this poster, we will present *Curiosity Practices,* our approach to helping parents and children develop a sense of curiosity around natural phenomena.

Grounding literature

Science outreach and education often (implicitly) assumes that improving individuals' knowledge of science content and the scientific process will improve their attitudes toward science, and how they participate in scientific activities. However, a growing body of evidence demonstrates this is not true: increased knowledge has only a modest impact on attitudes and actions (see review in National Academies, 2016). In this project, we build on an emerging literature from psychology to offer an alternative approach: *curiosity*—rather than knowledge—as a potentially powerful lever for changing *whether* and *how* individuals participate in ISEs (see Figure 1).

Figure 1. Theory of Change
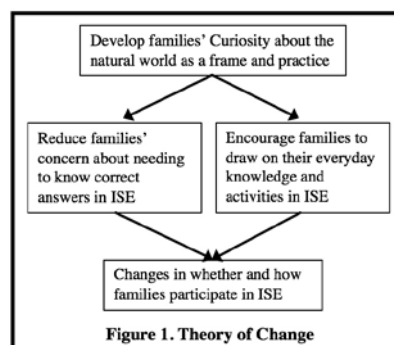
Whether one participates

Unfortunately, informal science experiences disproportionally serve the students and families who already have access to good science education (Dawson, 2014). In fact, research suggests that parents are likely to avoid ISEs when they believe that they need to provide their children an answer (Hill & Tyson, 2009). Thus, the parents who are less comfortable with science ideas are less likely to create opportunities to explore science with their children, thereby passing their discomfort on. This study builds on the increasing body of evidence showing that a sense of

curiosity can reduce this sort of anxiety around the right answer (Bishop et al., 2004) by decreasing an individual's worry about judgement and defensiveness about their (lack of) understanding, and hence, potentially increase the likelihood that they will participate in science activities.

<u>How one participates</u>
How one participates in science, and science adjacent, activities and discussions is deeply shaped by our identities (Kahan, Jenkins-Smith, and Braman, 2011). Instead of evaluating and considering evidence, we tend to discount contradictory information and bolster our existing ideas (e.g., Mercier, 2011) and the ideas of the communities with which we identify. For example, one's beliefs about climate and energy are more closely linked to political affiliation than knowledge of the underlying science (Pew Research, 2016). In short, our identification with "sides" reduces our curiosity about other ideas, which perpetuates and strengthens the polarization in our communities. Yet there is intriguing evidence that being more curious about science increases openness to ideas that contradict one's own beliefs (Kahan et al., 2017).

Design innovation
Formal schools are notoriously bad at fostering a sense of curiosity and informal science experiences in settings such as museums have shown mixed results highly dependent on the design of the ISE experiences and the social context of the experience (NRC, 2009). Thus, our project explores the possibility of developing a "practice of curiosity" in children and families through *Curiosity Practices*.

The term *Curiosity Practice* encapsulates the theoretical and practical parts of our innovation. Theoretically, we use the term practice to describe an activity in which a community regularly participates that entails shared norms and goals (Berland, 2011). Here, the term represents a shared norm of elevating curiosity – rather than content – in the families that participate. Practically, we use the term practice to describe an activity we do to get better at something—like soccer practice.

In the practical sense, Curiosity Practices – our novel instructional design approach – are informal conversations with children and adults in which they explore everyday science topics with the goal of exploring something puzzling, rather than explaining it. In these conversations, children and adults are encouraged to draw on their everyday knowledge, make connections between different ideas, and seek causal explanations as they develop curiosity about how the world around them works.

Our poster
Our poster is designed to introduce *Curiosity Practices* to the ICLS community and receive feedback on both the design of the activity and the theories grounding it. We will do so with a poster that has two foci. On one side, we will define *curiosity*, and its theoretical potential for transforming *whether* our of *Curiosity Practices,* and the principles guiding our design.

References

Berland, L. K. (2011). Explaining Variation in How Classroom Communities Adapt the Practice of Scientific Argumentation. *Journal of the Learning Sciences*, *20*(4), 625–664.

Bishop, S. R., Lau, M., Shapiro, S., Carlson, L., Anderson, N. D., Carmody, J., … Devins, G. (2004). Mindfulness: A Proposed Operational Definition. *Clinical Psychology: Science and Practice*, *11*(3), 230–241. https://doi.org/10.1093/clipsy.bph077

Dawson, E. (2014). Equity in informal science education: developing an access and equity framework for science museums and science centres. *Studies in Science Education*, *50*(2), 209-247.

Hill, N. E., & Tyson, D. F. (2009). Parental involvement in middle school: a meta-analytic assessment of the strategies that promote achievement. *Developmental psychology*, *45*(3), 740.

Hensley, Randy B. 2004. Curiosity and creativity as attributes of information literacy. *Reference & User Services Quarterly.*, 44(1): 31–36.

Kahan, D. M., Jenkins-Smith, H., & Braman, D. (2011). Cultural cognition of scientific consensus. *Journal of Risk Research*, *14*(2), 147-174.

Mercier, H., & Sperber, D. (2011). Why do humans reason? Arguments for an argumentative theory. *Behavioral and Brain Sciences*, *34*(2), 57–74.

National Academies of Sciences, Engineering, and Medicine. (2016). *Science literacy: Concepts, contexts, and consequences*. National Academies Press.

National Research Council. (2009). *Learning science in informal environments: People, places, and pursuits*. Washington DC: National Academies Press.

The Assessment of Digital Reading Skills With Cognitive Diagnose for the Reading Achievement Test in China

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Abstract: Reading skills has been viewed as a multifaceted construction with multiple constituents. What has been invested of skills multiplicity has expanded on previous literature by including paper reading skills constructs (comprehension, interest, and engagement). Advances in digital technologies are dramatically altering the texts and as tools available to students. Yet with the diagnose assessment of the digital reading skill hasn't come issue that can be detected by the cognitive diagnostic assessment. The study has obtained pre and post-reading performance based on the digital reading, reading perception self-reports. DINA was used in the processing of reading assessment, and the diagnosis feedback report was designed to improve students' reading skill. Furthermore, implications for the diagnose framework of the Progress in International eReading Literacy Study (ePIRLS) were discussed.

Keywords: Digital reading, cognitive diagnosis, DINA, reading perception, ePIRLS

The study questions

Digital-text media as one of the reading approaches, has been optioned by the most readers. IEA has introduced ePIRLS, which was a forwarding thinking computer-based extension to PIRLS in 2016(PIRLS, 2016). Most reading assessment was based on the simple scores, understanding how well students' reading comprehension, interpreting, and critiquing the information. However, it lack of diagnostic report to help students improve their reading skills. The study was conducted that what the reading features students have, and assess reading skills by cognitive diagnostic model to provide the personal feedback report for students to improve their reading performance.

Objectives

This study has several objectives. First, we explore how reading skills fourth-graders in Shanghai primary school using cognitive diagnose processing. Second, we explore whether fourth-graders would improve reading skills through diagnose feedback. Comparison between the pre with post-reading test was conducted to confirm the impacts on digital reading skills.

Significance of the study

Based on the previous literatures, there were not many researches on the cognitive diagnosis of reading skill, but scores. This study is a significant part in assessment students digital reading skills from the cognitive diagnose of their reading performance. The cognitive diagnose model is likely to be adopted into a comprehensive, criticizing reading skills to better understand the picture of students digital reading. This study will help better understand the relationship between students' reading characteristics and their learning performance, and likely to diagnose the learners with poor reading skill so that timely pedagogical intervention can be implemented to improve the situation.

Methodological and data sources

The study is part of a learning analytics project to portray students' learning within a learning technology and assessment technology in Shanghai. A cognitive diagnostic model was employed, involving five classes of 143 students in a primary school. In addition, a complex algorithm (DINA) was proposed to classify the reading scores based on the skills attributes and the diagnose feedback analysis has been established to identify what variables of students' reading scores have significant impact on their reading skills. Finally, the study would provide the feedback to each student to improve their reading ability.

Major findings

According to the Q matrix and the student response matrix, the DINA model is estimated and fitted. The grasp mode of the subjects was also analyzed in this study. At last, the correlation analysis was made with the students' end-of-term Chinese performance.

According to ePIRLS2016, the title of this test has been identified with the corresponding attributes. The resulting of Q matrix was shown in table 3. A1 has been stands for 'direct extraction'; A2: 'reasoning and understanding'; A3: 'integration and interpretation'; A4: 'criticism and evaluation'.

It can be learned from the table that all four attributes '1111' of the subjects had a total number of 15 students, accounting for about 10.5%. There are 38 students, who have mastered the two attributes, accounting for 26.6%.

The highest proportion of attribute mastery pattern was '1110', with a total of 54 people, accounting for about 37.8% of the students. The students have not mastered "criticism and evaluation", and the other three attributes have been mastered. There are three kinds of mastery pattern '0001', '1001', '1101', which were in accordance with these three types of mastery patterns. It can be found that the proportion of the attribute of criticism and evaluation was the highest.

Conclusions and implications

This study is still on-going to detect reading behaviors furtherly. Thus far, the preliminary analysis of the collect data suggested that (1) the DINA model analysis has shown that the reading skill of 'direct extracting information' and, 'direct reasoning ability' maintained excellent. However, the ability of 'integration and interpretation' and, 'criticism and evaluation' need still improving. (2) The diagnosis of feedback report has intervened personalized reading skills promotion. (3) Digital reading skills can be assessed by DINA, and T-test between pre and post-test was statistical significant. The limitation of the study is the sample size which was only focused on the one grade. Furthermore, it is necessary to pay attention on the learning behaviors during students doing reading and, the follow-up study is needed to be improved.

References

Biancarosa, G., & Griffiths, G. G. (2012). Technology tools to support reading in the digital age. *The Future of Children, 22*(2), 139-160.

Bus, A. G., Verhallen, M. J. A. J., & de Jong, M. T. (2009). How onscreen storybooks contribute to early literacy. Multimedia and literacy development: Improving achievement for young learners, 153-167.

IEA. PIRLS 2016 Assessment Framework, 2nd Edition. (2016). http://timssandpirls.bc.edu/pirls2016/downloads/P16_Framework_2ndEd.pdf.

Korat, O. (2010). Reading electronic books as a support for vocabulary, story comprehension and word reading in kindergarten and first grade. *Computers & Education, 55*(1), 24-31.

Leu D J, Gregory McVerry J, Ian O'Byrne W, et al. (2011). The new literacies of online reading comprehension: Expanding the literacy and learning curriculum. *Journal of Adolescent & Adult Literacy, 55*(1): 5-14.

Translating Theory to Practice: Technology Solutions to Solve Practical Issues for Teaching Reading Comprehension at the Secondary Level

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Abstract: We describe a theory- and evidence-based curriculum that improves reading comprehension skills needed to learn from difficult informational text and the theory's translation into an online program that allows for individualized instruction for greater scalability in today's technology-enhanced classrooms. Feature design is based on cognitive science, user input/experiences, and a configuration of highly flexible web-applications to provide interactive features necessary to adapt a teacher-led curriculum into one that is automated and tied to student achievement.

Introduction

The overall goal of our theory-based curriculum, BRAVO, is to teach students how to understand and learn from challenging, informational texts (IES Award #R305A110467). This requires effortful processing. Skilled readers with rich background knowledge on the topic may rely on comfortable, automatic processing to get the meaning of text. However, average to struggling readers need to rely on conscious problem-solving skills to deeply comprehend and learn from the text. Providing simplified texts or even texts that are within a student's comfortable reading level may help initially pique interest and motivation, as Guthrie, Klauda, & Ho (2013) argue, but this approach can also encourage passive comprehension and create a false sense of understanding. Instead, students need experience with difficult, real-life materials and the tools to deal with them. This is what the BRAVO curriculum has been developed to provide for middle/high school students. An implementation efficacy study, conducted in traditional teacher-led classrooms, showed significant promise at improving reading comprehension skills for struggling and average readers. However, this study also demonstrated a need for more individualized instruction that can best be achieved via electronic means of delivery to capture individual needs for instruction and practice. This research and development program has generated several important questions and possible answers for designing a curriculum that both improves learning effectively and is designed with teacher input and student experiences, increasing the likelihood of broader adoption of the curriculum.

BRAVO Curriculum

The BRAVO curriculum is based on Kintsch's (1998) model, which posits that readers engage in parallel processing during reading to create a textbase and a situation model. The textbase represents the information presented directly in the text, whereas the situation model represents deeper connections between the textbase, the reader's topic knowledge, and inferences they generate that go beyond the text. Specifically, our curriculum methodically teaches students advanced reading skills that include local cohesive linguistic strategies such as anaphora; global cohesive techniques such as text structures, transition words, and bridging inferences to help readers build a reliable textbase as well as the inferencing, questioning, and use of organizational supports to integrate the textbase content into a situation model, the deepest level of processing. Instruction and exercise of these components of reading comprehension is made possible because the instruction is uniquely embedded into a series of texts designed to build knowledge in a subject domain, in this case Ecology. Furthermore, this curriculum aligns with the growing consensus among educational researchers about the need to embed comprehension instruction in content area classes (e.g., Guthrie et. al., 2013; Mckeown et al., 2009; Romance & Vitale, 2011). Heller and Greenleaf (2007) state that

> …policymakers and education leaders should make it clear that content area teachers do have the responsibility to provide instruction in the kinds of reading and writing that are specific to the given academic disciplines… (p. 25-26).

However, trying to convince practitioners to blend comprehension instruction with content learning is a major obstacle, especially since many science teachers emphasize a hands-on approach to science education (e.g., observation, doing experiments, recording, analyzing, and presenting results—usually orally). Norris and

Phillips (2003) point out that although these instructional methods are all important for achieving scientific literacy, this approach often comes at the expense of textbased learning and communication of abstract concepts and theories. As a result, many students are severely unprepared for further academic training and/or professional careers (cf. Sullivan, 2016). An important aspect of scientific literacy is the ability to communicate with broader audiences through writing, and to read and evaluate what others have contributed on a topic of interest. Thus, reading skills are as crucial to science domains as they are to literature, history and social science expertise. The bottom line is that students need a lot more practice in reading and learning from complex materials, well before they fill out their college applications.

Practical barriers to implementation and scaling

Our initial findings and motivation for this project indicate that while this theory-based curriculum can be efficacious, there are practical issues that can only be addressed through technology and personalized learning. These practical issues include: 1. Reading teachers' discomfort with topics other than stories/literature. 2. Variability in secondary students in their reading comprehension skills from needing little guidance to needing extensive instruction and practice. The complete language arts curriculum for a struggling reader would slow down a general education content area class (e.g. science) to an unacceptable level. 3. Content area teachers are often not trained, evaluated, or comfortable teaching language arts in their class.

eBRAVO Web Application

The eBRAVO project addresses these issues with individualized instruction; practice and online instructional support is the driver of our continuing development and the focus of this poster (IES Award #R305A170142). The direction for this work comes from classroom implementation of BRAVO in Colorado and California at the middle school level, as well as qualitative analysis of teacher focus groups and workshops. We outline what teachers say they want regarding useful technology and literacy instruction; what they do and do not already do in their classrooms; how that aligns with what is still needed; and our strategy for integrating this information into a highly usable and effective learning tool for use in today's secondary classrooms.

Moving beyond the traditional classroom implementation of the BRAVO curriculum, eBRAVO relies on a web application to provide an adaptive, *personalized learning experience* to aid learners in reading comprehension while providing specific domain knowledge in a (STEM) subject area such as ecology. As such, the software must be flexible to support a number of varying workflows, be able to deliver a variety of content, be able to adapt its presentation and pacing based on inputs from the learner, and provide timely feedback and reporting to students and teachers.

Summary

This poster will illustrate the alignment of the teacher/student-centered needs with the technology design to individualize instruction, transforming this traditionally teacher-led, 8-week reading comprehension curriculum, into an online tutoring system and finally to online assistive technology for use in content area classrooms.

References

Guthrie, J. T., Klauda, S. L., & Ho, A. N. (2013). Modeling the relationships among reading instruction, motivation, engagement, and achievement for adolescents. *Reading Research Quarterly*, *48*(1), 9-26.

Heller, R., & Greenleaf, C. L. (2007). *Literacy instruction in the content areas: Getting to the core of middle and high school improvement*. Retrieved from the Alliance for Excellent Education website http://all4ed.org/wp-content/uploads/2007/06/LitCon.pdf

Kintsch, W. (1998). *Comprehension: A paradigm for cognition*. Cambridge; New York, NY, USA: Cambridge University Press.

McKeown, M. G., Beck, I. L., & Blake, R. G. (2009). Rethinking reading comprehension instruction: A comparison of instruction for strategies and content approaches. *Reading Research Quarterly*, *44*(3), 218-253.

Norris, S. P., & Phillips, L. M. (2003). How literacy in its fundamental sense is central to scientific literacy. *Science Education*, *17*(2), 224-240.

Romance, N. R., & Vitale, M. R. (2011). An Integrated Interdisciplinary Model for Accelerating Student Achievement in Science and Reading Comprehension across Grades 3-8: Implications for Research and Practice. *Society for Research on Educational Effectiveness*.

Sullivan, P. (2016). An open letter to high school students about reading. *Academe*, 102 (3). Retrieved from https://www.aaup.org/article/open-letter-high-school-students-about-reading#.V-BDkDW6NA5

Student Learning of Computational Thinking in a Robotics Curriculum: Transferrable Skills and Relevant Factors

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Abstract: This poster presents findings from the implementation of a robotics curriculum emphasizing applying computational thinking (CT) to solve both programming and everyday reasoning problems. Utilizing an online CT instrument as the pre-and-post measure, students' performance, improvement, and process data were analyzed. Results show that the curriculum helped students improve CT in both scenarios. While student self-determination was positively correlated to their score gains, other factors (gender, class, familiarity with problem settings) were not.

Introduction

Since Papert (1980) coined the term computational thinking (CT), it has gradually gained its momentum as an important learning goal. Wing (2006) made it clear that CT should be considered as a foundational skill students need to develop in and out of schools. However, scholars have yet to achieve a widely acknowledged definition; different explanations on what CT entails were proposed (Barr & Stephenson, 2011; Grover & Pea, 2013). Most of these interpretations framed CT in a problem-solving process and emphasized its power to transfer across tasks and domains (Wing, 2006; CSTA, 2011). Current practices of teaching CT in programming contexts have difficulty in preparing students to transfer problem-solving skills to other non-programming contexts. Moreover, it is difficult to assess CT gain for younger students with minimum prior programming experience.

In order to fill these gaps, we developed a robotics programming curriculum with an emphasis on CT as applicable to everyday settings together with an instrument in accordance with this connotation. We hope that by completing our robotics curriculum, students gain knowledge and skills that could be applied to solving not only programming but also everyday-reasoning problems. We are also interested in if certain student knowledge and characteristics (such as their familiarity with certain problem contexts) factor into their initial performance and learning gains. Two research questions guided our study: (1) Does the robotics programming curriculum improve students' CT in both programming and everyday reasoning contexts? (2) What student characteristics are relevant in explaining their initial performance and learning gains?

Methods and results

Based on experience gained from two pilot runs, we finalized a robotics curriculum for upper elementary school students using an autonomous, programmable humanoid robot platform NAO, with emphasis on both robot basics and application of learned concepts to solve everyday reasoning problems. The curriculum was implemented in a Title I elementary school in southeast United States. All the fifth grade classes (6 classes; 125 students) adopted the curriculum. Each class spent about two hours each day on the curriculum for 5 consecutive days.

Based on our framework of CT (Chen et al., 2017) adapted from the CSTA (2011) definition, our current online CT assessment could record students' answers to and actions with items. It has two types of scenario: robotics programming (programming a robotic arm to draw and a robot to move) and everyday reasoning (cooking, booking flight tickets, and doing laundry). The same assessment was used as the pre-and-posttest for this study. Students' familiarity of everyday settings involved in the assessment was asked in the pretest. And they were asked to complete a science motivation questionnaire adapted from Glynn et al. (2011) in the posttest. The assessment took students about 30-60 minutest to finish. In total 107 completed responses of both pre-and-posttest were analyzed.

In order to answer the first research question, paired t-test was used to calculate the statistical significance of learning gain. Results ($t(106)=-5.15$, $p=0.0000$, $d=0.24$) revealed that students did statistically significantly better, with low to medium effect sizes, in posttest than pretest. Moreover, they gained more in everyday reasoning items ($t(106)=-4.97$, $p=0.0000$, $d=0.36$) than programming items ($t(106)=-3.60$, $p=0.0002$, $d=0.18$). Also, fine-grained process data can provide insight into better understanding of student application of CT in problem solving. For example, some students' score gain from pretest to posttest could be validated and score lose explained. And calculation of problem solving time based on action timestamps revealed that whereas score increase might be due to students' improved CT skills that enabled them to spend more time in solving

this item, score decrease seemed to be caused by students' unwillingness to spend enough time in posttest. Their reluctance might be directly related to the boringness of writing lines of code.

To answer the second research question, two-sample t-test was used to test the gender differences in pretest and score gain. Neither a statistically significant difference was found between male and female students in pretest (t=-0.17, df=103.72, p=0.86), nor in score gain (t=-1.13, df=102.51, p=0.26). This indicates that gender did not have an effect on students' initial performance and gains after this curriculum. In addition, appropriate correlations were calculated to examine the possible relationship between student familiarity with everyday reasoning and programming settings and their pretest performance and gains. These results show that students' familiarity with and experience in both everyday scenario and programming settings did not associate significantly with their pretest performance and gains from pretest to posttest. Also, only self-determination is significantly and positively correlated with score gain (r=0.197, t(105)=2.06, p=0.041). One-way ANOVA was used to test class differences and their relationship with student pretest score and gains. The results show statistically significant difference among classes in terms of pretest score (F(5,101)=9.079, p=0.000). However, no significant difference was found for score gains among the six classes (F(5,101)=1.446, p=0.214). This result shows that although the students from different classes started with different pretest performance, they gained similarly from the curriculum.

Conclusion

This study summarized our effort to evaluate student progress in acquiring CT skills from participating in our robotics programming curriculum. The results showed that students benefited from the curriculum in solving both programming and everyday reasoning items as well as relevant student features in determining their initial performance and CT gain as indicated by their pre-and-posttest scores. This study also revealed the potential of using logged data to understand students' application of CT in problem-solving process toward a better understanding of their learning gain.

References

Barr, V., & Stephenson, C. (2011). Bringing computational thinking to K-12: what is Involved and what is the role of the computer science education community?. *Acm Inroads*, *2*(1), 48-54.

Chen, G., Shen, J., Barth-Cohen, L., Jiang, S., Huang, X., & Eltoukhy, M. (2017). Assessing elementary students' computational thinking in everyday reasoning and robotics programming. *Computers & Education*, *109*, 162-175.

CSTA (2011). Operational Definition of Computational Thinking for K–12 Education, 2011. Accessed from https://c.ymcdn.com/sites/www.csteachers.org/resource/resmgr/CompThinkingFlyer.pdf

Glynn, S. M., Brickman, P., Armstrong, N., & Taasoobshirazi, G. (2011). Science motivation questionnaire II: Validation with science majors and nonscience majors. *Journal of research in science teaching*, *48*(10), 1159-1176.

Grover, S., & Pea, R. (2013). Computational thinking in K–12: A review of the state of the field. *Educational Researcher*, *42*(1), 38-43.

Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas*. Basic Books, Inc.

Wing, J. M. (2006). Computational thinking. *Communications of the ACM*, *49*(3), 33-35.

Acknowledgements

The Challenge of Working With the Future Within STEM Education

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Abstract: Global crises and societal uncertainty mean that youth perceive the future no longer as a promise but as a threat, and have difficulty projecting themselves into the future. Future studies and action competence pedagogies partly inform our EU-funded strategic partnership to develop teaching strategies and materials that build future-scaffolding skills. The first teaching module on climate was implemented in June 2017 in Italy, with 24 Finnish, Icelandic and Italian upper secondary school students and their teachers. Qualitative data were analysed to shed light on how the module impacted on students' attitudes toward present and future.

Introduction

In post-modern societies, where social acceleration is a source of anxiety and frenetic standstill (Rosa, 2013), the young generation struggles to project themselves into the future and to develop scope as future professionals. Whereas for past generations science and technology were seen as positive possibilities for addressing challenges, now students perceive them as sources themselves of fears (Eurobarometer, 2015). In the face of such a changing world, what possibilities does STEM education offer for enabling young people to live their present in order to create their own future?

Although the interdisciplinary field of *futures studies* has been investigating this problem from a wide perspective, the inclusion of such perspectives within school science curricula is rather rare (for an interesting exception, see Paige and Lloyd, 2016). The notion of agency as a goal of education presents another pedagogical response to the complex challenges of the future, emphasising the ability to take enlightened decisions and actions as individuals and communities (Mogensen & Schnack, 2010). Agency and action competence are relevant to STEM education if students are to be able to overcome fear of the future and instead define their roles and ways forward through socio-scientific issues (Roth & Lee, 2004).

Our recent EU project I SEE (https://iseeproject.eu) studies the potential of *future studies* and action competence pedagogies within STEM education to support students in projecting themselves into the future as agents and active citizens.

Project, goal and methods

The project is formed by a strategic partnership among three secondary schools, two universities, an environmental NGO, a teachers' association and a private foundation coming from four European countries (Italy, Finland, Iceland and the United Kingdom). The project designs innovative approaches and teaching modules on cross-cutting and societally relevant fields to address the above-mentioned concerns. We have defined specific *future-scaffolding skills* (Levrini, Tasquier & Branchetti, *under review*) that should be developed through science education to render it personally, socially, professionally and scientifically relevant and enhance students' capacity to envisage themselves as agents of change and push their imagination towards future careers in STEM. Modules build on the action competence approach combined with the idea of *exposure,* i.e. to be able to choose an alternative future and become an agent of it, an individual has to be exposed to it. The first module, focusing on climate change, was implemented in June 2017 in Bologna, Italy, with a culturally diverse group of 24 Finnish, Icelandic and Italian upper secondary school students and their teachers.

The module implementation was monitored and analysed to answer this research question: *How did the module impact students' attitudes toward present and future?* During the whole implementation, specific tools were designed to collect mainly qualitative data. At this level, we analysed focus group discussions and individual interviews, the aim of which was to let the students express themselves about their overall experience of the module. Data were analysed through an iterative process that came up with a bottom-up de-briefing phase, conceived for identifying the emergent aspects in the data and generate first interpretative ideas.

Preliminary results

By analysing students' discourses during the focus groups and the interviews, we identified three main themes: i) future and agency; ii) cultural insights; and iii) STEM careers. The themes have been pointed out by highlighting students' sentences and grouping them.

With respect to the first theme, students' initial views confirmed the trends pointed out by the Eurobarometer report (2015) and showed a widespread feeling of negativity as well as a tendency to remove the future from their personal horizon because it is too fear-inducing. Indeed, they revealed a tendency to look to the future with pessimism and saw little hope for being able to do something about either their future or present, mainly citing a sense of negativity conveyed by the media. During the interviews, they declared to be aware that their positions deeply changed and became more positive. As evidenced by their words, they: a) became more confident in themselves and in their ability to manage difficult situations, b) acquired a sense of security in the sense of widening their perspectives and developing new ways of thinking, and c) saw the future within their reach and found ways to see themselves as agents and actors of their own future.

With respect to the second theme, the cultural issue appeared to be a constant reference for the students. They revealed that meeting with different cultures gave them something beyond conceptual knowledge, that is, an awareness of others' lifestyles, approaches, ways of reasoning, environmental cultures, etc., but that all the cultures present were still dealing with the same problems. What emerged with a strong emphasis from all students from the three different countries is the great opportunity they had to share values and desires to act together for changing the world internationally.

The third theme regarding STEM careers particularly referred to the students coming from one of the countries. Thanks to their experience with the first module, the students could see new kinds of professions; they saw jobs that they had never imagined before and, in this sense, they saw the possibility to create their own job in the future – not necessarily a conventional or existing one.

Conclusion

The students' reactions that emerged from the focus groups and the individual interviews imply that the activities of the module had a positive impact on students' perception of the future and sense of agency, on the personal experience of cultural diversities as well as on the capability to imagine future careers. To understand how the module brought about these outcomes, we have started a detailed analysis of students' discourse in the audio-recordings. We have already recognised systematic shifts and reactions within their discourse and perceived some new vocabulary that became part of their way of thinking about future. The results of this analysis will provide means to connect the outcomes to the *future-scaffolding skills* which were taught in the module. According to the preliminary analysis, many students abandoned their fear-inducing deterministic future views and started to talk about *future scenarios*, referring to a variety of possible, probable, plausible and desirable futures. They also showed vocabulary pertaining to *complex systems* and reasoned in terms of *circular causality*. Such findings from the discourse analysis help us understand which *future-scaffolding skills* were learned during the module and how they may contribute to students' thinking.

References

Eurobarometer (2015). Public opinion on future innovations, science and technology. *National report Italy, Eurobarometer Qualitative Study*, June 2015.

Levrini, O., Tasquier, G., Branchetti, L. (under review). Developing future-scaffolding skills through Science Education. Submitted to *International Journal of Science Education.*

Mogensen, F., & Schnack, K. (2010). The action competence approach and the 'new' discourses of education for sustainable development, competence and quality criteria. *Environmental Education Research*, 16*(1)*, 59-74.

Paige, K., & Lloyd, D. (2016). Use of Future Scenarios as a Pedagogical Approach for Science Teacher Education. *Research in Science Education* (1-23).

Rosa H. (2013). *Beschleunigung und Entfremdung - Entwurf einer kritischen Theorie spätmoderner Zeitlichkeit, Suhrkamp (*Eng. Trans: *Acceleration and Alienation - Towards a Critical Theory of Late-Modern Temporality*, 2015).

Roth, W.M., & Lee, S. (2004). Science education as/for participation in the community. *Science Education*, 88, 263-291.

The Role of Instructional Goal Setting for Teaching Computational Thinking in Robotics Classrooms

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Abstract: Robotics curricula offer rich, applied opportunities to learn computational thinking. However, these opportunities are likely to vary, as educators adapt curricula to their learning environments. A comparative case study approach is used to examine how two middle school Technology Education teachers conceptualize and articulate instructional goals when incorporating a novel computer science curriculum in their robotics classrooms. Evidence suggests tacit differences in teacher's framing of instructional goals around computational thinking, with implications for curricular design.

Computer science education is now widely considered to be an integral part of a well-rounded science, technology, engineering and mathematics (STEM) education. In the United States, the fastest growing careers are likely to require some degree of computational literacy, and the ability to use computers and programming logic to solve problems in a variety of applications. Researchers have used the term computational thinking to describe this particular 21st century skill, as "an approach to problem solving in a way that can be solved by a computer...a problem solving methodology that can be transferred and applied across subjects" (Barr & Stephenson, 2011). However, still relatively little is known about particular pedagogical practices that might be linked to effective instruction in this class of generalizable computational skills.

Robotics education is one field that has been studied by educational psychologists as learning environments that could provide authentic opportunities to learn generalizable computational skills in an applied setting (Grover & Pea, 2013). In the last few decades, robotics programs have become nearly ubiquitous in primary and secondary schools in the United States, both as elective after-school programs and recently within general education classrooms. Many of these technology-rich programs are situated in Technology Education ("Tech Ed") departments, which have historically focused on vocational training in specific and often localized industrial technologies, and are taught by teachers with varied training and experience in computer programming (Shields & Harris, 2007). Therefore, there is likely to be large variance in the particular focus and pedagogical approach to teaching computational thinking across robotics programs, as well as in learning outcomes for students.

Theoretical framework

Research has shown that teacher beliefs about pedagogy and content interact with curriculum to determine ways that materials are implemented, often creating disparities between the curriculum as designed and curriculum as enacted (Remillard, 2005). Instructional goal setting provides one useful framework for predicting how teachers activate resources in ways that differ from the intent of the designed curriculum (Stein & Meikle, 2017). Goals that are explicitly stated and refined into sub-goals at the lesson planning stage may improve the design of instructional activities that increase student achievement (Hiebert, Morris, & Spitzer, 2017). However, in complex and ill-defined learning environments like Tech Ed classrooms, it is likely that teachers hold multiple goals simultaneously, arranged in hierarchical systems that determine which goals are activated in certain situations (Davis, Janssen, & Van Driel, 2016; see Figure 1). In this framework, *horizontal incoherence* represents directly competing goals, which can lead to disparities in enacted curriculum as teachers prioritize one goal over another. *Vertical incoherence* arises when the pedagogical skills to plan and enact lesson activities aligned with higher level goals are unavailable, or not activated during a particular lesson.

Methods

This study employs a comparison case study design to examine the following research questions: 1) How do robotics teachers conceptualize and articulate computational thinking goals, particularly in a Tech Ed setting? 2) How do instructional goals play out in teachers' enactment of curriculum, through planning and classroom interactions?

Interviews and classroom observations were conducted with two in-service Technology Education teachers who were teaching an online, problem-based robotics curriculum that emphasizes computational thinking concepts. These teachers were purposively selected for analysis as their classroom observations and interviews revealed interesting contrastive cases of instructional goal setting, despite the overall similarity in their years of teaching experience, student populations, and content. In addition to classroom observations, teachers were asked to complete brief goal setting sheets during their planning period prior to each class. Data were analyzed using a

grounded theory approach, including iterative qualitative coding, and a constant comparison technique to identify themes across cases.
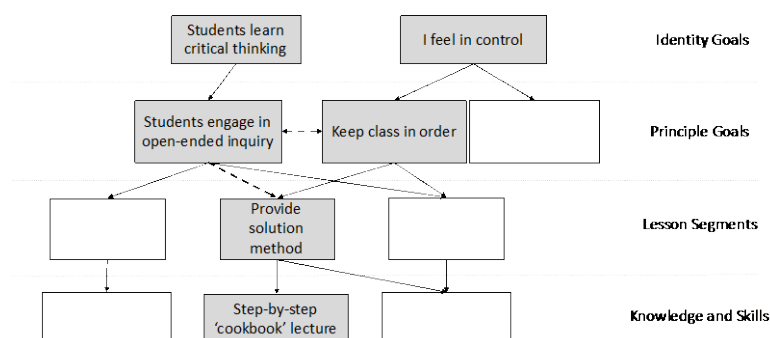
Figure 1. A sample hierarchical goal system, adapted from Davis, et al., 2016. Dotted arrows at the same level represent *horizontal incoherence*; dotted arrow across levels represent *vertical incoherence*.

Preliminary findings and implications

Overall, while both teachers initially expressed similar high-level instructional goals for their students, differences appeared in their enactment at the lesson planning stage, and during individual instructional interactions. For example, both teachers identify "using technology to solve problems" as a high-level goal. However, analyses of planning documents and classroom observation suggest different conceptualizations of the role of computational thinking in solving problems with technology: as either a specific and explicit set of skills learned separately from the technological content, or as more general, implicit problem-solving heuristics acquired through hands-on experiences with technology, and extensive trial and error. In a hierarchical goal system, these different conceptualizations of computational thinking may relate to the level of *vertical* and/or *horizontal incoherence* between computational thinking goals embedded in the curriculum, and competing instructional goals held by Tech Ed robotics teachers.

Further analyses using this approach could inform the design of curriculum that acknowledges and incorporates teachers instructional goal systems in educative materials, as well as have implications for the content of professional development in computational thinking for robotics teachers. It is also likely that unobserved, external barriers influenced how our case study teachers interpreted and implemented the curriculum. Future work that incorporates an organizational perspective could help account for these broader influences on teacher implementation.

References

Barr, V., & Stephenson, C. (2011). Bringing Computational Thinking to K-12: What is Involved and What is the Role of the Computer Science Education Community? *ACM Inroads*, *2*(1), 48–54. http://doi.org/10.1145/1929887.1929905

Davis, E. A., Janssen, F. J. J. M., & Van Driel, J. H. (2016). Teachers and science curriculum materials: where we are and where we need to go. *Studies in Science Education*, *7267*(May), 1–34. http://doi.org/10.1080/03057267.2016.1161701

Grover, S., & Pea, R. (2013). Computational Thinking in K-12: A Review of the State of the Field. *Educational Researcher*, *42*(1), 38–43. http://doi.org/10.3102/0013189X12463051

Hiebert, J., Morris, A. K., & Spitzer, S. M. (2017). Diagnosing Learning Goals: An Often-Overlooked Teaching Competency. In T. Lueders, K. Philipp, & J. Lueders (Eds.), *Diagnostic Competence of Mathematics Teachers* (11th ed., pp. 193–206). Cham, Switzerland: Springer International. http://doi.org/10.1007/978-3-319-66327-2

Remillard, J. T. (2005). Examining Key Concepts in Research on Teachers' Use of Mathematics Curricula. *Review of Educational Research*, *75*(2), 211–246. http://doi.org/10.3102/00346543075002211

Shields, C. J., & Harris, K. (2007). Technology Education : Three Reasons Stereotypes Persist. *Journal of STEM Teacher Education*, *44*(2), 60–72.

Stein, M. K., & Meikle, E. (2017). The nature and role of goals in mathematics education. In D. Spangler & J. Wanko (Eds.), *Research companion to principles to action* (pp. 1–11). Reston, VA: National Council of Teachers of Mathematics. http://doi.org/10.1007/978-3-319-31450-1

Concrete Definition of Beneficial Collaborative Dialogues

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Abstract: Collaborative learning is often superior to individual learning, but not consistently so. To understand why not, we applied the ICAP theory of cognitive engagement to define and operationalize various collaborative dialogue patterns and identified the co-generative pattern as the optimal one for maximizing learning. We used the definitions to code dialogues from data collected in our prior studies and show that dyads with higher co-generative scores learned more than dyads with lower co-generative scores. This suggests that collaborative learning is more effective if a certain dialogue pattern occurs.

Interacting with a peer through dialogues often promotes greater learning than learning alone (Dillenbourg, Baker, Blaye, & O'Malley, 1995; Perret-Clermont, Perret, & Bell, 1991), but not always (e.g., Barron, 2003). Although numerous reasons have been proposed over the last few decades for why collaboration is beneficial for learning (such as that learning is necessarily a social process, collaboration involves opportunities to resolve conflicts, etc.), few efforts have attempted to understand why collaborative learning sometimes fails to exceed the benefit of learning individually. We propose that specifying concrete operational definitions for dialogue patterns may explain when collaborative learning is not always beneficial. Concrete definitions may also pave the way for practitioners (e.g. teachers & instructors) to know how to enable and foster better collaborative learning.

The ICAP Theory

The collaborative dialogue pattern that is optimal for learning can be defined by applying the ICAP theory of cognitive engagement (Chi, 2009). ICAP classifies how students engage with instructional materials into four modes of activities: Students can *pay attention* to instruction and receive instructional information but do nothing else with it (e.g., just listen to a lecture, or watch a video, or read a text). By not manipulating or producing anything else with the instructional materials, this can be labeled the *Passive* mode of engagement. Alternatively, students can *manipulate* the instructional materials in some ways, such as underlining some of the text sentences or copying notes from a power point lecture, without incorporating any additional information. This is labeled the *Active* mode of engagement. Students can also engage in the *Constructive* mode, which is to *generate* information beyond the information provided in the instructional materials. For example, instead of copying the content of a teacher's power point slides, a student can *generate* additional information that was not provided in the power point slides, such as justification for a solution step to a problem, or posing a question about the solution step. Finally, students can engage with learning materials with a peer, and each peer can not only *generate* information beyond what was presented in the learning materials, but each peer can generate information by addressing and extending the partner's contributions, thus engaging in a *co-generative* way in the *Interactive* mode. Basically, the mode in which a student engages can be determined operationally simply by comparing the student's contributions (e.g. outputs or products) with the content materials provided in the instruction. So for the four modes, students' contributions are either: none *(attentive/Passive),* similar in content *(manipulative/Active),* in addition to content *(generative/Constructive),* or extend beyond content and partner's contributions *(co-generative/Interactive).*

ICAP posits that the mode in which students engage with instructional materials determines how much they learn or how deeply they learn. The *Interactive/co-generative* mode is the best, followed next by the *Constructive/generative* mode, then the *Active/manipulative* mode, and finally the *Passive/attentive* mode which is the least effective for learning. Thus, the order is I>C>A>P. This hypothesis about the amount or depth of learning as a function of engagement mode arises from the cognitive processes underlying each mode of activity. For example, being *generative/Constructive* means that students are making inferences, whereas being *manipulative/Active* means that students are merely activating prior knowledge and storing new information, but not generating many inferences. The predictions of the hypothesis are supported by hundreds of studies in the literature (Chi & Wylie, 2014).

Applying ICAP to define collaborative dialogues

The definitions of the four I, C, A, P modes can be applied to collaborative dialogues to determine the mode in which each partner of a collaborative dyad contributes. For example, the speaker is simply *paying attention/Passive* if her contribution is "Uh huh" or "ok". However, if the speaker responds to her partner's contribution with a paraphrase, a repetition, or an agreement type of response, then the speaker is contributing in a *manipulative/Active* way because the speaker is not providing any additional information. On the other hand, if

the speaker contributes an idea that differs from what was said before but does not extend the partner's contribution, then the speaker is responding in a *generative/Constructive* way. Finally, if the speaker responds by generating ideas that extend and build on the partner's contribution, then the speaker is being *co-generative/Interactive.* Thus, there are a variety of dialogue patterns, based on how each speaker contributes, such as both partners can be *Active,* or one partner is *Constructive* and the other partner is *Active* or *Passive,* or partners can both be *Constructive* in parallel, building on their own thinking but not building on the partner's thinking, or they can both be truly *Interactive/co-generative* in that they each build upon and extend their partner's thinking. There are potentially at minimum nine dialogue patterns, assuming partners cannot both be *Passive-Passive.* Our claim is that only one dialogue pattern, the *co-generative* one, can ensure that the benefit of collaborative learning exceeds learning individually.

Using data collected in Menekse, Stump, Krause, and Chi (2013), we coded multi-turn episodes of dialogues in answering each question from 24 pairs of college engineering students. Co-generative dialogue patterns received a score of 3; dialogue patterns in which only one partner was generative and the other partner was manipulative received a score of 2; and if the participants were both manipulative, or manipulative-attentive, or generative-attentive, then the dialogue pattern received a score of 1. The result of our coding showed that the six pairs with the highest interaction scores learned significantly better than the six pairs with the lowest interaction scores, based on an ANCOVA comparing post-test scores while controlling for pre-test scores, $F(1, 11) = 18.30$, $p < .01$. A similar analysis was carried out for data collected in another study (Muldner, Lam, & Chi, 2014), in which 40 undergraduates worked in pairs to complete a diffusion worksheet while watching instructional videos. The dialogues were coded in the same way. We again found that the six higher scored pairs had significantly greater learning gains than the six lower scored pairs, comparing adjusted post-test scores, $F(1, 11) = 5.31$, $p = .05$. Figure 1 plots the results from both studies, showing the same pattern of significantly higher learning gains when students collaborate in a co-generative way.

Conclusion

Applying ICAP's definition of modes of engagement to define interactive dialogue patterns allows us to operationally specify which dialogue pattern is optimal for collaborative learning. Our definition and coding results suggest that collaborative learning can exceed individual learning when dyads interact in a mutually-and-reciprocally co-generative way.
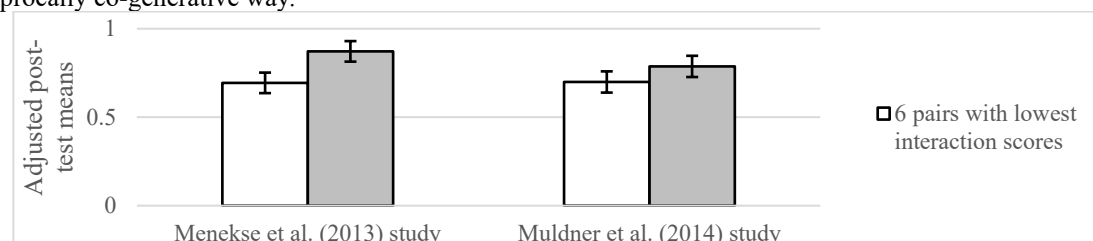
Figure 1. Adjusted post-test means of data coded from two separate studies. Error bars represent +/- 2 SE.

References

Barron, B. (2003). When smart groups fail. *The Journal of the Learning Sciences, 12*(3), 307-359.

Chi, M.T.H. (2009). Active-constructive-interactive: A conceptual framework for differentiating learning activities. *Topics in Cognitive Science, 1*, 73-105.

Chi, M.T.H., & Wylie, R. (2014). The ICAP framework: Linking cognitive engagement to active learning outcomes. *Educational Psychologist, 49*, 219-243.

Dillenbourg, P., Baker, M., Blaye, A., & O'Malley, C. (1996). The evolution of research on collaborative learning. In E. Spada & P. Reiman (Eds.), *Learning in humans and machine: Towards an interdisciplinary learning science* (pp. 189-211). Oxford, UK: Elsevier.

Menekse, M., Stump, G., Krause, S. & Chi, M.T.H. (2013). Differentiated overt learning activities for effective instruction in engineering classrooms. *Journal of Engineering Education, 102*, 346-374.

Muldner, K., Lam, R., & Chi, M.T.H. (2013). Comparing learning from observing and from human tutoring. *Journal of Educational Psychology, 106*, 69-85.

Perret-Clermont, A. N., Peret, J. F., & Bell, N. (1991). The social construction of meaning and cognitive activity in elementary school children. In L. B. Resnick, J. M. Leving, & S. D. Teasley (Eds.), *Perspectives on socially-shared cognition* (pp. 41-62). Washington, DC: American Psychological Association.

Acknowledgements

Concepts Before Coding: The Impact of Classroom Culture and Activity Design on Student Engagement With Computer Science Concepts

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Abstract: We developed a computer science curriculum, VELA, which provides non-programming activities for middle school students to learn variables, expressions, loops, and abstraction. Ongoing teacher and student case study research focuses on how sociocultural aspects of instruction help students productively engage with these concepts. We find that traditional classroom practices challenge students' engagement. We discuss the ramifications for VELA activity design and for policies around implementing effective computer science programs.

Introduction

In this poster, we present a sociocultural examination of how classroom features influence middle school students' engagement with non-programming activities designed for learning computer science (CS) concepts. We designed activities for students to build conceptual understanding before programming in block-based environments. We conducted case studies of teachers and students in three urban classrooms to document roles, expectations, values, and practices in the curricular structure and social organization of the classroom.

Block-based languages such as Scratch typically introduce learners to CS. But without proper guidance, students don't always understand how moving around programming blocks on the screen relates to CS concepts. We designed a curriculum, VELA, for middle school students to learn four key CS concepts: variables, expressions, loops, and abstraction. The VELA activities help students become familiar with and use these concepts in non-programming contexts (digital or unplugged) before they encounter them in a Scratch programming environment. For example, we treat variables and expressions as dynamic quantities or values that can change over time, and provide students with both digital and unplugged scenarios for applying these ideas. Details of VELA can be found in (Grover et al, 2018).

Theoretical background

Students often struggle with essential CS concepts, for example with variables in their efforts to use mathematical expressions and loops to solve more complex problems with appropriate abstraction techniques. While visualization tools help debugging code, understanding control flow and program state, they do not always help learners grasp how variables, expressions, and loops mutually interact to computationally solve a problem (Grover, Pea, & Cooper, 2015). VELA draws specifically on interactive dynamic representations in math to support these skills (Jackiw, 2009, 1991).

Dynamic representations derive from a constructivist model of learning focused on cognitive aspects. But learning involves both individual construction of knowledge and the sociocultural processes students partake in (Cobb & Yackel, 1996). Can students abstract CS knowledge and transfer that knowledge to block-based programming? Similar questions have been addressed in the literatures on situated cognition (Brown, Collins, & Duguid, 1989) and situated learning (Lave & Wenger, 1991). Learning happens within a sociocultural context. Students' understanding of their roles, the expectations from the teacher and the environment, the values communicated through the teacher and the overall structure, and the nature of the classroom practices influence how students approach content, interpret it, and organize it with existing knowledge structures.

Methods

The VELA curriculum was a 3-week unit embedded in a 9-week CS curriculum implemented in an urban school district. We conducted case study research of teachers and students. For four students in each of three classrooms, we collected VELA assessment outcomes and district demographic data, interviewed students twice, observed students in the classroom six times or more, and interviewed teachers about students. We observed teachers 7-8 times, interviewed teachers twice, and conducted group discussions with teachers.

We developed semi-structured interview protocols for teachers and student interviews. For classroom observations, we developed structured observation memos. The observations captured students' interactions with

the VELA activities, engagement with teacher and peers in whole class discussions, student collaboration, teacher talk and actions during lecture, whole class discussion, and teacher support to individual students and groups.

The VELA paper-pencil assessment targeted the CS concepts, and was designed using a principled assessment design framework with teacher feedback, student cognitive thinkalouds, and language review by an ELL expert. Question types included multiple-choice, open response, and the use of snippets of Scratch code.

Findings

All three classrooms gained significantly on the VELA pre-post assessment. The VELA activities engaged students productively with the CS concepts, in particular with variables, expressions, and loops. But students struggled with abstraction and Boolean variables and expressions. In interviews, students were mostly able to define variables, expressions, and loops, but less able to describe their applications. We believe traditional instruction and time constraints limited the depth of students' engagement with the activities and the concepts.

VELA encourages student roles such as collaborator, problem solver, and explorer. Students are expected to struggle with ideas and explore them in different ways. Play, making mistakes, creativity, and critical thinking are valued. Students have opportunities to collaborate with peers and participate in whole class discussions to problem solve together and have their own thinking and prior learning articulated and challenged.

The sociocultural environment of the classrooms differed. Teachers retained traditional roles of classroom managers. Student collaboration, problem solving, and exploration were limited by physical, temporal, and task boundaries defined by teachers. Teachers verbally encouraged collaboration, problem solving, creativity, and the importance of making mistakes, but actual practices often did not support them. Collaboration was limited and superficial. In whole class discussions, two teachers asked procedural and funneling questions. One teacher asked more open-ended and probing questions but did not facilitate conversations that built on student's ideas.

Teachers' negotiations of the constraints of the traditional classroom and the potentials for deeper engagement in the VELA curriculum turned on issues of time and the need to move the entire class along a common trajectory. The teacher in the high achieving class in a high achieving school noted that while differentiation is a big topic in the district, it rarely gets meaningfully addressed. She also said that while students were highly engaged with VELA, they lacked time to think deeply about the concepts; to return to the ideas, solidify them, calibrate misunderstandings, and build deeper understanding over time.

Conclusion and next steps

Policy and education leaders see computational thinking as necessary for all citizens. Our research makes a unique contribution to broaden participation in computing through engaging activities aimed at deeper conceptual engagement with CS concepts. Consistent with literature on education reform, our findings highlight the tension between efforts to support conceptual learning within the limits of an established system. We believe our work-in-progress research provides an important perspective on these issues through rich descriptions of teachers' negotiations of roles, beliefs, and practical constraints in their efforts to teach CS concepts.

References

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. Educational Researcher, 18(1), 32-42. Cobb, P., & Yackel, E. (1996). Constructivist, emergent, and sociocultural perspectives in the context of developmental research. *Educational Psychologist, 31*(3-4), 175-190.

Grover, S., Pea, R., Cooper, S. (2015). Designing for Deeper Learning in a Blended Computer Science Course for Middle School Students. *Computer Science Education, 25*(2), 199-237.

Grover, S., Jackiw, N., Lundh, P. (2018). Combining Non-Programming Activities with Programming for Introducing Foundational Computing Concepts. In *Proceedings of ICLS'18*. ISLS.

Jackiw, N. (2009, 1991). The Geometer's Sketchpad. Software. Ver, 1-5. Berkeley, CA: Key Curriculum Press.

Laborde, J. M., & Strässer, R. (1990). Cabri-Geometre: A microworld of geometry for guided discovery learning. *Zentralblatt für didaktik der mathematik, 90*(5), 171-177.

Lave, J., & Wenger, E. (1991). Situated learning: Legitimate peripheral participation. Cambridge, MA: Cambridge University Press.

Acknowledgments

Multimodal Reflection: Adolescents Remixing and Sharing Their Experiences in an Informal STEM+L Academy

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Abstract: This study reports how 31 adolescents enrolled in an informal academy focused on STEM and digital literacies reflected on their experiences by creating short multimodal videos. Initial findings reveal how students remixed a variety of modes—including photographs, videos, text, animation, and music—to reflect on their learning, collaborations, and digital projects. Students simultaneously composed for multiple audiences through their multimodal reflections, while learning more about themselves and new technical skills.

Keywords: reflection, multimodality, digital literacies, adolescents, STEAM learning

Introduction

Reflection is the process of returning to experience, connecting with thoughts and feelings during that experience, and reexamining it through a new perspective (Boud, Keogh, & Walker, 1985). The importance of reflection as a conduit for learning and personal growth has been emphasized for some time in educational research (Dewey, 1933). However, much of this work has occurred in English Language Arts settings with students writing reflections after they submit an essay (Yancey, 1998). To date, little research has examined how youth reflect on their processes when creating multimodal projects (however, see Smith & Dalton, 2016). This study contributes to this underdeveloped area by exploring how culturally and linguistically diverse adolescents reflected on their experiences in an informal STEM+L academy by creating multimodal video reflections.

Theoretical framework

We draw from social semiotics theory (Kress, 2010), which is based on the assumption that various modes (e.g., visuals, text, sound, movement) are integral in meaning making. The unique interweaving of different modes communicates messages that no single mode can express independently (Jewitt, 2009). In addition, composers leverage the modal affordances of specific modes when creating their messages (Kress, 2010).

We also employ a sociocultural view of multimodal composition which forefronts the dialogic relationship between composers and their composing tools (Wertsch, 1998). Just as modes offer communicative affordances (Kress, 2010), tools similarly offer unique possibilities for constructing meaning and reflection. Composers not only communicate through their orchestration of modes but simultaneously also form identities—representing personal goals, interests, and self-presentation techniques (Rowsell & Pahl, 2007).

Finally, remix is a core practice when students reflect through multiple modes. When remixing, composers manipulate and recombine modes and media to create new meaning (Knobel & Lankshear, 2008).

Methods

The study was conducted in the context of a STEM+L ("L" stands for digital literacies) academy for adolescents (ages 10-13) to develop knowledge, interests, and identities related to STEM practices and digital literacies. Participating students worked in small groups to produce a multimodal science fiction as their final project. The academy consisted of three components: a five-day summer camp, fall extension (once every month), and final presentation. A total of 42 students completed the summer camp (26 male, 16 female; 19 Latino/Hispanic, 14 Black, 5 Other, 4 White), and a total of 33 students returned on the first session for the fall extension.

During the first fall session, students were taught how to use Windows Moviemaker to produce videos and then asked to individually create a 1-minute video that reflected upon their experience in the summer academy. Students had freedom in the content and format of their videos and were offered a variety of prompts, including how they collaborated, favorite and challenging aspects of the academy, and main "take-aways." Students were provided a variety of multimedia data from the study, including photographs and videos of

student presentations, guest speakers, group work, and their final products. Students also had the latitude to include their own visuals, text, or music. The entire task, including a tutorial, took ~90 minutes.

Initial data analysis involved recursively coding students' video reflections and their perspectives gathered through online surveys to generate emergent categories for how students reflected through multiple modes. Future analysis will also involve creating multimodal transcripts for videos and incorporating video observations for focal students as they created their reflections.

Preliminary findings and implications

A total of 31 videos were produced (length ranging from 14-209 seconds). Students leveraged the affordances of multiple modes and digital tools to reflect upon their experiences in the academy in three distinct ways.

First, there were similarities in how students remixed different modes and media in their reflections. Students relied on visuals—photographs and embedded video clips—to "show" important elements of their collaborative process and interesting guest speakers. Text was often layered on top of visuals to provide details on their experience (Figure 1). Sergio explained, "Videos show what we did. Text and voice explain the video." Music was used to convey affective dimensions of students' experience (e.g., "optimistic music").

Figure 1. Examples of different ways students remixed media in their multimodal reflections.

Second, students' reflections were targeted for multiple audiences. A majority of students explained they had other viewers in mind when creating their video—including to "show people how we learn and what we do" and "how fun the academy was." Sean explained, "My goal was to create a video that would persuade viewers to come to [the STEM+L academy] and experience these moments themselves. I wanted to create something appealing and also interesting." In addition to reaching others, students also explained personal goals (e.g., "to please myself") and motivations to have "the best" video out of their peers.

Lastly, students' videos and perspectives revealed how they learned on multiple levels through creating their reflections. Along with sharing the collaboration skills and science content they acquired, students also explained how their experience of creating the videos helped them to acquire new technical skills. Additionally, some students shared personal benefits from the video reflection. Maya revealed how she "learned that sharing experiences can help you connect with other people" and Fabian explained, "I learned that I like science."

We believe our study will shed light on the value of asking students to reflect upon and share their experiences through multiple modes in digital spaces.

Selected References

Boud, D., Keogh, R., & Walker, D. (1985). *Reflection, turning experience into learning*. London, UK: Kogan Page.
Dewey, J. (1933). *How we think.* Boston, MA: D.C. Heath.
Knobel, M., & Lankshear, C. (2008). Remix: The art and craft of endless hybridization. *Journal of Adolescent & Adult Literacy, 52*(1), 22–33.
Kress, G. (2010). *Multimodality: A social semiotic approach to contemporary communication.* NY: Routledge
Smith, B. E. & Dalton, B. (2016). "Seeing it from a different light": Adolescents' video reflections about their multimodal compositions. *Journal of Adolescent & Adult Literacy, 59*(6), 719-729.
Yancey, K.B. (1998). *Reflection in the writing classroom.* Logan: Utah State University Press.

Acknowledgements

Eliciting Student Explanations in an Undergraduate Biology Course

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Abstract: Our research described discourse patterns during a planned elicitation discussion in an undergraduate biology laboratory course taught by undergraduate teaching assistants (TAs). We examined how discourse patterns changed from the first to the second semester of the TA's appointment. Conference participants will discuss the usefulness of organizing discourse patterns within a two dimensional space along axis of TA talk moves for visualizing change in ambitious science teaching practice and the implications for TA professional development.

Keywords: ambitious instruction, elicitation discussion, teaching assistant, professional development

Undergraduate biology laboratory courses and scientific discourse

Visions for undergraduate biology education and sociocultural theories of learning highlight student participation in scientific discourse as a cornerstone for learning (AAAS, 2011; Lemke, 1990; Warren et al., 2001). However, supporting discursively rich scientific experiences in the classroom is challenging, especially for novice teaching assistants (TAs). To support TAs in this challenge, we drew on ideas of ambitious instruction that have been described for K-12 teachers and may also be fruitful for postsecondary TAs (Windschitl et al., 2012). Teacher preparation programs for elementary and secondary teachers have incorporated ideas of ambitious instruction and some research examines how teachers appropriate and implement moves associated with ambitious instruction (Stroupe, 2016; Thompson, Windschitl, & Braaten, 2013). However, there is a need for research describing how postsecondary TAs implement ambitious science teaching practices. This research focused specifically on the practice of eliciting student ideas as a basis of instruction. We asked two research questions: (1) What patterns of discourse emerged across multiple iterations of a planned "elicitation discussion" in a biology lab course? and (2) How did discourse patterns for the same planned "elicitation discussion" change between a TA's first and second semesters teaching the course?

Methods

Study context and participant selection

The course was a biology lab for non-science majors taught by undergraduate TAs at a large research university in the Southeastern United States. The curriculum included 12 labs where students collected evidence to construct a scientific argument in response to a guiding question. We used a criterion sampling strategy (Miles and Huberman, 1994) to select participants that met the following criteria: (1) they taught the course for the first time in Fall 2015 and (2) they taught for a second time in Spring 2016. Thirteen of the 21 undergraduate TAs met the criteria. TAs attended weekly 2-hour professional development sessions to learn biology content, to witness models of ambitious instruction and discuss instructional moves to enact ambitious instruction, and to anticipate what students may say or do in response to instruction. Additionally, TAs were required to observe a peer teaching the lab investigation each week and keep a reflective teaching journal. All 1000 students enrolled in the course each semester were asked to participate in the study and 75% agreed each semester.

Data sources and analysis

Each lab investigation began with a planned "elicitation discussion" intended for TAs to elicit students' initial ideas about a phenomenon (Michaels & O'Connor, 2012). The data sources included transcripts of the Lab 2 elicitation discussion from each semester for the 13 participants and each TA's reflective teaching journal. We analyzed the Lab 2 elicitation discussion to allow TAs and students to adjust to course norms during Lab 1 before we captured the discourse patterns in their first semester as a TA to compare to discourse patterns of the same discussion one semester later. The planned aspects of the Lab 2 elicitation discussion were: (1) students have a common experience with the "fight or flight" response, (2) the TA elicits student observations of their physiological responses to the stimuli, (3) the TA presses students for possible explanations of how these physiological responses occurred, (4) students observe an earthworm and a cricket's response to stimuli, and (5) the TA presses students to consider how the explanations they co-constructed for humans may or may not apply to other organisms. The transcripts were blinded and analyzed using an a priori coding framework based on the classroom talk literature (e.g., Oliveira, 2010; Windschitl et al. 2012) and for explanatory rigor of student talk

(Thompson et al., 2016). Cases were individually developed for each TA, compared, and categories were developed iteratively to qualitatively describe common discourse patterns that emerged, how discourse patterns changed over time, and how change in TA practice was connected to teaching reflections.

Findings and implications

Four distinct discourse patterns emerged from the analysis: "Mostly Facts", "Mostly Observations", "Facts, Observations, and Explanations", and "Observations and Explanations". The poster presentation will include figures and further discussion of the discourse patterns. The patterns of student contributions were related to patterns of TA talk moves. To portray these relationships, we positioned each of the four student discourse patterns on a two-dimensional plane based on how the initial question elicited student thinking (horizontal axis) and how the TA response extended student thinking (vertical axis) (see Figure 1A). This framework allows us to locate a TA's practice within this space and could be useful to design professional development to support TA practice along the appropriate axis (initial questions or responses) to elevate explanatory rigor. We examined change in TA practice over time by mapping maintenance (O) and movement (→) within this space and patterns of change corresponded to the focus of TAs' reflective teaching journals (e.g. classroom and time management, classroom climate, student thinking) (see Figure 1B). Further discussion of these connections and the utility of this framework for designing TA professional development will be held at the poster session.
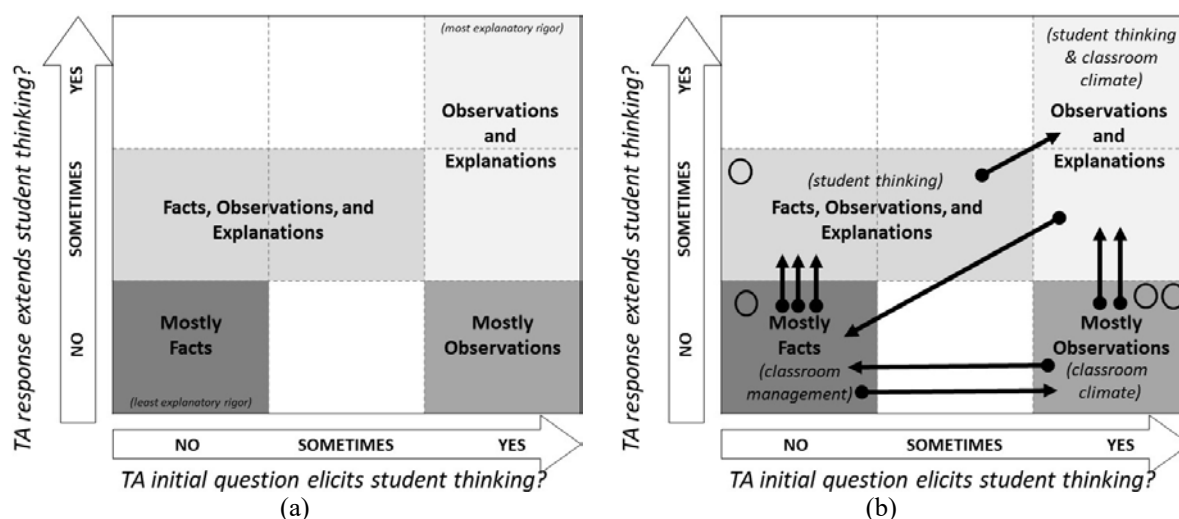
Figure 1. The four discourse patterns mapped onto TA talk move space (a) and TA change within that space (b).

References

American Association for the Advancement of Science. (2011). *Vision and change in undergraduate biology education: A call to action*. Washington, DC: AAAS.

Lemke, J. L. (1990). *Talking science: Language, learning, and values*. Norwood, NJ: Ablex.

Michaels, S., & O'Connor, C. (2012). *Talk science primer*. Cambridge, MA: TERC.

Miles, M. B., & Huberman, A. M. (1994) *Qualitative data analysis: A sourcebook of new methods* (2nd ed.). Thousand Oaks, CA: Sage.

Oliveira, A. W. (2010). Improving teacher questioning in science inquiry discussions through professional development. *Journal of Research in Science Teaching, 47*(4), 422-453.

Stroupe, D. (2016). Beginning teachers' use of resources to enact and learn from ambitious instruction. *Cognition and Instruction, 34*(1), 51-77.

Thompson, J., Hagenah, S., Kang, H., Stroupe, D., Braaten, M., Colley, C., & Windschitl, M. (2016). Rigor and responsiveness in classroom activity. *Teachers College Record*, *118*(7), 1-58.

Thompson, J., Windschitl, M., & Braaten, M. (2013). Developing a theory of ambitious early-career teacher practice. *American Educational Research Journal*, *50*(3), 574-615.

Warren, B., Ballenger, C., Ogonowski, M., Rosebery, A.S., & Hudicourt-Barnes, J. (2001). Rethinking diversity in learning science: The logic of everyday sense-making. *Journal of Research in Science Teaching*, *38*(5), 529-552.

Windschitl, M., Thompson, J., Braaten, M., & Stroupe, D. (2012). Proposing a core set of instructional practices and tools for teachers of science. *Science Education*, *96*(5), 878-903.

Developing a Text-Integration Task for Investigating and Teaching Interdisciplinarity in Science Teams

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Abstract: Integrating information from multiple sources is an important literacy skill that involves: identifying intra and inter-textual ties; modeling relationships between sources and claims; and evaluation of the claims made. Tasks that involve reading, interpreting and synthesizing multiple sources have been explored particularly in the epistemic cognition literature. Interdisciplinarity is a growing area of interest in education, with commensurate interest in the learning sciences regarding the means by which we induct students into interdisciplinary ways of thinking and working. While interdisciplinary contexts frequently involve connecting multiple sources, from different disciplines, these text-integration tasks have not been well investigated.

Introduction: Text integration as a lens on learning

Rouet (2006), suggests key skills important in the context of dealing with multiple sources (particularly rich-multimedia environments): *integration* of prior knowledge and across documents (including competing claims); *sourcing* of features that identify the provenance, genre, etc. of the information; and *corroboration* to check information across multiple sources. A task that probes these processes is text-integration or synthesis writing, in which students construct representations of how multiple sources fit together in relation to a particular task or issue (Goldman, Lawless, & Manning, 2013). As Goldman, Lawless and Manning (2013) highlight, synthesis can occur in a number of different task contexts, including: Integrating differing genres of texts targeted at a shared theme; integrating texts that contain agreements and contradictions on a shared theme; and integrating texts that each contain pieces of information regarding a particular theme, each contributing a part of the picture.

A body of work in this area has explored these abilities to comprehend and integrate information from multiple sources, specifically viewing such behaviours through the lens of epistemic cognition (see Ferguson, 2014, for an overview). In this work, students' cognition around the certainty, simplicity, source, and justification of knowledge is seen as a key mediator for how sources are treated and made use of, assessed through knowledge-tests or constructed responses. Thus, in text integration tasks, the ways in which sources are drawn on may give insight into learning. However, students may not source well, only drawing on limited sources, or failing to integrate them. Recent work on literacy and epistemic cognition (Anmarkrud, Bråten, & Strømsø, 2014; Bråten, Braasch, Strømsø, & Ferguson, 2014) suggests that students tend not to explicitly source, or to use the full list of sources available to them.

Text integration is receiving increased attention in writing research, as a higher-order learning activity in its own right (Klein & Boscolo, 2016). Alongside this attention, there is increasing recognition of the disciplinary nature of writing (Klein & Boscolo, 2016). Despite the dual recognition of text integration tasks as a higher-order learning activity, and of the nature of writing as disciplinary, a feature of text integration tasks that has been little explored is the nature of disciplinary context. In interdisciplinary contexts, text integration is particularly interesting, and under-researched. Much of the, limited, research on learning to do interdisciplinary research focuses on ways of collaborating, sharing and translating knowledge from different disciplines in teams. For example, Pennington et al. (2016) highlights the key stages of (1) identification of an appropriate research question; (2) agreement on a shared vocabulary; (3) the co-creation of boundary negotiating objects; (4) tools for visualizing and combining data, with the aim of (5) producing a new, connected model of understanding. Given that a common output for research teams is in written form, whether an article, policy recommendation, or research proposal, text integration is key to the successful synthesis of disciplinary perspectives and appropriate communication to stakeholders.

In Bråten et al. (2011) the authors describe some key relationships between a model of multiple document comprehension, and epistemic cognition. In that piece, they highlight, for example, that we would expect those people who have less adaptive perspectives on the 'simplicity' of knowledge to engage with multiple documents in a way that emphasizes simple over complex sources, and accumulation of facts over integration. Adapting this work to interdisciplinary contexts, we posit that prior work on epistemic cognition and sourcing in text integration tasks can inform our understanding of interdisciplinary synthesis production. Thus, interdisciplinary learning contexts can draw on text-integration literature to develop tasks to probe key epistemic concerns in interdisciplinary problem solving. These tasks can be developed by providing learners with texts from

multiple disciplines, within a particular context in which they must work towards identifying a specific problem, using a shared vocabulary, and set of resources to develop new understanding towards some ends, such as a policy recommendation or research proposal.

Present study

In the research conducted, 13 graduate students from diverse disciplines completed a text-integration task as part of a wider summer school program on interdisciplinary approaches in the environmental sciences (Thompson et al., 2017). Students were asked to write a synthesis of three articles, on a shared theme (the water-food-energy nexus), but each from a different disciplinary context. The students were asked to draft syntheses on day 3, with opportunities to redraft on days 5 and 8, and a final submission at the end of the event. To analyze the syntheses, we identified features of the text that align with the high-level constructs to develop a rubric based on our prior work investigating a text integration task (Knight, 2016; Knight et al., 2017), intended to be useable by an instructor or student without the need to undertake a laborious coding of individual sentences or idea units within a given text. The rubric builds on prior work focusing on: the specific content that students include in their texts; their use of explicit and implicit citation; the evaluation of the citations and the content drawn on; and the ways in which that information is synthesized (both within individual texts and across multiple sources). The syntheses were thus analyzed with respect to their inclusion of topics or themes from the sources, intra- and inter-textual synthesis, evaluation, and sourcing (which articles were explicitly referred to). Analysis of the texts using this rubric facilitated the generation of specific feedback designed to address the key features of textual synthesis. The development of this task has shown that synthesis writing, and its links to features of epistemic cognition – simplicity, complexity, identifying sources, and justification – provide opportunity for investigating models of interdisciplinary learning and collaboration.

References

Anmarkrud, Ø., Bråten, I., & Strømsø, H. I. (2014). Multiple-documents literacy: Strategic processing, source awareness, and argumentation when reading multiple conflicting documents. *Learning and Individual Differences*, *30*, 64–76. https://doi.org/10.1016/j.lindif.2013.01.007

Bråten, I., Braasch, J. L. G., Strømsø, H. I., & Ferguson, L. E. (2014). Establishing Trustworthiness when Students Read Multiple Documents Containing Conflicting Scientific Evidence. *Reading Psychology*, *0*(0), 1–35.

Bråten, I., Britt, M. A., Strømsø, H. I., & Rouet, J.-F. (2011). The role of epistemic beliefs in the comprehension of multiple expository texts: Toward an integrated model. *Educational Psychologist*, *46*(1), 48–70.

Ferguson, L. E. (2014). Epistemic Beliefs and Their Relation to Multiple-Text Comprehension: A Norwegian Program of Research. *Scandinavian Journal of Educational Research*, *0*(0), 1–22.

Goldman, S. R., Lawless, K., & Manning, F. (2013). Research and development of multiple source comprehension assessment. In M. A. Britt, S. R. Goldman, & J.-F. Rouet (Eds.), *Reading: From words to multiple texts. New York: Routledge* (pp. 180–199). NY: Routledge.

Klein, P. D., & Boscolo, P. (2016). Trends in Research on Writing as a Learning Activity. *Journal of Writing Research*, *7*(3 (February 2016)), 311–350. https://doi.org/10.17239/jowr-2016.07.03.01

Knight, S. (2016). *Developing Learning Analytics for Epistemic Commitments in a Collaborative Information Seeking Environment* (PhD). Open University, Milton Keynes, UK.

Knight, S., Rienties, B., Littleton, K., Mitsui, M., Tempelaar, D. T., & Shah, C. (2017). The relationship of (perceived) epistemic cognition to interaction with resources on the internet. *Computers in Human Behavior*, *73*, 507–518. https://doi.org/10.1016/j.chb.2017.04.014

Pennington, D., Bammer, G., Danielson, A., Gosselin, D., Gouvea, J., Habron, G., … Wei, C. (2016). The EMBeRS project: employing model-based reasoning in socio-environmental synthesis. *Journal of Environmental Studies and Sciences*, *6*(2), 278–286. https://doi.org/10.1007/s13412-015-0335-8

Rouet, J.-F. (2006). *The Skills of Document Use: From Text Comprehension to Web-Based Learning* (First Edition edition). Mahwah, NJ: Routledge.

Thompson, K., Danielson, A., Gosselin, D., Knight, S., Martinez-Maldonado, R., Parnell, R., … Wheeler, P. (2017). Designing the EMBeRS Summer School: Connecting Stakeholders in Learning, Teaching and Research. In *Proceedings of the 25th International Conference on Computers in Education*. New Zealand: Asia-Pacific Society for Computers in Education.

Acknowledgments

Making Uncertainty Work: How Youth Manage Uncertainty to Shape Learning Trajectories in a School Makerspace

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Abstract: In this paper, we use positional, conceptual, and epistemological dimensions of student framing to investigate how youth navigated open-ended work in a school-based maker club, and how opportunities to pursue personally consequential learning differed across participants. We identity four ways that uncertainty functioned in interaction.

Keywords: uncertainty, youth, making, learning ecology, agency, framing, collaboration

Introduction

Maker spaces are typified by fluidity of roles, products, audiences, and values (Sheridan et al., 2014). Such open ended, resource-rich spaces hold potential for generative and equitable learning (Bell, Van Horne, & Cheng, 2017), but also create challenges as students learn to navigate concerns of technological tools, varied resources, and the power and social dynamics present in all learning environments. Investigating how young people shaped their learning opportunities, we analyzed collaborative work on open-ended projects in a high school-based "maker club". We came to focus on how *moments of uncertainty* acted as pivot points that young people used to position themselves within their project group in order to access and build on existing areas of expertise.

Theoretical framework

To understand how young people navigated collaborative product design, we turn to framing theory, which allows for analysis across three dimensions: *positional*, *conceptual* and *epistemological* (Van de Sande & Greeno, 2012). Hand, Penuel, and Gutierrez (2012) propose framing theory as a tool for developing equity oriented educational designs, noting that "who gets to define what and when a frame is," is central to the distribution of power and opportunity. The question of who defines frames is especially relevant to making spaces, where familiar, school-like frames have been destabilized. Moments of uncertainty in collaborative work are a productive place for inquiry into this process and into how learning happens (Jordan & McDaniel, 2014).

Methods

This study was part of a larger design-based research project in which we co-developed a "maker club" that operated for 3 months at a public charter high school. We acted as participant observers, leading workshops and mentoring youth, while also recording audio and video data, collecting field notes, and debriefing with our research team and the partnering teachers. Fifteen youth, ages 14 to 16, participated in the maker club – 7 boys, 7 girls, and 1 gender non-conforming; 5 African-American, 3 Latinx, 3 White, and 4 multiracial. A focal group comprised three young women and one young man, and their project type and the problems (both technical and social) that arose were similar to those seen in other groups.

In this paper, we consider observation data from the third session of Maker Club, when students moved out of skill-building workshops and began work on their project ideas. We transcribed interaction from the full day (4.5 hours), then coded the transcript for framing at positional, epistemological and conceptual levels. We began to notice moments of uncertainty as key sites at which frames were asserted, contested, or reinforced. Using verbal and non-verbal markers of uncertainty, such as questions, hedges, and hypotheticals (Jordan & McDaniel, 2014), we re-analyzed the transcripts, identifying places in the day where uncertainty was raised. In analysis of thirteen key moments, we identified themes in how moments of uncertainty functioned in the framing work students were doing. We present four of these themes here.

Findings

Theme 1: Solidifying positions, purposes & power

At moments of uncertainty we saw participants attempting to frame roles and resources in ways that established authority or solidified relationships. For example, in one episode, two participants, Casey and B, sustained uncertainty around technical details – like the spelling of "laser" – in ways that allowed them to strengthen connection to each other and reinforce their roles as project leaders. This action simultaneously served to

position another participant, Deonne, as a social and technical outsider.

Theme 2: Pursuing areas or topics of interests

Simply *raising* areas of uncertainty provided a way for participants to pursue areas of interest by directing attention to desired features. For example, Deonne, asked a disproportionately high number of questions about aesthetics and engraving, the aspect of project work that aligned most closely with her expertise and learning goals for the maker club. Raising uncertainty about a feature allowed participants to make bids for responsibility of those features by framing their own expertise or interest.

Theme 3: Directing activity toward personal resources

Management of uncertainty played an important role in students' ability to bring outside resources – material, conceptual and cultural - to bear, such as when Casey suggested a re-design that would have allowed the group to work at her house, instead of the school. The move would have helped her access expertise in carpentry, as well as tools that she had at home. Rather than building personal connections into a project during initial ideation, moments of uncertainty across the project allowed participants to frame priorities and direct solution paths toward familiar toolsets that allowed them to participate centrally and knowledgeably.

Theme 4: Inviting new perspectives, resources, and positions

When participants resurfaced issues of uncertainty they had shut down or let drop, they shifted the resources, constraints, and epistemologies that could be brought to bear. Students left some issues unresolved only to re-engage when a shift in context directed attention toward new resources, or provided for a new perspective on old resources. For example, when Deonne asked about project dimensions, the group did not address the issue, with Isaiah claiming they were "just prototyping." When a mentor raised the same question shortly after, his authority and knowledge of tool limitations reframed the issue for the group. They began a process of measuring, sketching and debate, but Deonne shifted from the center of discussion to the margins.

Implications

Collaborating on open-ended work in the maker club was a process of negotiation and compromise; each project decision had aesthetic and structural implications, consequences for how each group member was positioned in subsequent work, and consequences for what and how each team member learned through discussion and construction. Uncertainty was pervasive and persistent, conceptually and relationally. Resolution was non-linear and often seemed secondary to learner purposes for participation. Learners had to tolerate ambiguity while selecting where and when to raise questions and concerns.

Moments of uncertainty created cracks in the organization of learning situations, opening room for student agency. Functioning like pivot points (Calabrese Barton, Tan, & Shin, 2016), these moments were places of flux where young people had opportunity to push on what kinds of resources and knowledge were brought to bear. Framing work accomplished with introduction of or response to uncertainty had strategic effect, providing opportunities to capitalize on and extend existing expertise and positions of some youth. Conversely, management of uncertainty also served to thwart project features and discussions to the detriment of some interests, purposes and practices. How young people manage uncertainty plays an important role in STEM trajectories, critical to whether or not they can leverage identities and build expertise across settings and time.

References

Bell, P., Van Horne, K., & Cheng, B. H. (2017). Special Issue: Designing Learning Environments for Equitable Disciplinary Identification. *Journal of the Learning Sciences, 26*(3), 367-375.

Calabrese Barton, A., Tan, E., & Shin, M. (2016). *Mobilities of Criticality: Space-Making, Identity and Agency in a Youth-Centered Makerspace* Paper presented at the Transforming Learning, Empowering Learners: The International Conference of the Learning Sciences (ICLS) 2016, Singapore.

Hand, V., Penuel, W. R., & Gutiérrez, K. D. (2012). (Re)Framing Educational Possibility: Attending to Power and Equity in Shaping Access to and within Learning Opportunities *Human Development, 55*.

Jordan, M. E., & McDaniel, R. R., Jr. (2014). Managing Uncertainty During Collaborative Problem Solving in Elementary School Teams: The Role of Peer Influence in Robotics Engineering Activity. *Journal of the Learning Sciences, 23*(4).

Sheridan, K., Halverson, E., Litts, B. K., Brahms, L., Jacobs-Priebe, L., & Owens, T. (2014). Learning in the Making: A Comparative Case Study of Three Makerspaces. *Harvard Educational Review, 84*(4).

Van de Sande, C. C., & Greeno, J. G. (2012). Achieving Alignment of Perspectival Framings in Problem-Solving Discourse. *Journal of the Learning Sciences, 21*(1), 1-44.

Interdependence as a Treatment Effect:
An Example From Group Awareness Research

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Abstract: Interdependence of data within collaborative learning is often viewed as a mere statistical phenomenon. However, interdependence may provide valuable information about the collaboration process. Thus, we report data of an exemplary study ($N = 82$) about the impact of metacognitive group awareness information on collaborative learning to illustrate how this information may add to data interpretation. Our analyses indicate that interdependencies after collaboration may be part of the treatment effect and point towards differential collaboration strategies.

Introduction

One great challenge for quantitative research in CSCL is the interdependence of individual data when learners interact in dyads or groups. Usually, dealing with hierarchical data is done in a stepwise procedure: first, the actual data is tested for statistical interdependence and – depending on the outcome – the data is analyzed accounting for interdependence if necessary (Cress, 2008). If there is no interdependence, independence may be assumed, and corresponding statistical analyses can be used. However, collaboration processes usually rely heavily on interaction between group members and should thus foster non-independence on some levels. Additionally, treatments varied experimentally are often specifically designed to foster collaboration and thus explicitly target interaction between subjects. Thus, we cannot assume interdependence to be a mere effect of the overall collaboration task, but it might be part of the treatment effect and thus more heavily apply to groups of learners within one experimental condition. In this paper, we will describe exemplary data to show how a treatment targeting interaction between individuals learning in a dyadic setting may affect interdependence differently and how this information can enrich our analyses.

Empirical study: Group awareness tools to foster collaboration

Group awareness tools are designed to inform learners about aspects of group members or the group in order to implicitly guide their learning processes (Bodemer, Janssen, & Schnaubert, in press). Thus, they affect collaboration in a way that is thought to be beneficial for individual learning. Empirical research uses a great variety of target concepts of such tools, and especially tools providing cognitive group awareness information may support relevant learning processes (cf. Janssen & Bodemer, 2013). For example, they may visualize individual needs or conflicting assumptions, thus fostering partner modelling central for collaboration processes (Dillenbourg, 1999). Thereby they may help learners to structure and coordinate joint learning processes (Clark & Brennan, 1991) and to tail their conversation to the needs of the individuals (Clark & Murphy, 1982). In our study, we aimed at investigating whether metacognitive group awareness information has an additional benefit to cognitive group awareness information. We hypothesized that learners receiving information on metacognitive confidence regarding specific assumptions learn more during collaboration than learners who do not receive this information due to improved collaboration processes and that they gain more confidence in the process, since insecurities signaling individual need for clarification may explicitly be addressed during collaboration.

To test our hypotheses, we evaluated data of an experimental study with 41 dyads of learners randomly assigned to two (between-dyad) research conditions varying the availability of metacognitive confidence information during collaboration (MC+ vs. MC-). Dependent variables were assessed pre and post collaboration (within-subject). All participants each read a text on diabetes mellitus and answered questions regarding the topic individually, and then came together in dyads to discuss the topic guided by the questions on a multi-touch tabletop. Afterwards, they answered the questions again individually. They gave a confidence rating with each answer, but the display of this information during collaboration depended on experimental condition. Our dependent variables were (a) the number of learning tasks each individual solved correctly pre and post collaboration to assess knowledge gain (performance) and (b) the number of confidently solved items per person pre and post collaboration to assess changes in confidence levels (confidence). While the treatment was implemented on dyad level during collaboration, outcome measures were assessed individually. Because we worked with partially-dependent data for our analyses on learning outcomes (individuals nested within dyads), we computed intra-class-correlation coefficients (ICC; Shrout & Fleiss, 1979) for each experimental condition.

To analyze the data, we conducted two-factorial MANOVAs with repeated measures on one factor with dyads and individuals as units of analyses, and additionally analyzed the data via a dyadic multi-level model using linear mixed modeling with restricted maximum likelihood estimation. We found a multivariate main effect of time and an interaction effect. Univariate ANOVAs confirmed main effects of time with performance and confidence levels rising significantly from pre to post and a significant interaction effect with MC+ learners' performance increasing more from pre to post than the performance of learners in MC-.

While these results largely corresponded with our expectations, taking a closer look at ICC values produced some unexpected results: We found that after collaboration, the two conditions (MC+ vs. MC-) differed considerably in their statistical interdependence, leading us to assume different collaboration processes. While learners within dyads in MC+ were more interdependent with regard to resulting confidence levels (ICC = .56) than learners in MC- (ICC = .26, n.s.), the latter were more similar regarding performance levels (ICC = .67) than learners in MC+ (ICC = .31, n.s.). Thus, providing metacognitive information may have shifted attention to different aspects of the learning processes and may have resulted in different collaboration efforts. While it was assumed that learners gain from metacognitive information performance-wise, the assumption was based on improved collaboration processes where learners more efficiently exchange information or co-construct knowledge (Dillenbourg, 1999). However, this should have resulted in higher dependencies regarding performance, which was not the case. Rather, it could be that visualizing metacognitive information may have given the learners less need to negotiate their understanding of the content, since displayed uncertainties might be a way to maintain differences while reducing cognitive conflict.

Conclusion

While statistical interdependence is often seen as a nuisance due to constrains they put on the usage of standard statistical analyses, it is worth noting that various collaborative learning scenarios explicitly target dependencies of learners who interact whilst influencing the learning partners' cognitive processes (Dillenbourg, 1999). Hence, the focus of this paper was to exemplarily show how ICCs may add valuable information that may easily be lost when merely compensating for interdependence rather than interpreting it. Interdependence is not a mere statistical phenomenon, but a result of common exposure to situational factors (shared experiences) or of reciprocal influence and thus interaction (Cress, 2008). Especially the latter is in the core of collaborative learning, where peers interact while pursuing a learning goal (Suthers, 2012) and thus, low ICCs may often not be in line with the (more or less explicit) theoretical assumptions made about collaborative processes. It is thus not surprising, that treatments designed to foster collaborative learning processes may differentially influence interdependence, since they affect the interaction processes between learners within a learning group.

References

Bodemer, D., Janssen, J., & Schnaubert, L. (in press). Group awareness tools for computer-supported collaborative learning. In F. Fischer, C. E. Hmelo-Silver, S. R. Goldman, & P. Reimann (Eds.), *International Handbook of the Learning Sciences*. New York, NY: Routledge/Taylor & Francis.

Clark, H. H., & Brennan, S. E. (1991). Grounding in communication. In L. B. Resnick, J. M. Levine, & S. D. Teasley (Eds.), *Perspectives on socially shared cognition* (pp. 127–149). Washington, DC: American Psychological Association.

Clark, H. H., & Murphy, G. L. (1982). Audience design in meaning and reference. *Advances in Psychology*, *9*(C), 287–299. https://doi.org/10.1016/S0166-4115(09)60059-5

Cress, U. (2008). The need for considering multilevel analysis in CSCL research—An appeal for the use of more advanced statistical methods. *International Journal of Computer-Supported Collaborative Learning*, *3*(1), 69–84. https://doi.org/10.1007/s11412-007-9032-2

Dillenbourg, P. (1999). What do you mean by "collaborative learning"? In P. Dillenbourg (Ed.), *Collaborative-learning: Cognitive and computational approaches* (pp. 1–19). Oxford, UK: Elsevier.

Janssen, J., & Bodemer, D. (2013). Coordinated computer-supported collaborative learning: Awareness and awareness tools. *Educational Psychologist*, *48*(1), 40–55. https://doi.org/10.1080/00461520.2012.749153

Shrout, P. E., & Fleiss, J. L. (1979). Intraclass correlations: Uses in assessing rater reliability. *Psychological Bulletin*, *86*(2), 420–428. https://doi.org/10.1037/0033-2909.86.2.420

Suthers, D. D. (2012). Computer-supported collaborative learning. In N. M. Seel (Ed.), *Encyclopedia of the sciences of learning*. New York, NY: Springer.

ORBIT - Overcoming Breakdowns in Teams With Interactive Tabletops

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Abstract: ORBIT implements and studies a joint problem-solving activity at a tabletop tangible user interface (TUI) providing participants with the opportunity to develop their collaboration methods through jointly overcoming breakdowns. The design and the research process relies on user-centered design methods and on an ethnomethodological conversation analytic framework. The project will both generate scientific knowledge on participants' collaboration methods and create a powerful TUI-mediated collaborative learning tool.

Introduction

There is an increasing recognition that future societal and intellectual challenges can only be solved collaboratively (Stahl, 2010). However, constructive collaboration on new challenges is a difficult matter and the mere joining of people's forces does not help unless people know *how* to collaborate (Schwarz et al., 2015). Hence, learning to learn and to work together must become an important goal in education and professional training. So, the design research project ORBIT aims at implementing and studying a joint problem-solving (JPS) activity mediated by a tangible user interface (TUI). The main objective of the project is to implement and study a TUI-mediated JPS activity that gives adult participants the opportunity to deal with and overcome breakdowns through collaboration (by that way learning to collaborate). Accordingly, the following research questions will be addressed: (1) How to design a TUI-mediated joint problem-solving activity eliciting participants' collaboration to overcome breakdowns? (2) How do the participants cope with and overcome breakdowns in a TUI-mediated joint problem-solving activity through collaboration?

Methodological framework

Having both analytic and design components that are closely interwoven, the current project adopts a design-based research approach (DBR) (Reimann, 2011). Koschmann et al. (2007) point to the need for conducting fine-grained video-analytic studies of instructional practice to address the issue of how to account for the functioning of the design in authentic settings and to have at their disposal an appropriate method to "document and connect processes of enactment to outcomes of interest". They advocate for the implementation of an approach that relies on ethnomethodology (Garfinkel, 1967) and conversation analysis (Sacks et al., 1974) to systematically and rigorously study practice. In the meantime, many CA investigations go beyond talk and also take into account gestures, gaze, body postures and movements, and spatial and material resources mobilized by the participants. Additionally, the TUI developments in the DBR process will turn to user centered design (UCD) methods (e.g., prototyping, multi-disciplinary design workshops, walkthroughs) which give attention to the needs of the end-users. CA and UCD are "rooted in a shared methodological credo. To understand human interaction and the use of technologies, CA rigorously examines the participants' perspective" and UCD takes "as point of departure how the users interact with technologies" (Egbert, 2001, 208).

Study design

The ORBIT problem-solving activity will be implemented in two different settings: with in-service teachers during of a workshop on "collaboration", and with municipal staff members in the context of their trainings on soft skills and diversity. The TUI-activity will be based on a rule induction problem whose difficulty will increase as the participants progress. In a first phase, participants will, for example, have to discover how to steer an unknown vehicle demanding them to simultaneously operate several control devices (materialized by widgets). The process of mastering the steering of the vehicle will provide participants with a shared experience of successful joint problem solving. In the subsequent phase the difficulty of the problem is increased by implementing software-generated breaches in order to generate breakdowns (1) which have to be overcome by the participants to complete the task successfully. More precisely, the breaches will be designed either as "information gaps" or as "procedural mismatches". The former distribute essential information unevenly among the participants thus creating an asymmetry of knowledge, while the latter change the rules of the underlying system. Coping successfully with the dynamics of the designed problem requires the participants to rely on multiple resources, create a joint focus, work interdependently, exchange ideas and information, and co-

construct a shared understanding. However, the research team is aware that "intended pedagogical aims and ideas" (task-as-workplan) do not necessarily "translate directly" into actual problem-solving practice, and so the main focus "will be on what actually happens, that is the task-in-process" (Seedhouse, 2004, 93, 95), which is reflected in our EM/CA approach. The design process will use seven iterations (two walkthroughs and five trials), which progressively deal with a different focus and related sub-activities of the JPS activity (see Figure 1). The five trials will be video-recorded from different angles and perspectives (see Arend et al., 2014) generating approximately fifteen hours of video data. The latter will be searched to identify relevant sequences (accounts of collaboration, accounts of breakdown) and the findings will feed back into the design process.
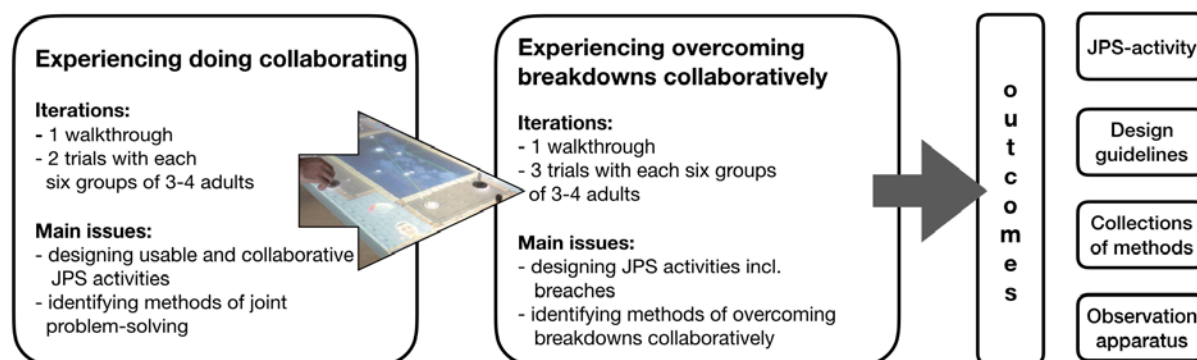
Figure 1. Synoptic plan of ORBIT.

Expected outcomes

The project will result in the design of a TUI mediated JPS activity of high usability and integrating series of breaching moments with the aim of supporting learning to collaborate. In this vein, it will develop and refine design guidelines to support the design of TUI-mediated JPS activities. Furthermore, ORBIT will contribute to the construction of a theoretical and methodological framework regarding the analysis of collaboration processes and methods to overcome breakdowns in a digitally mediated environment. More precisely, it will create collections of participants' accounts of breakdowns, of participants' methods of overcoming breakdowns, and of participants' methods of doing collaborative work; and contribute to the creation of a methodological and technical apparatus for instantiating and researching JPS activities.

References

Arend, B., Sunnen, P., Fixmer, P. & Sujbert, M. (2014). Perspectives do matter – Expanding Multimodal Interaction Analysis with Joint Screen. *Classroom Discourse, Special Issue Multimodality*, 5, 1, 38-50.

Egbert, M. (2011). Conversation Analysis Applied to User-Centred Design: A Study of Who 'The User Is'. In C. Antaki (ed.), *Applied Conversation Analysis. Intervention and Change in Institutional Talk* (pp. 207-221). New York: Palgrave Macmillan.

Garfinkel, H. (1967). *Studies in Ethnomethodology*. Englewood Cliffs/NJ: Prentice Hall.

Koschmann, T., Stahl, G. & Zemel, A. (2007). The Video Analyst' Manifesto. In R. Goldman et al. (eds), *Video Research in the Learning Sciences* (pp. 133-143). Mahwah, NJ: LEA.

Reimann, P. (2011). Design-Based Research. In L. Markauskaite, P. Freebody & J. Irwin (eds.). *Methodological Choice and Design* (pp. 37-50). New York: Springer.

Sacks, H., Schegloff, E.A. & Jefferson, G. (1974). A simplest systematics for the organization of turn-taking for conversation. *Language*, 50, 4, 696-735.

Schwarz, B.B., de Grootet, R., Mavrikis, M. & Dragon, T. (2015). Learning to learn together with CSCL tools, *International Journal of Computer-Supported Collaborative Learning*, 10, 3, 239-271.

Seedhouse, P. (2004). *The Interactional Architecture of the Language Classroom.* Malden, MA: Blackwell.

Stahl, G. (2010). Group Cognition as a Foundation for the New Science of Learning. In M.S. Khine, & I.M. Saleh (eds.), *New Sciences of Learning: Cognition, Computers and Collaboration in Education* (pp. 23-44). New York: Springer.

Acknowledgments

Growing Teamwork Competency: A Mixed Methods Study of an Iterative Digital Formative Assessment Approach

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Abstract: This paper reports on an intervention project, based on a digital formative assessment approach, to grow students' teamwork competency. In this intervention, a pedagogical framework and a teamwork competency measure were supported by a techno-pedagogical system. The intervention was carried out over two iterations with the same teacher and class, over two different collaborative inquiry tasks. Student participants (n=39) were in Secondary One when they started. The study employed the design-based research methodology with a convergent parallel mixed methods design. The quantitative results of students' peer-rated teamwork ratings all increased positively in iteration two while the qualitative analysis of the teamwork reflection text revealed that students had a deeper understanding of their teamwork competency. The converging findings indicate that the intervention has helped students to grow their personal teamwork competency. Implications and future work of the study are highlighted.

Introduction and background

Teamwork is one of the core competencies for the 21st Century student, yet, the mechanisms of teamwork are often complex, and assessing teamwork can be difficult (Phielix, Prins, Kirschner, Erkens, & Jaspers, 2011). This is especially as there has been less research on the metacognitive, social and emotional aspects in group work as compared to cognitive processes (Järvelä et al., 2015). Being competent in teamwork, or teamwork competency, is a multi-dimensional construct that focuses on the process of members working in a team. We focus on four dimensions of teamwork competency: coordination (COD), mutual performance monitoring (MPM), constructive conflict (CCF), and team emotional support (TES; Koh, Hong, & Tan, 2018).

While there have been many approaches to grow teamwork, a digital formative assessment approach, which refers to pedagogical mechanisms that utilize assessment for learning by means of electronic tools, has shown some promise (Phielix et al., 2011). In this paper, we highlight how students' perceptions of teamwork changed through a digital formative assessment approach. This approach was designed as a pedagogical framework, the Team and Self Diagnostic Learning (TSDL) framework (Koh et al., 2018), and supported by a techno-pedagogical system. This system had the core functions of a lesson page, ratings, visual analytic, reflections and steps-setting, and a status check page. It was implemented as part of an authentic collaborative inquiry task in a class of Secondary One students over two iterative trials. We ask, to what extent and in what ways does the approach help students to grow their personal teamwork competency? The study employed the design-based research methodology with a convergent parallel mixed methods design.

Team self diagnostic learning framework

The TSDL framework (Koh et al., 2018) is a four staged approach draw from theories such as experiential learning, socially shared regulation, and the pedagogical framework for learning analytics intervention design. It aims to build students' teamwork competency through the following staged mechanisms:

- *team-based concrete experiences* that engage students in team experiences such that they have prior knowledge and understandings of working with the members of their team.
- *self and team awareness building* primarily through making visible teamwork processes through formative assessment. This is currently enacted through self and peer ratings of their teamwork behaviors, and a visual analytic provided.
- *team and self reflection and sensemaking* that enables students to evaluate the visual analytics, diagnose their teamwork information and create new insights. Students are challenged to set specific goals to grow their teamwork individually and as a team.
- *team and self growth and change* through providing students the agency to monitor and enact the teamwork goals they have set.

Method and brief findings

Design-based research was the overall methodology. Using convergent parallel mixed methods design, quantitative and qualitative data were collected simultaneously. The focus of this paper is on the peer-rated teamwork competency scores and the reflection text that students wrote over the two iterations.

There were 39 student participants, who were in the two iterations, with the same teacher over two different collaborative inquiry tasks in the subject, Interdisciplinary Project Work (IPW). This is part of the curriculum for Secondary One and Two students. Each IPW was six months long and the intervention was designed to integrate with it. There were two cycles of TSDL in each iteration, i.e., two ratings.

We focus on the peer-rated teamwork dimensions, i.e., how a student was rated by the members in his team, as this provides a sense of how the team members perceived the participant in teamwork, a form of others-ratings. The results show that time one and two ratings for each dimension was significantly positively correlated. However, a paired samples t-test revealed no significant relationships between the dimension ratings in iteration two. Interestingly, in iteration two, there was a significant average difference between MPM scores between TSDL cycle one and two (t_{38} = 3.324, p < 0.002). On average, peer-rated MPM scores grew .23 points (95% CI [.090, .370]). For TES too, there was a significant average difference, t_{38} = 2.990, p < 0.005. Peer-rated TES scores grew .18 points (95% CI [.057, .294]).

As for the qualitative reflection text, two researchers thematically coded the text. Three themes emerged - teamwork competency shifted from head knowledge to applied knowledge, vague teamwork descriptions changed to realizations of what one has to improve on, and from general reflecting to the quality of teamwork and the collaborative inquiry task. For example, student 122ZC at the end of cycle 2 reflected on MPM, *"this dimension is important as monitoring each other helps to complete the work faster as we can concentrate better and complete work on time."* As can be seen, the reflection highlights this student's deeper understanding of the teamwork dimension in personal terms. Another student even wrote out a heuristic formula, *"no constructive conflict – [means] no interaction, [leads to] low productivity by group"*, suggesting an internalization and application of teamwork competency in the student.

Discussion and concluding remarks

A digital formative assessment approach was trialed in two iterations on a class of Secondary One students. The findings converge to indicate that the students grew in their teamwork competency perceptions. However, this change was seen only in iteration two. It could be that students were not keenly able to meta-cognitively think about and reflect on their personal teamwork competency in the first iteration. This suggests that more time is needed for students to cultivate the meta-cognitive thinking processes and language in understanding and growing their teamwork competency. Still, these findings have their limitations, and require further examination of other data sources. Also, the study has several confounding factors such as the maturity of the students, and the lack of a control group.

One key practical implication is the extent that future collaborative inquiry tasks can employ this digital formative assessment approach. A key concern would be the time needed for such metacognitive activity. This suggests the need for instructional leadership and other stakeholder support. Also, further refinement is needed to strengthen the pedagogical mechanisms and the flow of activities such that it integrates smoothly with the curriculum. Nevertheless, the findings from this study highlight that such an intervention can work to nurture the teamwork competency of 21st Century learners.

References

Järvelä, S., Kirschner, P. A., Panadero, E., Malmberg, J., Phielix, C., Jaspers, J., . . . Järvenoja, H. (2015). Enhancing socially shared regulation in collaborative learning groups: designing for CSCL regulation tools. *Educational Technology Research and Development, 63*(1), 125-142.

Koh, E., Hong, H., & Tan, J. P.-L. (2018). Formatively assessing teamwork in technology-enabled twenty-first century classrooms: exploratory findings of a teamwork awareness programme in Singapore. *Asia Pacific Journal of Education*, 1-16. doi:10.1080/02188791.2018.1423952

Phielix, C., Prins, F. J., Kirschner, P. A., Erkens, G., & Jaspers, J. (2011). Group awareness of social and cognitive performance in a CSCL environment: Effects of a peer feedback and reflection tool. *Computers in Human Behavior, 27*(3), 1087-1102.

Acknowledgments

Visualizing Knowledge in the Era of Instructional Software and Gamification: Challenges in Design, Method and Practical Use

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Abstract: The present study examines behavioral and metacognitive effects of visualizing acquired knowledge in instructional software. This was done by letting 117 Swedish primary school students use two varieties of an educational game – one with and one without a tool where tokens with knowledge related content were received as proofs of achievement. Although no significant positive impact of the tool was found, the study reveals interesting findings regarding the challenges of visualizing knowledge in learning applications.

Introduction

The role of metacognition in learning has been a hot topic during the last decades (Greeno, Collins and Resnick, 1996; Hattie, Masters & Birch, 2016). Research findings on the subject also reveal that didactic interventions, such as regular visualizations and reviews of student achievements versus goals and sub-goals, can have a significant impact on learning outcomes (ibid.). In addition, other studies indicate a need for decreasing the gap between the student's and the teacher's appreciation of the student's own knowledge and understanding (Zohar, 1999). When it comes to digital learning environments, these issues have often been emphasized when promoting or discussing e-portfolios or LMS's (Paris & Paris, 2001). However, to the author's knowledge, the topic has never been investigated in instructional software. Typically, in learning applications, learners perform a series of exercises without saving any substantial traces of them. After finishing the tasks, the possibility of reviewing or evaluating the obtained know-how is very limited. Subsequently, the aim of the present study has been to design and evaluate a function that preserves and presents achievements in an educational game. Hence, the following hypotheses were formulated: i) A visual representation of the student's obtained knowledge will catch the student's attention, and it will be interacted with during play, ii) Such representations will serve as motivational tokens and will affect self-regulatory aspects, e.g. endurance at voluntary play.

Method

The software used in the study was *Guardians of History (GoH)*, an educational game for students in the 4th to 6th grade that has been developed and utilized as a research instrument by Lund and Linköping University in Sweden (Kirkegaard, 2016). In the game, students are given missions for which they perform time-travels to historical persons and events, explore these environments, and solve tasks. The metacognitive support designed for the study had the shape of a diary, called "*the Magic Book*". The diary was placed as a clickable feature in the upper left corner of the screen and contained information about completed, ongoing and future missions. After solving a task or a sub-task, the player received tokens in the shape of souvenirs, corresponding to graphical objects from the original time-travels. These souvenirs represented the semantics of the student's correct answers from the tasks and was accompanied by textual information. To attract the student's attention, the book blinked anytime a new souvenir was added.

Five classes were recruited from two Swedish primary schools and two versions of the Magic Book - one with the functionality and graphics presented above (Type B), and one where the content was limited to a help-page (Type A) - were equally distributed within each class. In total, 117 11-12-year-olds (61 girls and 56 boys) participated. Each class spent three lessons with the study. The sessions were conducted in ordinary class-rooms, and all participants received the same instructions and support. Between the second and third session, half an hour (or longer, depending on the students' interest) was designated to play-time at home. The third session contained tests and inquiries (belonging to this and another concurrent study on cognition and learning), and discussions on user experience and general game improvement.

Results

As dependent variable for testing the first hypothesis: *"The visualization of the user's knowledge will be attended to and interacted with"*, the time spent (in seconds) on clicking and hovering on elements of the Magic Book was used. A Mann-Whitney's U-test here revealed a large and significant difference between Type A (*Mdn* = 10, *Range* = 0-105) and Type B (*Mdn* = 158, *Range* 0-607); *W* = 286, *p* < 0.001. For testing the second hypothesis: *"The visualizations will affect self-regulatory aspects of game behavior"*, the student's amount of

playtime at home (in minutes) was selected as a dependent variable. In this case, a Mann-Whitney's U-test ($W =1397$, $p = 1$) revealed no significant differences between conditions. Additional quantitative findings from data logs indicated further, that the main part of the time spent in the Magic Book was in the very beginning of the game. The players also dedicated most of their time to briefly scan through the content in the diary and very little time was spent on hovering the souvenirs for displaying textual information.

The students' subjective responses were analysed inductively, resulting in four relevant aspects of game design related to learning and metacognition: *Challenge, Simplification or scaffolding, Exploration* and *Learning and meaning*. In sum, the students requested an engaging application with a thrilling content, accompanied by meaningful rewards that later could be used as leverage for new tasks – a common structure in computer games. However, medium and high performing students made comments on the possibility of storing books and historical inventions from time-travels, and also requested opportunities to repeat tasks and topics. Interestingly, these students mainly came from the Type A condition – without the souvenirs in the Magic Book.

Discussion

The lack of positive metacognitive impact of the Magic Book might, of course, depend on its specific content, but it could also be due to constraints and affordances of digital medias in general. For example, a screen-based application has a sequential nature with limited physical space and dimensionality. Consequently, one activity (e.g. interacting with a parallel tool) easily overshadows another (e.g. the actual game-play), affecting cognitive resources as well as user experiences. An alternative design could therefore be to utilize the flow and narrative of a game for repeating and visualizing learning progress. In GoH, this might be done by adding game-elements where new assignments reflect earlier achievements, by forcing the players to attend to old performances through special tasks, or by reformulating dialogues and displayed information. The figure below shows the present conceptual structure of the game together with an alternative design where the diary is updated fewer times and with a more mandatory and meaningful use of it. Finally, it is also highly likely that such a design would benefit from a more iterative design-and test process with qualitative data collection, as well as more direct instructions before actual play.
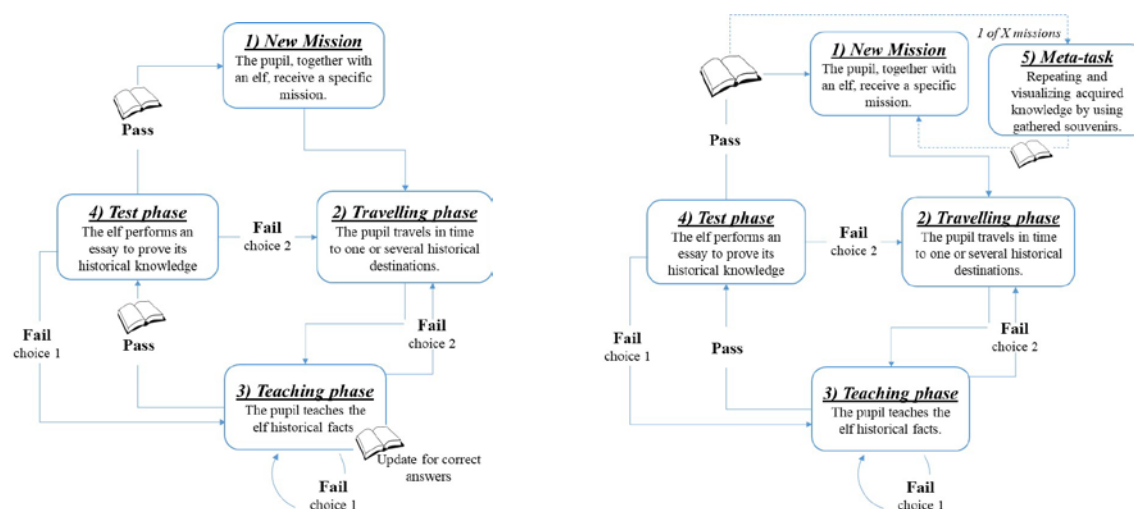
Figure 1. The structure of Guardians of History, with the tested design of the Magic Book (left) and an alternative design (right). The book icon shows when the Magic Book was/could be updated with new content.

References

Greeno, J., Collins, A. & Resnick, L. (1996) Cognition and Learning. in Berliner, D. & Calfee, R. (eds.) *Handbook om Educational Psychology,* (pp. 15-46), Macmillan, New York

Hattie, J., Masters, D. & Birch, K. (2016). *Visible Learning into Action*. Routledge, NY.

Kirkegaard, C. (2016). *Adding Challenge to a Teachable Agent in a Virtual Learning Environment*. Licentiate Thesis in Cognitive Science, Linköping University, Sweden: Linköping University Electronic Press.

Paris, S. G. & Paris, A. H. (2001). Classroom Applications of Research on Self-Regulated Learning. *Educational Psychologist, 36*, 89–101

Zohar, A. (1999). Teachers' metacognitive knowledge and the instruction of higher order thinking. *Teaching and Teacher Education, 15*, 413-429

Unpacking Why Student Writing Does Not Match Their Science Inquiry Experimentation in Inq-ITS

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Abstract: Science assessments should evaluate the full complement of inquiry practices (NGSS, 2013). Our previous work has shown that a large proportion of students' open responses did not match their scientific investigations (Li et al., 2017a). The present study both unpacks and compares the sub-components underlying students' performance for experimenting to their written open responses. These findings have implications for the assessment of inquiry practices, design of real-time scaffolding, and teachers' instruction of science.

Keywords: science inquiry assessment, educational data mining, natural language processing

Introduction

The Next Generation Science Standards (NGSS Lead States, 2013) are driving the need for assessments that can accurately measure students' inquiry practices, including: asking questions, planning and carrying out investigations, analyzing and interpreting data, warranting claims, constructing explanations, and communicating findings. Many researchers seek to develop assessments of students' inquiry practices. In particular, several assessments have been developed to capture students' scientific explanations, argumentation, and communication competencies (Liu et al., 2016; McNeill et al., 2006).

Inq-ITS (Inquiry Intelligent Tutoring System; www.inqits.com) is an online inquiry environment for middle school science in which students engage in both experimental and communicative NGSS practices. In Inq-ITS, students' experimental actions are captured in log files which are then automatically analyzed in real-time using patented algorithms (Gobert et al., 2016a; Gobert et al., 2016b). Students' written explanations are constructed in the format of claim, evidence, and reasoning, and are recorded as part of the explaining findings stage of each Inq-ITS virtual lab. Access to student performance in terms of both their actions and writing allows for not only capturing the complement of students' inquiry practices, but also for identifying any potential discrepancies in student performance between their "doing" and "communicative" inquiry practices. Specifically, a study by Li et al. (2017a) found inconsistencies between students' doing and writing for almost half of the participants who engaged in the Inq-ITS Density virtual lab. In the study, "doing" referred to the actions students took as they engaged in virtual science inquiry investigations, such as asking questions, planning and carrying out investigations, and analyzing and interpreting data (NRC, 2012). "Writing" referred to the construction of written scientific explanations containing argumentative components based on the results of students' virtual investigations. The findings from Li et al. (2017a) imply that assessments capturing only students' "doing" or "writing" may result in false positives when students are adept at parroting what they have read or heard but do not understand the science content or inquiry practices. Assessments may also result in false negatives when students who are skilled at science cannot articulate what they know in words.

Present study

The present study further explored the extent to which students' written scientific explanations reflected their doing during an experiment at a more fine-grained level by using specific science inquiry practices (i.e. experimental interpreting and experimental warranting) assessed within the Inq-ITS system as the units of analyses. This study investigated three research questions: (1) To what extent do students' competencies in communicative practices reflect their competences in experimental practices? (2) What distribution is displayed in terms of high versus low competency in experimental practices and high versus low competency in communicative practices? (3) To what extent does high versus low competency in experimental and writing practices mutually affect students' performance on experimental practices or writing practices alone?

293 middle school students (the same students from Li et al. (2017a, 2017b)) completed one Inq-ITS density virtual lab. We performed *K*-means cluster analyses (*K* = 2) on the sub-components of experimental and writing practices, respectively, and classified students into low versus high for each practice (resulting in four quadrants: Low (experimentation) –Low (writing), Low–High, High–Low, and High–High). We performed the Chi-square analysis and multivariate general linear model on experimental interpreting scores and written interpretation scores, as well as on experimental warranting and written warranting to examine the distribution of

students among the four quadrants. Multivariate general linear models (GLM) were performed to examine the extent to which the performance on experimental versus written interpretation and experimental versus written warranting practices differed among the four quadrants.

Findings and implications

Results of the linear regression for experimental and written interpretations showed that only one sub-component of experimental interpreting (i.e. interpreting IV) significantly predicted the written interpretation scores, $B = 1.30$, $t(293) = 2.78$, $p = .006$, $R^2 = .194$. Results of the linear regression for experimental and written warrants showed that two sub-components of experimental-warranting (i.e. the number of single trials ($B = 1.18$, $t(293) = 3.58$, $p < .001$) and all controlled trials ($B = -.34$, $t(293) = -2.13$, $p = .034$)) significantly predicted the written warranting scores, $R^2 = .056$.

Results of the Chi-square analysis for experimental and written interpretations showed that experimenting and writing were not independent, $\chi^2 (1, N = 293) = 21.77$, $p < .001$. Results of the Chi-square analysis for experimental and written warranting showed that experimentation and writing were not independent, $\chi^2 (1, N = 293) = 4.56$, $p = .033$. More than 30% of the total students exhibited discrepancies between experimental and written interpretation performance, and approximately 60% exhibited discrepancies between experimental and written warranting performance.

Results of the multivariate general linear model for interpreting revealed a statistically significant difference between experimental and written interpretations across the four groups, $F(6, 578) = 285.01$, $p < .001$; $\eta^2 = .747$. Tests of between-subjects effects indicated that group had a statistically significant effect on both experimental scores ($F (3, 289) = 1085.37$; $p < .001$; $\eta^2 = .918$) and written interpretation scores ($F (3, 289) = 182.95$; $p < .001$; $\eta^2 = .655$). Results of the multivariate general linear model for warranting also revealed a statistically significant difference in experimental and written warranting scores among the four groups, $F(6, 578) = 510.26$, $p < .001$; $\eta^2 = .841$. Tests of between-subjects effects indicated that group had a statistically significant effect on both experimental scores ($F (3, 289) = 509.06$; $p < .001$; $\eta^2 = .841$) and written warranting scores ($F (3, 289) = 511.89$; $p < .001$; $\eta^2 = .842$).

Results of the study revealed discrepancies between students' performance on inquiry practices through unpacking relations between students' experimental and communicative practices. The results of this study will significantly enhance research on teaching and the science of learning for the following two reasons. First, this study unpacks the complexity of scientific writing based on students' actions while conducting investigations. This study will inform teachers and researchers of the relationship between what students do during science inquiry and write accordingly. If students successfully engage in an experimental practice, can they report/reflect on what they have done as per NGSS (2013) expectations? Second, this study will promote the improvement of teaching methods for science inquiry in order to address students who demonstrate discrepancies between their experimental doing and explanatory writing performance.

References

Gobert, J. D., Baker, R. S., & Sao Pedro, M. A. (2016a). Inquiry skills tutoring system. *U.S. Patent No. 9,373,082.* Washington, DC: U.S. Patent and Trademark Office.

Gobert, J., Sao Pedro, M., Betts, C., & Baker, R.S. (2016b). Inquiry skills tutoring system (alerting system). *US Patent No. 9,564,057.* Washington, DC: U.S. Patent and Trademark Office.

Li, H., Gobert, J., & Dickler, R. (2017a). Dusting off the messy middle: Assessing students' inquiry skills through doing and writing. In E. André, R. Baker, X. Hu, M. Rodrigo, & B. du Boulay (Eds.), *Artificial Intelligence in Education* (Vol. 10331, pp. 175-187). Cham: Springer.

Li, H., Gobert, J., & Dickler, R. (2017b). Automated assessment for scientific explanations in on-line science inquiry. In X. Hu, T. Barnes, A. Hershkovitz, & L. Paquette (Eds.), *Proceedings of the 10th International Conference on Educational Data Mining* (pp. 214-219). Wuhan, China: EDM Society.

Liu, O. L., Rios, J. A., Heilman, M., Gerard, L., & Linn, M. C. (2016). Validation of automated scoring of science assessments. *Journal of Research in Science Teaching*, *53*(2), 215-233.

McNeill, K. L., Lizotte, D. J., Krajcik, J., & Marx, R. W. (2006). Supporting students' construction of scientific explanations by fading scaffolds in instructional materials. *The Journal of the Learning Sciences*, *15*(2), 153-191.

Next Generation Science Standards Lead States (2013). *Next generation science standards: For states, by states.* Washington, DC: The National Academies Press.

Acknowledgements

Science Literacy in Controversial Contexts:
An Epistemic Balancing Act

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Abstract: "Science literacy" is considered important for thinking and deciding about everyday personal and social issues relating to science, including controversial topics, such as anthropogenic climate change. In recent years, science literacy has been conceptualized as the ability to access and make sense of scientific expertise in the time and in the context of need. Recently, evidence has shown that when people attempt to make sense of controversial issues, their processing of scientific information is biased by their existing ideologies and worldviews. This is considered the culprit of persistent controversy about scientific findings, such as the findings that indicate anthropogenic climate change. Here, we propose an implication to this evidence: To promote science literacy, educators should promote an "epistemic balancing act" in the science classroom, avoiding both credulity and hyper-skepticism. Implications for educational policy are discussed.

Introduction

Individuals and groups often make decisions with scientific components. For example, voters go to the ballots and consider whether, in fact, the climate is changing, and if so, what should be done to mitigate the changes. For decades, scholars have been discussing what "scientific literacy" (SL) people need to make such decisions. Despite efforts to promote SL through science education, concerns about the usefulness of science education in everyday life persist (e.g., Aikenhead, 2006).

Here, we briefly review theoretical and empirical notions of SL and maintain that people often refuse to accept valid scientific findings that challenge their beliefs, values and interests. e.g., regarding anthropogenic climate change. We argue that as part of SL, laypeople must be taught to perform an "epistemic balancing act" when interacting with scientific expertise: They must avoid both credulity on one hand and hyper-skepticism in the other. We relate this "balancing act" to the epistemic virtue of open-mindedness.

Theoretical notions of science literacy

Although the body of literature on SL is immense, there is no general agreement on the definition or constituent parts of this construct. Alongside the diversity, there is some common ground. A committee of the US National Academies of Sciences, Engineering and Medicine (2016b) (hereafter NASEM) identified seven commonly hypothesized aspects of SL on the individual level: (1) foundational literacies, such as numeracy and textual literacy; (2) content knowledge, such as scientific terms, concepts and facts; (3) understanding of scientific practices, such as collecting and analyzing data and peer review; (4) identifying and judging appropriate scientific expertise; (5) epistemic knowledge, i.e., understanding how scientific claims are supported by scientific procedures; (6) cultural understanding of science and (7) dispositions and habits of mind, such as inquisitiveness and open-mindedness. Aspects 2, 3 and 5 are found in the PISA 2015 conceptual framework for SL as "content knowledge", "procedural knowledge" and "epistemic knowledge" (OECD, 2016).

The competent outsider: An evidence-based notion of SL

Several studies provide a modest base of evidence about lay reasoning with and about science in everyday settings, and some preliminary clues into the capabilities this reasoning requires. Feinstein (2011) suggested that to be considered "science literate," people must be able to *identify* when science is useful for their own needs and interests and to "*interact* with sources of scientific expertise in ways that help them achieve their own goals", or, in other words, be "*competent outsiders* with respect to science" (p. 180, emphasis by authors). By analogy, the "competent outsider" is like a competent water-drawer, who can identify when water might be useful (e.g., when one is thirsty), and then find an appropriate well. The science literate person can then use the well's pulley system to draw needed amounts of water, and then brew tea, launder clothes, etc.

Open-mindedness and the competent outsider

Scientific propositions on socially controversial topics, such as global warming, can threaten beliefs, values and interests, posing a difficulty to defer to scientific expertise. A recent consensus report on science communication

emphasized the role of motivated reasoning in interpreting scientific findings, especially when "individuals feel their values, identity, or interests are threatened" (National Academies of Sciences Engineering and Medicine, 2016a, p. 47).

One may expect schooling to help alleviate this problem. However, unfortunately, the available evidence suggests the opposite: In several contexts, scientific knowledge polarizes attitudes towards scientific facts. Thus, belief in human-caused climate change interacts with science knowledge and numeracy by individuals' political affiliations and cultural world-views: Among US adults who subscribe to an egalitarian, communitarian world-view, belief in human-caused climate change grows with scientific knowledge and numeracy. However, among US adults who subscribe to an individualistic, hierarchical world-view, belief in human-caused climate change *declines* with science knowledge. Science knowledge has been observed to contribute to polarization about private gun possession and hydraulic fracturing, but not nanotechnology or genetically modified food. This polarization contributes to persistent controversy on these topics (Kahan, 2017).

Building upon Feinstein's notion of the "competent outsider," Hendriks, Kienhues, & Bromme (2016) argued that to establish shared understanding, "trust is critical for 'insiders' as well as 'outsiders'" (p. 144). Their notion of "epistemic trust" for "outsiders" entails both willingness to be dependent on appropriate sources of scientific knowledge and vigilance towards being misinformed. We propose to add a complementary claim: Just as epistemic trust is necessary to rely on scientific knowledge claims, open-mindedness (part of NASEM aspect 7) is needed for "outsiders" to begin assessing such claims in the first place.

This approach is reflected in Taylor's (2016) conceptualization of open-mindedness as a "virtue that is a mean between the opposing vices of closed-mindedness and credulity" (p. 609). She suggests that this virtue requires one to have (1) intellectual humility (the ability and willingness to judge one's own fallibility); (2) intellectual courage (the willingness to take risks in the pursuit of knowledge despite threats to one's identity); and (3) intellectual diligence (the willingness to persist in pursuing knowledge and understanding). Thus, we propose viewing science literacy in controversial contexts as an "epistemic balancing act": Outsiders must be able to avoid erring both on the side of credulity and on the side of closed-mindedness.

This claim has important policymaking consequences. The Framework for K-12 Science Education states that scientists and citizens must "make evaluative judgments about the validity of science-related media reports" and have "[t]he knowledge and ability to detect 'bad science'" (National Research Council, 2012, p. 71). The Framework even cites Ben Goldacre's popular book, "Bad Science" (Goldacre, 2009). Although a critical stance is often appropriate, missing from this part of the document, and others like it, is an apt reference to identification of "good"– yet counter-attitudinal – scientific knowledge as well.

References

Aikenhead, G. S. (2006). *Science Education for Everyday Life: Evidence-Based Practice*. New York: Teachers College, Columbia University.

Feinstein, N. (2011). Salvaging science literacy. *Science Education*, *95*(1), 168–185. https://doi.org/10.1002/sce.20414

Goldacre, B. (2009). *Bad Science*. London: Harper Perennial.

Hendriks, F., Kienhues, D., & Bromme, R. (2016). Trust in Science and the Science of Trust. In B. Blöbaum (Ed.), *Trust and Communication in a Digitalized World: Models and Concepts of Trust Research* (pp. 143–159). https://doi.org/10.1007/978-3-319-28059-2

Kahan, D. M. (2017). On the Sources of Ordinary Science Knowledge and Extraordinary Science Ignorance. In K. H. Jamieson, D. M. Kahan, & D. A. Scheufele (Eds.), *The Oxford Handbook of the Science of Science Communication*. New York: Oxford University Press.

National Academies of Sciences Engineering and Medicine. (2016a). *Communicating Science Effectively*. Washington, D.C.: National Academies Press. https://doi.org/10.17226/23674

National Academies of Sciences Engineering and Medicine. (2016b). *Science Literacy: Concepts, Contexts, and Consequences*. Washington, D.C.: The National Academies Press. https://doi.org/10.17226/23595

National Research Council. (2012). *A Framework for K-12 Science Education*. Washington, D.C.: National Academies Press. https://doi.org/10.17226/13165

OECD. (2016). PISA 2015 Science Framework. In *PISA 2015 Assessment and Analytical Framework: Science, Reading, Mathematic and Financial Literacy* (pp. 17–46). Paris: OECD Publishing. https://doi.org/http://dx.doi.org/10.1787/9789264255425-3-en

Taylor, R. M. (2016). Open-Mindedness: An Intellectual Virtue in the Pursuit of Knowledge and Understanding. *Educational Theory*, *66*(5), 599–618. https://doi.org/10.1111/edth.12201

Navigating "Disability": Complexity and Small Environments

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Abstract: Exploring how children's conceptions might advance through *their* implicit knowledge provides a fundamental view into children's mathematics and elucidates possible alternative definitions of "learning difference (LD)". I present an evolving theoretical framework that depict children with LD's knowing and learning as nascent understandings that emerge from a real-time negotiation of meaning within "small environments" of instructional intervention. These negotiations are supported, or not, by the teacher's propensity to engage in the knowledge of children and use teaching to construct *shared goals* for learning. Implications of the work include new ways educators might define LDs as a complex phenomenon that reflects how children's knowledge of mathematics advances, or not, through a shared cognition grounded in children's unique knowing and learning.

Conceptualizing "Difference" in terms of knowing and learning mathematics

The major issues addressed in this work are conceptualizing "disability" and what it means to "know and learn mathematics" in instructional settings. Historically, researchers define instruction for these students as intervention: the addressing of deficiencies or differences in children's mathematical knowledge (e.g., Hudson & Miller, 2006). In some research, specific factors (e.g., working memory, processing, spatial reasoning, retrieve basic facts, identifying and/or compare number magnitudes and symbols) are tested alongside instruction (or before and after instruction) in a predictive manner to explain "learning disabilities" as a non-response to explicit, teacher-led instruction (e.g., Compton, Fuchs, Fuchs, Lambert, & Hamlett, 2012; Jordan, 2007; Mazzocco & Devlin, 2008; Murphy, Mazzocco, Hanich, & Early, 2007; Vukovic, 2012).

The propensity to equate these children's knowing and learning as a response to direct or explicit instruction is probable due to the manner in which disability is being defined or conceptualized. Societal norms, the teacher's knowledge, or some combination thereof becomes the driving force behind mathematical knowledge as a remediation (Vygotsky, 1978). Yet, this literature is incomplete and at times misleading for those who do not equate *remediation* with *learning*. I frame learning as adaptation (Piaget, 1951/1972/1980) and argue that because disabilities or differences in learning are far more dissimilar than they are similar (Compton et al., 2012), instruction should be based in a complex model of children's knowing and learning that I call "small environments".

Learner complexity in "Small Environments" — mind, goals, and environment

"Small environments" ground learning within adaptation as opposed to remediation done through direct instruction or explicit strategy modeling. If we accept that students possess a way of knowing mathematical content (DiSessa, 1988), then we also have to accept that even if students engage with learning situations in unexpected ways, their knowing and reasoning cannot be conceptualized as "deficient" or, arguably, even "different." It must be conceptualized as *their knowledge*: unique, complex organisms comprised of strengths and challenges that every person utilizes to make sense (Rose & Fischer, 2009). I draw from Piaget (1967/1972/1980), who argued that, often times, these ways of making sense are individualized, especially when we consider that the ways children reason are not the same as adults (Flavell, 1996). For Piaget (1972), knowing and learning was defined by the individual child, or "little scientist," who learned through a complex way of adapting her internal cognition (e.g., prior experience; current conceptions) through interactions with her environment that facilitate negotiated meanings.

Negotiated meanings take place in the small environment <u>first</u> as children's attempt to adapt their internal cognition with the environment and <u>second</u> as a bi-directional reasoning and sense making process started by children and facilitated by the teacher as a responsiveness to children's reasoning (Brown, 1992; Bruner, 1999; Piaget, 1951, 1972). A focus on the process through which cognition exists and adapts inside children's minds (i.e., schemes) as they negotiate the environment is one way to understand learning. Piaget (1972) argued that, in attempts to assimilate their environments, children notice differences between what they "know" and their environment; this creates *disequilibrium*. The disequilibrium occurs when the knowledge children already have (i.e., how they "see" things) differs from their environment. Children's reflections within goal-driven activity caused by the disequilibrium are thought to promote abstractions and generalizations in reasoning. The core element that children draw upon within this reflective activity is the *goal* that drives their learning; this goal can be formed and motivated by various factors (e.g., social, personal, logical, Piaget). Defining learning, or differences in learning, in this way is provoking because it illuminates an inferred build-up

of learning (i.e., such that learning becomes new knowledge) on the part of children as they negotiate their own minds (e.g., Boyce & Norton, 2017; Hunt, Tzur, & Westenskow, 2016; Simon, 2017; Steffe & Olive, 2010).

However, I assert that a sole focus on inferred processes by which children negotiate their own minds leads to incomplete depictions of learning or, arguably, *disabled* learning. This is because children's interactions with other people in the environment are also defining learning. Children constantly form and refines their goal for learning in activity, so their interactions with the small environment are already complex. Additional complexity is presented when an adult interacts with the child in the small environment, with her or his own "goals" for learning, which can also have varying motivators (e.g., pacing guides, mathematical content goals, mathematical process goals, depictions of growth from developmental trajectories, etc.). Children's learning, then, becomes negotiated by more than just their own interactions with the environment: learning becomes negotiated by the goals of the other person in the environment.

In this way, I equate complexity inside the small environment with the real-time negotiation of the goals these children experience in their own activity with adult's goals for children's learning as either perceived by the child, explicated by the adult, or set by the learning situation. I argue that within this negotiation, assumptions are made about who is setting the goals and what those goals are relying upon. *Children and teachers both set goals,* and these goals may differ. This is critical because each person's goals are effecting the interactions necessary for little scientists to understand and adapt to the small environments.

Responding to children's reasoning as they adapt it in intervention is critical (Empson, 1999) yet by no means an easy task. One reason is that children's prior experiences may not align with the teacher's theories for learning. Children may take a different kind of ownership of mathematical thinking (Woodward, 2004), attributing knowing and learning as quick response to teacher-given explanations or procedural steps (Woodward, 2004). Or, children may not believe that mathematics is attributable to effort, hard work, and mistakes (Boaler & Greeno, 2000). In the same way, teachers may have their own perceptions and beliefs about knowing and learning (Boaler, 2011). All or some part of these factors change learning and the goals that children and teachers set for themselves in the small environment.

Implications: Advancing or reducing shared understandings

Implications of this work are threefold. First, *if* researchers and teachers respond to the complexity of children's thinking in the small environment, then children respond to adults and adapt to the environment. They either match "how they see things" to what they perceive, are exposed to, or interact with (utilize existing mental schemes to make sense), or not (change existing mental schemes to make sense). In either case, the child makes an adaptation in themselves to "understand", not assimilate to, the environment.

Second, I argue that this definition of knowing and learning is far more empowering to children thought to have a cognition that *could* begin differently than a definition that seeks to impose onto children knowledge that they may not make sense to them. Zawojewski, Magiera, & Lesh (2013) illuminate why some children do not "progress" past certain ways of knowing:

> Do all students optimally learn along a particular normalized path (learning line, learning trajectory)? Do all students learn the "end product" in the same way? Likely not…. Particular goals for students' learning [are] regions… that are individualistic and dependent on a variety of interacting factors. (p. 473).

Finally, bi-directional constructions of understanding speaks to the human endeavor. *Equilibration*, then, can become multi-dimensional: a dilation and revitalization to children *and* teachers. Truly shared understandings can be a real result. This multi-dimensional knowing and learning is an expansion of child-driven negotiations of small environments into larger societies and shared, valuable understandings in STEM education.

Selected References

Boaler, J. (2016). Mathematical mindsets: Unleashing students' potential through creative math, inspiring messages, and innovative teaching. San Francisco, CA: Jossey-Bass.

Brown, A. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. *The Journal of Learning Sciences*, *2*(2), 141-178.

Piaget, J. (1951). *The child's conception of the world* (No. 213). Rowman & Littlefield.

Acknowledgments

Increasing the Use of Formative Feedback: Utilizing Game-Based Principles

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Abstract: Formative feedback has been identified as an important mechanism to help students enhance their areas of weaknesses (Shute, 2008). This study investigated a game-based formative feedback report system to delivery simple, real-time, and skill-based feedback to students. Preliminary results indicate many students (33.9%) who received the game-based feedback used it 3-4 times each week and select groups of these students showed statistically significant improvements in their final unit grades (F(1,53)=4.621, p<0.05).

Introduction

Formative feedback is crucial to the process of knowledge and skills acquisition (Leighton, Chu, & Seitz, 2013; Shute, 2008). The use of formative feedback during learning is complex because it is not only a cognitive process but also requires the considerations of affective dispositions (Immordino-Yang & Damasio, 2007). To facilitate successful and positive experiences of learning, educators need to consider how human emotions enhance or hinder students' use of formative feedback (Lajoie, 2008; Sawyer, 2006). In meeting the goal of developing a learning environment that is sensitive to students' emotions, game-based environments are a powerful ally (Shute & Ventura, 2013). Feedback provided to students during a digital game environment (e.g., earning in-game money or jewels) are often reflected upon by students, and used to enhance their future in-game performance (Gee, 2007; Shute & Ventura, 2013). As such, the principles behind these digital game feedback systems are useful in an educational environment to help provide formative feedback that is used in a meaningful way.

Theoretical framework

Learning error and formative feedback (LEAFF) model

The LEAFF model outlines that a learning environment deemed emotionally safe by students allows them to feel at ease revealing their learning errors which is hypothesized to develop more meaningful feedback for students to use during their learning (Leighton et al., 2013). When students feel at ease revealing what they do not understand and thus share their misunderstandings, educators can help correct these misconceptions by providing relevant formative feedback that is specifically targeted to the errors revealed. Formative feedback that is deemed meaningful and relevant to students' performances are expected to be accepted and used by students than they would otherwise (Smith, diSessa, & Roschelle, 1993). Most players deem the game environment as emotionally safe, which leads to positive evaluations of the feedback and increased motivation to use it. Hence, there is a need to investigate this type of game-based feedback so that students may be receptive of and use their formative feedback to improve their performance in an educational environment.

Research Questions

The main objective of this study was to investigate whether a game-based formative feedback reporting system using classroom-based formative assessments may enhance students' use of formative feedback in the classroom as well as knowledge and skill acquisition during the unit. Specifically, the research questions that guided this study was:

1. Do students use game-based formative feedback provided in their classroom?

2. How do students use the game-based formative feedback they receive in the classroom?

3. Does the use of game-based formative feedback improve students' achievement during the unit?

Methods

This study was designed to work with the same two teachers while they were teaching the same two concurrent units over a two-year period. Students in the first year of the study completed all their formative and summative

assessments without an enhanced formative feedback report while students in the second year of the study completed the same formative assessments, but had their feedback provided using a game-based formative feedback report system.

Participants

A total of 126 Grade 9 students and their English and Mathematics teachers (n=2) participated in this study over a two-year period. During the first (n=69) and second (n=57) years of this study, students' data was collected during the specified units.

Measures used and data collected

During the first year of the study, students' achievement records (e.g., students' performance on the formative and summative assessments during the poetry and circle geometry units) were collected. During the second year of the study, students' achievement records during the same two units as well as surveys and open-ended responses investigating student usage of game-based formative feedback were collected.

Analyses

Initial analyses of the survey data, which targeted the first research question, indicated that most students (33.9%) who received the game-based formative feedback used the feedback at least 3-4 times a week for each of the two units. The qualitative data, which investigated the second research question, is currently being analyzed using thematic analysis. Students' achievement data, which focused on the third research question, was split into strong, medium, and weak achievers as identified by their course grades before the poetry and circle geometry units. Statistical comparison of students' achievement data revealed statistically significant differences (F(1,53)=4.621, p<0.05) for students who were considered medium achievers. Specifically, students in the medium achiever group who received the game-based formative feedback scored higher (80.22%) when compared to their peers who did not receive the enhanced feedback (74.66%).

Significance of study

There is a need to develop and use game-based formative feedback reports in the classroom because they encourage students to use the feedback in a meaningful way Considering the large amount of effort and resources placed on formative assessment and its feedback, it is important to develop proper feedback reports so that students may understand the feedback and use it to enhance their areas of weakness (Black & Wiliam, 1998). This game-based formative feedback system indicates the need to consider digital game design principles when developing formative feedback report systems for educational environments (O'Connor, 2011).

References

Black, P. & Wiliam, D. (1998). *Inside the black box: Raising standards through classroom assessment.* London, United Kingdom: School of Education, King's College.

Gee, J. P. (2007). *Good videogames + good learning: Collected essays on videogames, learning and literacy.* New York, NY: Peter Lang Publishing.

Immordino-Yang, M. H. & Damasio, A. (2007). We feel, therefore we learn: The relevance of affective and social neuroscience to education. *Mind, Brain, and Education, 1*(1), 3–10.

Lajoie, S. (2008). Metacognition, self-regulation, and self-regulated learning: A rose by any other name? *Educational Psychology Review, 20*, 469-475. doi: https://doi.org/10.1007/s10648-008-9088-1

Leighton, J. P., Chu, M-W., & Seitz, P. (2013). Cognitive diagnostic assessment and the learning errors and formative feedback (LEAFF) model. In R. Lissitz (Ed.), *Informing the practice of teaching using formative and interim assessment: A systems approach* (pp. 183-207). Information Age Publishing.

O'Connor, K. (2011). *Fifteen fixes for broken grades (Canadian ed.).* Pearson Canada.

Sawyer, R. K. (2006). Introduction: The new science of learning. In R. K. Sawyer (Ed.), *The Cambridge handbook of: The learning sciences* (pp. 1-16). New York, NY: Cambridge University Press.

Shute, V. J. (2008). Focus on formative feedback. *Review of Educational Research, 78*(1), 153-189. doi: 10.3102/0034654307313795

Shute, V. J., & Ventura, M. (2013). *Measuring and supporting learning in games: Stealth assessment.* Cambridge, MA: Massachusetts Institute of Technology Press. Retrieved from http://myweb.fsu.edu/vshute/pdf/white.pdf

Smith, J. P., diSessa, A. A. & Roschelle, J. (1993). Misconceptions reconceived: A constructivist analysis of knowledge in transition. *Journal of the Learning Sciences, 3*(2), 115-163.

Measuring Awe and Critical Thinking in a Science Museum

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Abstract: Museums and informal science learning centers often use awe to entice, inspire and educate. Recent studies have suggested that awe can also impact critical thinking skills. We gave surveys to 1,057 guests at a science and an art museum to look for how aspects of awe differ among spaces and activities. Critical thinking was also measured utilizing a framework established in the art museum field.

Introduction

Science museums and many other informal learning spaces use awe to entice, inspire and educate. Foundational work in the field of psychology has suggested that awe can also be a key step in supporting science learning (Valdesolo, Shtulman, & Baron, 2017) and impact critical thinking (Griskevicius, Shiota, & Neufeld, 2010). We report on results of the first phase of a planned mixed method study to answer the question: How do science museums inspire awe in guests and how does that impact critical thinking?

Awe has recently been proposed as a catalyst for science learning (Valdesolo, Shtulman, & Baron, 2017). When students are curious or experience interest they persist longer at learning tasks and get better grades (Silvia, 2008). Awe has also been shown to promote critical thinking via a lower likelihood of being persuaded by weak arguments (Griskevicius, Shiota, & Neufeld, 2010) and promoting ethical decision-making (Piff, Dietze, Feinberg, Stancato, & Keltner, 2015). Critical thinking has been measured in art museums using a framework developed for the Visual Thinking Strategies (VTS) curriculum, a method utilized to promote critical thinking through aesthetic development. VTS is based on eliciting feedback from guests about what they see in an object and connecting it with specific evidence (Housen, 2002; Greene, Kisida, & Bowen, 2014).

Methods

Surveys were given to guests at locations in a large science museum that were *a priori* expected to reflect differing levels of awe. They include the museum's parking garage (as a baseline condition), the Rotunda (a large, dramatic central domed area with exhibit entrances on all sides), a submarine exhibit (centered on an indoor, authentic German U-boat) and in front of the ground floor entrances of the Museum (surrounded by classical, Beaux Arts style architecture in large, open park land). We also collected data in front of the entrance of a local art museum, which is situated in a substantially different community environment (dense urban) and has a very different architectural design (modernist).

The survey consists of three main sections: awe, critical thinking, and demographic information. The awe section was centered on the Situational Awe Scale (SAS) - a 19-item Likert measure designed to assess respondents' momentary experiences of awe (Quinn & Krenzer, 2017). It has four factors: (1) awe as liberating (the self) and connecting (to the world); (2) awe as oppressing and isolating; (3) physiological correlates (e.g., chills, goosebumps), and (4) the self as small within a vast world. For analysis, Likert survey data was converted into an ascending numerical scale from -3 (strongly disagree) to 3 (strongly agree). Mean scores were computed for each of the SAS factors.

To measure critical thinking, we developed constructed-response items based on VTS. Each guest was randomly shown 2 of 3 science themed images or art work. They were asked to answer three VTS questions about each image. Each response was coded by a researcher using a rubric with 8 categories adopted from Adams, et al. (2006). In each category, the first 135 responses were coded by two researchers who reached an IRR of 86%-96% across categories. We conducted exploratory analyses linking critical thinking and awe using separate hierarchical logistic regression models. 0 codes were removed and the remaining categories were recoded as 0 and 1. Subject was the random effect for all regression models. Separate models were run using each SAS factor to predict each VTS code.

Preliminary results and discussion

Guests reported significantly different levels of awe for each SAS factor across all measured spaces, according to ANOVAs with each of the individual SAS factor means as a DV and the locations as the IV and p value set to .05 (Table 1). Overall, we found positive aspects of awe were more likely to be experienced in the internal spaces than the outdoor spaces. In contrast, these differences are not evident for negative awe.

Table 1: Mean scores on the SAS scale.

	Location		SAS Factor						
		Liberating & Connecting[*]		Oppressing & Isolated[**]		Physiological Characteristics[**]		Small Self in Relation to Vast World[**]	
		N	M (SD)	N	M (SD)	N	M (SD)	N	M (SD)
Indoor	Parking Garage	302	.81 (1.2)	301	-1.2 (1.3)	302	-.91(1.5)	301	.16 (1.2)
	Rotunda	256	.63 (.99)	256	-1.6 (1.1)	256	-.12 (1.3)	256	.73 (1.1)
	Submarine	94	.62 (1.2)	94	-.98 (1.2)	94	.11 (1.3)	94	.64 (1.2)
Outdoor	Science Museum	171	.96 (1.1)	171	-1.8 (1.2)	171	-1.63 (1.4)	171	-.28 (1.4)
	Art Museum	122	.91 (1.1)	122	-1.1 (1.3)	122	-1.5 (1.5)	122	-.14 (1.4)

We conducted exploratory analyses linking critical thinking and awe using separate hierarchical logistic regression models. Subject was the random effect for all regression models. Separate models were run using each SAS factor to predict each VTS code. Most of the VTS codes were not related to reported awe emotions. However, we did find strong, *negative* relationships between VTS scores related to "comparing elements within an image" and awe. We also found a negative relationship between the Physiological aspects of awe and some of the VTS codes suggesting that as guests feel more awe, they show less evidence of critical thinking. Maybe awe decreases critical thinking immediately because the awe experience is positive and people are motivated to stay in the moment rather than do anything (like thinking critically) that would pull them out of the moment. Perhaps awe's effect on critical thinking can only be seen over time, in terms of later motivation to learn. To answer our research questions: Different spaces in the Museum instill different aspects of awe. These aspects also seem to impact some critical thinking experiences. However, the impact seems to be mostly negative using this specific measure of critical thinking using aesthetic analysis and observation. We are currently analyzing interviews to look for explanations for that relationship. Our results suggest that high levels of awe may not be conducive to critical thinking in-the-moment. Planned follow up studies include using other measures of critical thinking and also looking for differences between in situ and recalled feelings of awe.

References

Greene, J. P., Kisida, B., & Bowen, D. H. (2014). The educational value of field trips. *Education Next*, *14*(1).

Griskevicius, V., Shiota, M. N., & Neufeld, S. L. (2010). Influence of different positive emotions on persuasion processing: A functional evolutionary approach. *Emotion*, *10*(2), 190-206.

Housen, A. C. (2002). Aesthetic thought, critical thinking and transfer. *Arts and Learning Research*, *18*(1), 2001-2002.

Quinn, K. A., & Krenzer, W. L. D. (2017, January). *Measuring awe: Exploratory factor analysis and preliminary validation.* Poster presented at the annual meeting of the Society for Personality and Social Psychology, San Antonio, TX.

Shiota, M. N., Thrash, T. M., Danvers, A. F., & Dombrowski, J. T. (2014). Transcending the self: Awe, elevation, and inspiration. In M. M. Tugade, M. N. Shiota, & L. D. Kirby (Eds.), *Handbook of positive emotions* (pp. 362-377). New York, NY: Guilford.

Valdesolo, P., Shtulman, A., & Baron, A. S. (2017). Science is awe-some: The emotional antecedents of science learning. *Emotion Review*, *9*(3), 215-221.

A Look at the First Two Years of a 5-Year Longitudinal Study of an OST Program's Impact on STEM Career Interest

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Abstract: We report on the first two years' of data for a longitudinal study about the impact of a STEM-based high school OST program on career interests. Quasi-experimental survey data from 132 youth across two annual cohorts is analyzed. Results show the treatment group (program alumni) dropped by 10% while the control group's STEM career interest dropped by 34% after their first year of college. Results suggest this program's impact may extend into early college experiences.

Introduction

This study focuses on a museum-based, positive youth development program based on scientific inquiry, public speaking/self-efficacy and college readiness. Typically beginning at the start of high school, youth visit for 10 Saturdays in a session with up to 3 sessions per year. The average youth is active in the program for 2.6 years. Developing YOUth! is a multi-year study of the program supported by the National Science Foundation (DRL#1514593). Following a quasi-experimental design, the study includes an annual, longitudinal survey of graduates from the SMA program along with a control group consisting of youth who have recently visited a science themed cultural institution. Three cohorts will be followed for at least 5 years after graduation.

Literature review

STEM-based out-of-school time (OST) programs have shown consistent success in supporting STEM career interests of those in middle and high school (Young, Ortiz & Young, 2017). However, beyond high school there is less evidence about their impact. Retrospective studies looking at long-term impacts have suggested that they can provide opportunities to engage in STEM-related activities and practices, ways of thinking, and communities (McCreedy & Dierking, 2013). Jaber & Hammer (2016) found that opportunities in learning environments that allow students to meaningfully engage with science learning positively affect their science identity development and prolonged interest in science. Also, despite the national trend of female youth losing interest in STEM careers in high school at a higher rate than males, an earlier retrospective study of this particular program found the opposite – that female youth's STEM career interest increased more than their male counterparts (Price, Kares, Segovia & Brittian Lloyd, 2018). However, such retrospective studies are subject to positive response bias and may overstate their effect (Storksdieck, Haley-Goldman & Jones, 2002). The framework for our study is based on Social Cognitive Career Theory (Lent, Brown, & Hackett, 1994) and ethnic identity, an individual's sense of belonging to an ethnic group defined by one's cultural heritage (Phinney & Ong, 2007), which has been linked to career decision making (Duffy & Klingaman, 2009).

Methods

The survey is first given to graduates of the SMA program (treatment) and Museum visitors (control) in the summer after high school graduation and every summer thereafter. The survey has three sections: cultural experiences in education, attitudes towards persistence in science, and career interests. The cultural items were Likert and constructed-response items (ex: "Race mattered in my educational experience" followed by "Provide an example of when race did or did not matter in your educational experience"). The attitudes items come from a scale to measure science aspirations and related factors by Dewitt, Archer, Osborne, Dillon, Willis & Wong (2011) (Hereafter: "DeWitt scale"). Two constructed response items asked about their current career goals. They were categorized as being STEM or non-STEM based on definitions established by the National Science Foundation except that we included medical and computer science careers. Our first cohort consists of 23 treatment and 20 control group youth who took the survey in year one and 21 and 16 (respectively) who took it in year two. Our second cohort consists of 19 treatment and 72 control who took the year one survey and have not yet been given their year two survey. A third cohort will be recruited next summer. Youth self-report as 57% female, 43% male, <1% nonbinary. Ethnicity/Race reported as 46% White, 15% Hispanic, 15% multi-racial, 13% African American, 10% Asian and 2% other race/ethnicities.

Preliminary results

While in college, the control group's interest in STEM careers dropped from 67% to 33% (Table 1). This is in line with the 2013 NCES study of undergraduates that showed a drop in STEM career interest from 64% to 36% their first year of college (Chen, 2013). However, the treatment group's STEM career interest only dropped from 90% to 80%.

Using repeated-measures ANOVAs, we also looked for changes in the cultural items and in the DeWitt scale factors between years 1 and 2. In the cultural items, we found no differences between groups that were statistically significant. However, we did find overall that both groups reported race mattered less and also felt more empowered in their first year of college than in high school. In the DeWitt scale, we only found a difference in a factor linked to aspirations in science, $F(2,37) = 4.35$, $p < .05$, $eta^2 = .12$. In that factor, mean ratings from the control group dropped from 3.52 to 3.25 while the treatment group increased from 4.30 to 4.43. We did not find differences in levels of confidence that they can achieve their career. We did not find any relationship between racial identity and career interest.

Table 1. Reported interest in STEM careers.

	Control (N=91)			Treatment (N=42)		
	Year 1	Year 2	Diff	Year 1	Year 2	Diff
STEM Career Goal	67%	33%	-34%	90%	80%	-10%
STEM Dream Job	65%	29%	-36%	81%	75%	-6%

Implications

The first year of college poses substantial challenges for those majoring in STEM careers, with nearly one-third of early STEM majors switching to a non-STEM disciplines by the end of the academic year. Our data shows that a long duration, science themed OST program can help attenuate that decline. Dabney, et al. (2012) found a relationship between high school STEM OST experiences and *initial* STEM career interest in college. This study presents evidence that the association may persist through college. Results and ability to derive factors contributing to them are limited by our sample size, which is not yet large enough to allow us to do between-subjects comparisons.

References

Chen, X. (2013). STEM Attrition: College Students' Paths into and out of STEM Fields. Statistical Analysis Report. NCES 2014-001. *National Center for Education Statistics*.

Dabney, K. P., Tai, R. H., Almarode, J. T., Miller-Friedmann, J. L., Sonnert, G., Sadler, P. M., & Hazari, Z. (2012). Out-of-school time science activities and their association with career interest in STEM. *International Journal of Science Education, Part B, 2*(1), 63-79.

DeWitt, J., Archer, L., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2011). High aspirations but low progression: the science aspirations–careers paradox amongst minority ethnic students. *International Journal of Science and Mathematics Education*, *9*(2), 243-271.

Duffy, R. D., & Klingaman, E. A. (2009). Ethnic identity and career development among first-year college students. *Journal of Career Assessment*, *17*(3), 286-297.

Jaber, L.Z., & Hammer, D. (2016). Engaging in science: A feeling for the discipline. *Journal of Learning Sciences, 25*(2), 156-202.

McCreedy, D., & Dierking, L. D. (2013). *Cascading Influences*. Philadelphia: The Franklin Institute Science Museum

Phinney JS, Ong AD. (2007). Ethnic identity development in immigrant families. In: Langford E, editor. *Immigrant families in contemporary society*. New York, NY: Guilford Press. pp. 51–69.

Price, C. A., Kares, F. K., Segovia, G. & Lloyd, A. B. (2018). Staff Matter: Gender differences in STEM career interest development in adolescent youth. *Applied Developmental Science*.

Storksdieck, M., Haley-Goldman, K., & Jones, M. C. (2002). *Impact of the New York Hall of Science career ladder program on its former participants*. Unpublished technical report, Annapolis, MD, Institute for Learning Innovation. Retrieved from http://www.informalscience.org/sites/default/files/report_236.PDF.

Young, J., Ortiz, N., & Young, J. (2017). STEMulating Interest: A Meta-Analysis of the Effects of Out-of-School Time on Student STEM Interest. *International Journal of Education in Mathematics, Science and Technology*, *5*(1), 62-74.

Talking Past One Another: Looking for Signs of Conversational Mismatch in One 6th grade Science Classroom

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Abstract: This study analyzes two days of middle school science sensemaking conversations to argue for the existence and explanatory power of *conversational mismatch*, an interactional achievement in which students and their teacher seem to be "on the same page" about the nature of their classroom discourse, but the students' framing and teacher's framing of the classroom activity differ in subtle ways—a misalignment they don't notice until later. Conversational mismatches, we contend, arise in part from tensions between instructional goals of fostering students' engagement in authentic scientific sensemaking and guiding them toward particular understandings of pre-determined concepts and models.

Introduction: Shared vs. discordant framing in classroom discussions

Recent U.S. science education reforms emphasize the importance of classroom talk for developing and refining scientific knowledge (e.g. NGSS Lead States, 2013). Productive classroom discourse relies on participants "being on the same page" about the nature of the classroom activity (van Zee & Minstrell, 1997), which relies on the development of shared norms and routines. Researchers have used conversation and framing analysis to analyze where and how classroom participants get and stay on the same page, and what that page *is* (Berland & Hammer, 2012; Hutchison & Hammer, 2010). In this study, we use the same analytic tools to examine talk that preceded a moment of discord similar to the one documented by Berland and Hammer (2012), where students resist the teacher's bid to shift the classroom activity— a charged exchange we'll call the *explosion*. While our initial analysis of the pre-explosion frame negotiations revealed smoothness in the conversation, we also found evidence of unrealized mismatches in expectations that only became apparent upon the explosion. We conclude by posing methodological and theoretical questions emerging from our analysis, and by discussing implications of *conversational mismatch* for teachers and teacher educators.

Curriculum, classroom context, and focal lesson

Our data come from a 6th grade classroom in the United States using *IQWST*, a curriculum which emphasizes sense-making discussions (Krajcik et al., 2011). During a larger study of teachers' enactment of the same IQWST lessons, we observed an explosive event at the end of a lesson that was designed to help students explain the 'disappearance' of certain components of white light when passing through filters. Prior to the explosion, students discussed patterns in their observations and tried to make sense of *what happened* to those missing colors.

Retrospective analysis

We developed two alternative hypotheses about what led to the Explosion. One is that Ms. J and her students were "on the same page" throughout the discussion, but Ms. J's attempts to steer the class toward consensus led to the disagreement—just like the "explosion" in Berland & Hammer (2012). A second hypothesis is that tacit discord existed throughout the lesson; Ms. J and the students were never fully on the same page. By this account, Ms. J and her students interpreted one another's utterances in ways that convinced them they were "in sync," whereas they were actually framing the discussion in subtly different ways. The explosion occurred when the subtle framing misalignment came fully into view; what counted as explanatory (and hence conversational) closure for Ms. J different from what the students sought in an explanation.

Drawing on both frame and conversational analysis (Goffman, 1986; Pomerantz &Fehr, 1997), we engaged in two rounds of retrospective analysis to identify evidence for both hypotheses. For hypothesis 1, we looked for evidence of "smooth" conversation—bids taken up, conversational repairs quickly offered and taken up, shared expectations about what kinds of responses are appropriate, and so on. For hypothesis 2, we knew from the explosion to look for subtle differences in the epistemological component of framing (Hammer et al., 2005). We engaged in several rounds of review of one another's identified evidence and vetted them looking for confirming and disconfirming evidence. We returned to the classroom video to re-examine tone, inflection, and body language by the teachers and students at particular moments.

Findings

We found evidence to support both hypotheses, with neither set of evidence outweighing the other. Throughout the lessons, the students and teachers appeared to maintain a shared framing of the classroom activity as a discussion of students' ideas, as evidenced by smooth turn-taking (or crosstalk reflecting excitement), taken-up bids for changes in expectations about students' responses (towards more explanation), but with student ideas always valued and foregrounded. Given this evidence, we would have concluded that Ms. J and the students were "on the same page"—if the explosion hadn't prodded us to revisit. However, by focusing on epistemological aspects of how Ms. J and the students were framing the classroom activity, we found evidence for two related misalignments. One was different expectations about which pockets of knowledge the students' explanations should privilege. The students recruited diverse intellectual resources, such as their understanding of color and color mixing. Other students drew on analogies, drawing parallels between the demonstration and a *filter system*, while others relied on the consensus model they constructed earlier in the unit, using words like *absorb*, *transmit* and *reflect* to describe what happened. Ms. J, however, privileged the consensus model. For instance, when one student said the missing colors became invisible and disappeared, Ms. J countered *light cannot disappear*: according to their previous model, light could only reflect, transmit through, or get absorbed. Ms. J repeated her bid for students to use (only) the model, in both day 1 and day 2, indicating that students weren't stably taking up this bid; they continued using pockets of knowledge including but not limited to the consensus model.

Implications for teaching and teacher education

In classrooms where teachers foster students' engagement in authentic science practices while also "covering" pre-determined concepts, —teachers will likely face tensions between (i) facilitating scientific sense-making, which can lead to incorrect explanations, and (ii) guiding students toward the targeted concepts/models (Hammer, 1997). If the teacher's guidance is gentle, a conversational mismatch like the one in Ms. J's classroom can occur; students may frame the activity as *brainstorming/debating mechanistic explanations* while the teacher may frame it as something more like *using science practices to figure out the concepts/model*, especially when time pressure builds. The mismatch could go unrecognized for a while, as in Ms. J's class, because the students and teacher share a broader shared framing of the activity as a *sense-making discussion*.

Ms. J's classroom illustrates, conversational mismatches, once discovered, can lead to negative affect. So, when teachers need to start guiding students toward "correct" ideas, they might consider announcing this shift, explicitly distinguishing *using science practices to figure out the concepts/model* from a more free-form *brainstorming and/or debating mechanistic explanations*. Of course, this move could shut students down. We think it is worth studying whether and how teachers can help students sustain their sense-making even when the students know they are being guided. We also urge studies of ways in which examples such as Ms. J's class could therefore be used in professional development to introduce teachers to *conversational mismatch*, with the goal of helping teachers make more conscious decisions about when and how to shift classroom discussions.

References

Berland, L. K., & Hammer, D. (2012). Framing for scientific argumentation. Journal of Research in Science Teaching, 49(1), 68–94. https://doi.org/10.1002/tea.20446

Goffman, E. (1986). Frame Analysis: An Essay on the Organization of Experience. Northeastern.

Hammer, D. (1997). Discovery learning and discovery teaching. *Cognition and Instruction*, 15(4), 485–529.

Hammer, D., Elby, A., Scherr, R. E., & Redish, E. F. (2005). Resources, framing, and transfer. In J. Mestre (Ed.), *Transfer of Learning: Research and Perspectives* (pp. 89-120). Greenwich: Information Age Publishing.

Hutchison, P., & Hammer, D. (2010). Attending to student epistemological framing in a science classroom. *Science Education*, 94(3), 506–524.

Krajcik, J. S., Reiser, B. J., Sutherland, L. M. & Fortus, D., (2011). IQWST: Investigating and questioning our world through science and technology. Greenwich, CT: Sangari Active Science.

NGSS Lead States. (2013). Next Generation Science Standards: For States, By States. Washington: NAP.

Pomerantz, A., & Fehr, B. J. (1997). Conversation analysis: An approach to the study of social action as sense making practices. *Discourse as Social Interaction*, 2, 64–91.

van Zee, E. H., & Minstrell, J. (1997). Reflective discourse: developing shared understandings in a physics classroom. *International Journal of Science Education*, 19(2), 209.

Acknowledgements

Uncertainty Management in Science Argumentation

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Abstract: The purpose of this study is to investigate how an experienced 5th grade teacher helps students approach and manage uncertainty during scientific argumentation. Transcripts of nineteen lessons over the course of the school year were analyzed using the constant comparative method and the enumerative approach and were coded for social negotiation and epistemic engagement of an argument. Results include that over time the dialogic move gradually shifted from teacher-directed to a more student-directed pathway.

Keywords: Argumentation, uncertainty, social negotiation, epistemic engagement, inquiry

Introduction

Argumentation has recently been advocated a critical need for science education (e.g., National Research Council [NRC], 2012) because it helps students learn to discern what counts as good evidence, manage uncertainties, and reach consensus through dialogic negotiation (Berland & Lee, 2012; Buck, Lee, & Flores, 2014). *A Framework for K-12 Science Education* states: "Scientific knowledge is a particular kind of knowledge with its own sources, justifications, ways of dealing with uncertainties, and agreed-on levels of certainty (NRC, 2012)." However, engaging students in dealing with uncertainty through argumentative practice is ambitious and challenging. Transferring this unique form of practice from expert settings to classrooms is not unproblematic (Watkins, Hammer, Radoff, Jaber, & Phillips, in press); understandably, the intentions and ways that scientists work are not familiar to students.

Uncertainty is defined as "an individual's subjective experience of doubting, being unsure, or wondering," and experiencing uncertainty "likely plays an important role in content learning and in interaction during collaborative learning tasks." (Jordan & McDaniel, 2014). This study aims to unpack and track how an experienced teacher engages fifth-grade students in dealing with uncertainties over the course of a school year. Previous research on uncertainty during the development of scientific understanding has focused on the experiences of individual students (e.g., Chen, Park, & Hand, 2016; Metz, 2004) or small groups (e.g., Jordan & McDaniel, 2014) rather than of the class as a whole. This study aims to add to the body of knowledge regarding uncertainty during argumentation by considering the social negotiation and epistemic engagement of an argument that take place during whole-class argumentation.

Methods

The Science Talk Writing Heuristic (STWH) approach (Chen, Benus, & Yarker, 2016) was utilized to create curriculum and instructional strategies that promote building disciplinary core ideas while using talk and writing to engage students in scientific practices. The STWH approach consists of five phases: (1) exploring beginning ideas/generating an inquiry question, (2) designing tests/observations to gather data, (3) engaging in social negotiation to debate claim/evidence, (4) reading to compare ideas with experts, and (5) reflecting through writing. Given the purpose of this study, i.e., how a teacher helps students engage in managing uncertainties through social negotiation, the analysis focused on the third phase.

Nineteen classroom observations of whole-class discussions were purposefully selected over four units—ecosystem (six classes), human body system (six classes), day and night (three classes), forces and motion (four classes). Each unit had the same overall structure, starting with a "big idea" to guide students' questions, investigations, and whole-class discussions that occurred after students designed and conducted experiments to answer their guiding question about the "big idea" (Chen, Hand, & Park, 2016).

The analysis of the nineteen classes involved two complementary analytical approaches: (1) the constant comparative method (Strauss & Corbin, 1990) and (2) the enumerative approach (LeCompte & Preissle, 1993). All nineteen classroom observations were transcribed and each transcript was broken into individual utterances, defined as an idea that contributed to the discussion. Because this study is particularly interested in how teacher and students use social negotiation (e.g., collaboratively construct and critique arguments to build consensus) and epistemic engagement of an argument (e.g., understand what counts as a good argument and apply that understanding to argumentation) as resources to manage uncertainties (Duschl, 2008), each utterance was coded for both social negotiation and epistemic engagement. Figure 1 shows the coding scheme as applied to one event in the sixth transcript of the first unit (ecosystem), in which one group of students stated their claim about the

effect of temperature on the germination of seeds to the rest of the class, and the teacher raised uncertainty by asking the group to clarify their claim. The resulting discussion involved social negotiation and epistemic engagement of an argument by both teacher and students, at the end of which the group restated their claim.

Transcript 01, Event #6 – Temperature Group presents their claim
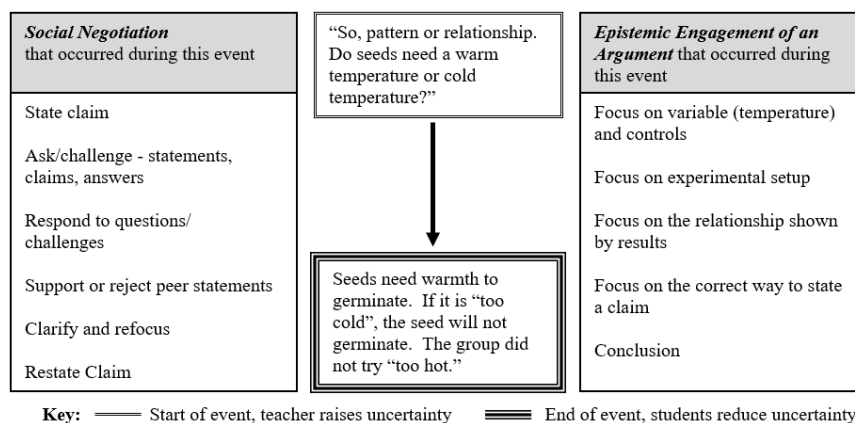
Figure 1. Event map from the ecosystem unit showing the social negotiation and epistemic engagement of an argument components of a teacher-directed dialogic pathway (see Results, below).

Results

Three dialogic pathways have been identified through analyzing each event: (1) teacher-directed pathway: teacher raises an uncertainty, guides and intervenes to maintain the uncertainty through engaging students to evaluate and improve their arguments, and resolve the uncertainty resulting in the group reaching a consensus, (2) serpentine pathway: teacher or students raise an uncertainty, teacher and students cooperate together to maintain and resolve uncertainty, and (3) students-directed pathway: students raise an uncertainty, maintain an uncertainty through comprehending, constructing and critiquing the argument, and eventually resolve the uncertainty. As the semester proceeded with increasing opportunities for students to engage in uncertainty management, the dialogic moves shift from teacher-directed to serpentine and student-directed pathway. Students started to learn how to raise, maintain, and resolve uncertainty.

References

Berland, L. K., & Lee, V. R. (2012). In pursuit of consensus: Disagreement and legitimization during small-group argumentation. *International Journal of Science Education, 34*(12), 1857-1882.

Chen, Y. C., Benus, M. J., & Yarker, M. B. (2016). Using models to support argumentation in the science classroom. *The American Biology Teacher*, *78*(7), 549-559.

Chen, Y. C., Park, S., & Hand, B. (2016). Examining the use of talk and writing for students' development of scientific conceptual knowledge through constructing and critiquing arguments. *Cognition and Instruction, 34*(2), 100-147.

Duschl, R. (2008). Science education in three-part harmony: Balancing conceptual, epistemic, and social learning goals. *Review of Research in Education*, *32*(1), 268–291.

Jordan, M. E., & McDaniel, R. R. (2014). Managing uncertainty during collaborative problem solving in elementary school teams: The role of peer influence in robotics engineering activity. *Journal of the Learning Sciences*, *23*(4), 490–536.

LeCompte, M. D., Preissle, J., & Tesch, R. (1993). Evaluating qualitative design. *Ethnography and qualitative design in educational research*, 315-356.

Metz, K. E. (2004). Children's understanding of scientific inquiry: Their conceptualization of uncertainty in investigations of their own design. *Cognition and Instruction*, *22*(2), 219–290.

National Research Council (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: National Academies Press.

Strauss, A. L., Corbin, J. (1990). *Basics of qualitative research (Vol. 15)*. Newbury Park, CA: Sage.

Watkins, J., Hammer, D., Radoff, J., Jaber, L. Z., & Phillips, A. M. (2018). Positioning as not-understanding: The value of showing uncertainty for engaging in science. *Journal of Research in Science Teaching, 55*(4), 573-599.

The Santa Trap: When Scaffolding is Not Enough to Challenge Teachers' Pervasive Beliefs

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Abstract: In this poster, we examine how middle school teachers performed on a task adapted from a study with high school students. We asked 32 middle grades teachers to complete a think-aloud protocol that included the task with three scaffolds to determine whether teachers performed differently than students.

Keywords: Proportional Reasoning, Teacher Knowledge, Mathematics

Major issue addressed and potential significance

Research has shown that students often use linear reasoning in nonlinear situations. In one such study, De Bock, et al. (2002) examined students' reasoning about the Santa Task, which provides two images of Santa: one is small and the other is similar but dilated to be three times taller. The task asks how much paint will be needed to paint the taller Santa, which is 168 cm tall, if 6 ml was needed to paint the smaller Santa, which is 56 cm tall. In their study, De Bock et al. posed the Santa Task with scaffolds to help students (ages 12-13 and 15-16) attend to the area relationship. The researchers found that two students were initially able to answer the Santa task correctly. Even with the five scaffolds, only 32 of the 40 participants were able to determine a correct answer.

Because we are interested in teachers' knowledge of the mathematics they teach, we wondered how teachers would respond to a version of this task. We modified the task scaffolds to be teacher appropriate. Scaffold 1 presented teachers with two different answers from the students in the class: 18 ml and 54 ml and asked the teacher how the students with the wrong answer might be reasoning about the task. In Scaffold 2, we provided the Santa images with rectangular boxes drawn around each. We asked teachers whether this would be a productive approach. In Scaffold 3, the hypothetical student simplified the task by treating the original quantity of paint used as 1 tube and used that to find the new quantity. Again, we asked whether this would be useful for students. In this poster, we examine the teachers' engagement with this set of tasks and its implications for teachers.

Despite the importance of proportional reasoning in the curriculum, little is known about how teachers reason about proportions (Lamon, 2007). There is a growing body of research focused on teachers' understanding of proportions, covariation (e.g., Thompson et al., 2017), and the relationship between teachers' understanding of proportions as it relates to their teaching (Copur-Gencturk, 2015). We add to this literature by examining how teachers understand one relationship with a goal of improving teacher development.

Theoretical and methodological approaches

We work from the knowledge in pieces perspective (diSessa 2006), which posits that understandings develop as fine-grained knowledge resources that are refined and connected through our experiences. From this view, developing expertise requires creating connections between knowledge resources as well as creating more knowledge resources. Thus, learning needs to be comprised of both knowledge resource development and knowledge resource linking opportunities.

To study teachers' understanding of whether proportional reasoning was appropriate for this task, we included the task in a think-aloud protocol sent to 32 teachers from four states. Their responses were captured using Livescribe pens that allowed us to capture both their voices and their written inscriptions. Data were transcribed verbatim. For this paper, we considered whether a participant's response was correct, after which scaffold each participant's reasoning became correct, and what resources were used in solving the task.

Major findings

Similar to the original study of high school students, teachers in this study were misled by the task. Of the 32 participants, nine (28%) (correctly) used an area-interpretation from the outset. Three teachers found their error in scaffold 1 and corrected their responses, none corrected their responses in scaffold 2, and one corrected their responses in scaffold 3. By the end of the task, only 13 (40%) of the 32 teachers solved the task using area interpretation rather than a height-only interpretation.

Teachers' abilities to correctly reason about the Santa situation was critical to their ability to make sense of the student work presented. Teachers who were reasoning mathematically correctly had a much higher likelihood of making sense of the students' responses than those who were not using correct reasoning. For example, in Scaffold 1, all 13 teachers who used area reasoning were able to identify the mistake the students had made. In contrast, none of the teachers using height-only reasoning did this. In Scaffold 2, 12 of the 13 area-reasoning teachers believed that drawing the frame around the Santa would be useful. Many noted that it would help students see both height and width. Of the height-only reasoners, six (32%) recognized that the frames helped to show area, but this did not change their thinking. Four of the 19 height-only teachers (21%) saw the frame as highlighting one dimension (e.g., height), and six rejected (32%) the frames saying the frames inappropriately focused students on area, which they perceived to be incorrect. Scaffold 3 was harder overall. Among teachers (correctly) attending to area, nine (69%) believed that using easier numbers was appropriate and usable for their students. Two were okay with the hypothetical student using the approach, but would not want their own students to use it and three teachers (23%) were unable to make sense of the situation. In contrast, none of the height-only reasoners believed this was a useful approach. Eight of the 19 (42%) pointed out that it yielded incorrect answers and six (32%) could not make sense of what was happening or were unclear. Interestingly, four (21%) of the teachers rejected this approach because they believed that one cannot reason about tubes as the unit in this way.

Conclusions and implications

Consistent with DeBock et al. (2002), participants in this study were lured to interpret the Santa Task as being about one dimension. As mentioned above, four of the 19 height-only reasoners rejected using a simpler task (Scaffold 3). Data suggests that the teachers did not recognize that this was an appropriate approach because 9 : 1 is the same relationship whether it is describing 9 tubes to 1 tube or 9 ml to 1 ml. The teachers' approach to the task itself suggests that teachers are not making appropriate sense of the task. This adds to literature suggesting that teachers need additional opportunities in determining the nature of tasks (e.g., Izsák & Jacobson, 2017). Finally, teachers who approached the task incorrectly were unable to follow student reasoning in the three scaffolds. The main implication of this is that it suggests teachers' abilities to make sense of student thinking is tied to students' abilities to produce expected answers.

References

Copur-Gencturk, Y. (2015). The effects of change in mathematical knowledge on teaching: A longitudinal study of teachers' knowledge and instruction. Journal for Research in Mathematics Education, 46, 280-330.

De Bock, K., Van Dooren, W., Janssens, D., & Verschaffel, L. (2002). Improper use of linear reasoning: An in-depth study of the nature and irresistibility of secondary school students' errors. Educational Studies in Mathematics, 503, 311-334.

diSessa, A. A. (2006). A history of conceptual change research: Threads and fault lines. In R. K. Sawyer (Ed.), The Cambridge handbook of the learning sciences (pp. 265-282). New York: Cambridge University Press.

Izsák, A., & Jacobson, E. (2017). Preservice teachers' reasoning about relationships that are and are not proportional: A knowledge-in-pieces account. Journal for Research in Mathematics Education, 48(3), 300-339.

Lamon, S. (2007). Rational numbers and proportional reasoning: Toward a theoretical framework for research. In F. K. Lester (Ed.), Second handbook of research on mathematics teaching and learning (pp.629-667). Reston, VA: National Council of Teachers of Mathematics.

Thompson, P. W., Hatfield, N. J., Yoon, H., Joshua, S., & Byerly, C. (2017). Covariational reasoning among U.S. and South Korean secondary mathematics teachers. Journal of Mathematical Behavior, 48, 95-111. doi: 10.1016/j.mathb.2017.08.001

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Developing Historical Thinking in PBL Class Supported With Synergistic Scaffolding

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Abstract: As PBL has gained popularity across disciplines, there is an increasing need to understand how to successfully implement PBL in a large classroom. In this study, we investigated how PBL was used to support development of historical thinking skills in a large university history class. Video analysis showed that the instructor interacted with both the students and representational tools to provide multiple synergistic supports during the PBL sessions.

Although Problem-based Learning (PBL) has been studied in a variety of contexts (e.g., Walker et al., 2015), PBL in large active learning classrooms has been less well studied. Adapting PBL for large classes requires a careful balance of PBL practices with the interactions in which PBL scaffolding is provided (Puntambekar, 2015). In PBL, instructors employ multiple forms of scaffolds to support collaborative learning and disciplinary problem-solving. These scaffolds include shared representational tools like structured whiteboards, but an instructor's timely and contingent support is a crucial scaffolding element; this is generally only possible in classrooms with a small instructor-to-student ratio (Puntambekar, 2015). Visual representations make student thinking visible to instructors in large classrooms, allowing quick access to the current state of students' inquiry process and making synergistic scaffolding possible. Our PBL intervention was situated in a large university history classroom, in which small groups of students arranged at oblong tables equipped with whiteboards and large computer monitors to serve as shared representational tools. The tables fostered collaboration in an open active learning space where instructors could wander and engage with the students. We focused on investigating interactions between the instructor and students as they used these representational tools in order to understand how PBL was appropriated among students in order to develop historical thinking skills, and how multiple forms of scaffolding function in a synergistic and contingent way to make PBL in this large learning space achievable for both instructor and students.

Methods

This study was conducted with 93 undergraduate students in a large PBL history classroom at a public Midwestern University. Students were divided into 16 groups of 5-6 students in an active-learning classroom with oblong tables that promote small-group collaboration via shared table space and a large shared monitor. Five groups volunteered to participate in the research and were video-recorded during three 75-minute class sessions. Open space between tables facilitated a larger shared workspace by allowing the instructor and 2 teaching assistants to wander and observe the groups in between the instructor's mini lectures to the whole class. Students anchored their PBL in an ill-structured question about historical responses to bubonic plague, and each PBL encounter added iterative complexity to the question. The first question asked, "What *single* element was the most significant factor in the responses to plague in the 6th century Justinianic Plague?"; the second asked "What *two* elements interacted to explain responses to plague in the 14th century"; the last question asked "What *single* element helps explain plague in three different outbreaks (6th century, 14th century and 20th century)." In the first two interventions, groups were required to organize their historical thinking via a structured collaborative PBL workspace divided into 4 quadrants. These quadrants integrated history-learning principles from the American Historical Association (AHA) together with the inquiry-oriented principles of PBL: "potential hypotheses", "what we know (evidence with citations)", "what we don't know", and "research agenda". In the third intervention, students were given an open-ended question and allowed to structure their own group collaboration.

Five groups were video recorded three times in the semester. We then narrowed our focus to three groups that were provided with different representational tools (either computers, whiteboards or iPads). Interaction Analysis (IA) was employed to observe the distributed and ongoing social processes which occur moment-to-moment during collaboration in order to gain insights into students' development of historical thinking skills and instructor provision of contingent scaffolding for students learning (Jordan & Henderson, 1995).

Findings

Over the course of the three PBL sessions, students gradually began to appropriate the norms of PBL to refine their responses to, and marshal evidence for, increasingly complex questions. At the first PBL session, students

struggled with understanding PBL, with the ill-structured problem, and with finding appropriate evidence to support their hypotheses. For example, one student asked "What are we supposed to do?" on first encounter with the PBL task, and another student answered "5 minutes to be confused." This conversation demonstrated that students struggled with the PBL process while also admitting that it was acceptable to be confused in the "messy" and complex PBL learning environment.

However, students gradually appropriated the PBL process to develop historical thinking skills over time with multiple forms of scaffolding functioning in a synergistic and contingent way. For example, at the second encounter of PBL session, the visual representations of PBL quadrants on whiteboard, computer and iPad exposed students' reasoning process, allowing the instructor to assess the current status of the group's inquiry process and give adjusted feedback in a more responsive and contingent manner. In particular, the PBL quadrant made students' thinking immediately visible to the instructor without the instructor interrupting the discussion or making students repeat themselves. The instructor's responses throughout the discussion drew on the students' visual representation of their thinking to validate the students' performance in the inquiry process to date. (i.e., instructor's asking "Is there an element of, you guys had talked about medical response?" and suggesting "So, now you need to hunt down evidence and figure out how to go get more.")

At the third encounter of the PBL session, students demonstrated that they had appropriated not only the underlying disciplinary norms that required them to synthesize three separate historical contexts into one argument but also the value of elaborating the argument in a shared PBL quadrant. More importantly, the instructor's scaffolding was taken up by the students properly and was effective. For instance, the students appeared to regulate their argumentation process, as evidenced by the statement that they should clearly indicate the draft nature of their statement so the instructor "doesn't come and say that doesn't make sense." Here, students acknowledged the fact that they would receive ongoing feedback based on what was written on the quadrant. The integration of PBL norms, instructor scaffolding, and representational tool allowed students to advance their reasoning but in a very cautious and mindful way (i.e., using "not complete" wording on the whiteboard). This kind of interaction demonstrated how the PBL quadrants supported both instructor evaluation of, and feedback, about student selection of the vocabulary that would best demonstrate their historical thinking skills, as well as the challenge inherent in student appropriation of historical norms. (i.e., student's initial frustration "Oh, my god")

Discussion

This study illustrates how PBL, and particularly visual representations of students learning process, can support the development of historical thinking skills in large undergraduate classrooms in an active learning environment. By co-constructing the PBL quadrants, students in a history classroom were able to engage in an inquiry-oriented activity by generating multiple hypotheses to answer a central problem. This activity can be considered as *doing* history, which involves navigating multiple perspectives, evaluating the reliability of evidences the students built, and experiencing the nature of history which is interpretive and ill-structured (Monte-Sano, 2012). As the semester unfolded, student inquiry strategies evolved over time, in the later stages of the class, students demonstrated the ability to craft strong hypotheses, locate appropriate evidence to support these hypotheses and evaluate the validity of a hypothesis without the instructor's explicit support. These learning processes were possible in a large PBL classroom because of the affordances of synergistic scaffolding. The representational tools common to PBL not only served as a communication channel to mediate student learning processes but also allowed the instructor to provide more contingent and efficient scaffolding without interrupting students. The instructor's actions with the tools allowed her to successfully implement contingent scaffolding despite the generally perceived difficulty of doing so in a large classroom. Although more studies will be necessary in other disciplinary environments, we argue that this study effectively demonstrates the promise of PBL in a large history classroom, provided that care is taken to provide synergistic scaffolding that effectively integrates the instructor, students, and representational tools.

References

Jordan, B., & Henderson, A. (1995). Interaction analysis: Foundations and practice. *Journal of the Learning Sciences, 4*, 39-103.

Monte-Sano, C. (2012). Build skills by doing history. *Phi Delta Kappan, 94*(3), 63-65.

Puntambekar, S. (2015). Distributing scaffolding across multiple levels: Individuals, small groups, and a class of students. In A. Walker, H. Leary, C. E. Hmelo-Silver & P. Ertmer (Ed.), *Essential readings in problem-based learning* (pp. 207–221). Indiana: Purdue University Press.

Walker, A. E., Leary, H., Hmelo-Silver, C. E., & Ertmer, P. A. (Eds.). (2015). *Essential readings in problem-based learning*. Purdue University Press.

Personal Experience and Emotion in Making Sense of Literary Texts

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Abstract: In academic contexts, students' everyday knowledge and understandings are often undervalued as instruction attempts to supplant these with sanctioned content. However, in reading and interpreting literary texts, personal experience and emotional reactions can both guide and inform reader sense-making of texts. This work looks at how students' personal insights, emotions, and experience enrich discussions of literary texts and contribute to broader understandings of human nature and the world.

Introduction

Literary texts offer readers opportunities to explore ideas about the world and human nature in relation to their own experiences and through discussion with others of various perspectives on the text. In making sense of literary texts, readers rely on various types of knowledge, including knowledge of the genre, author, cultural and historical context, and rhetorical devices. However, making meaning with literary texts is also informed by personal experiences, social interactions, and cultural understandings (Lee, Goldman, Levine, & Magliano, 2016). Readers often use literary narratives to make sense of human actions and events of the world as these texts mirror human reality (Mar & Oatley, 2008). In addition, readers often react to characters and events with emotions rooted in sympathy, empathy, or identification (Mar, Oatley, Djikic, & Mullin, 2011) that may alter the way readers see the world. Therefore, in literary reasoning, what a reader brings to a text through personal experience or emotional connection is an integral part of reading and interpreting texts.

Learning environments designed to support literary reasoning need to consider the importance of what students bring to the interpretive process as well as the knowledge, skills, and strategies students need to be able to make sense of literary texts. Research around instructional interventions to support literary reasoning practices indicates the importance of sequencing texts and tasks (Sosa, Hall, Goldman, & Lee, 2016), of providing students with opportunities to learn explicit strategies related to literary interpretation (Lee, 2007; Levine, 2014), and of using class discussions to build understanding (Applebee, Langer, Nystrand, & Gamoran, 2003). Discussions allow spaces for students to make sense of texts while listening and responding to the ideas of others. Indeed, discussions before, during, and after reading serve as bridges between students' own world and experiences and the texts as well as provide opportunities to listen to and explore others' perspectives on text and on the world.

Students' personal experiences, emotions, and expertise play a pivotal role in meaning-making but are often treated as less pertinent and, therefore, are rarely foregrounded. We base our work on the idea that drawing from student expertise about the social world promotes meaning making and transaction with texts. Accordingly, we examined classroom discussions to understand the role of student experiences, emotions, and expertise.

Methods

This work draws from a year-long study that focused on interactions and learning enabled by students sharing their embodied experiences and related understandings of the social world, while explicitly learning interpretive strategies necessary to connect their insights to literary texts. The focus class was a regular tracked 9th grade ELA class in a large urban district with a White male teacher and 30 students: 25 Black, three Latino, and two White.

Table 1: Lesson descriptions

Lesson	Text	Objective
A	Images of racist mascots	Build socio-historical understandings of racism and exclusion of Native Americans prior to reading story
B	Short poem: "For Black Poets Who Think of Suicide"	Practice discussion techniques and interpretive strategies with unfamiliar poem
C	An autobiographical piece titled, "With a little help from my friends."	Connect to the experiences of the author after reading autobiographical excerpts
D	Statements around themes for novel: *Of Mice and Men*	Explore ideas around themes related to novel prior to reading the novel

This study examines four classroom lessons described in Table 1 that took place during the first semester of the school year. Data sources were video recordings and field notes from classroom observations. The video was transcribed, and each discussion was analyzed for the types of knowledge and practices that the participants used to make sense of literary texts. Focus was on how personal experiences, emotional reactions, and cultural understandings were made explicit in the discussions and how those contributed to collective sense-making.

Findings

Analyses indicated that discussions that were centered on students' ideas, experiences, connections, and feelings with texts supported them in building understandings as a basis for literary interpretation. These discussions created a space in which students were willing to ask questions and seek clarity about surface aspects of texts. This is important as readers must know the basic character and plot information before engaging in higher level interpretation (Hillocks & Ludlow, 1985). For example, students were open about not being sure if Native Americans still existed in the United States, about assuming the main characters in *Of Mice and Men* were Black during the first few chapters, and about the reality that mascots many deem racist are still used by major sports teams. Understanding characters and the implications of how authors portray them is essential for making interpretive arguments. Students also related character experiences and their own social world. For example, students connected the argument around the use of the N-word, a highly offensive racial slur for Black people, (Lesson D) to discussions related to racist mascots and Native Americans (Lesson A) by noticing how charged racist names are and how heavily the offense is related to who uses the terms.

In addition, analyses revealed that students connecting their understandings of the social world to the text world focused attention to the ways language is used and its function such as symbolism, metaphors, and imagery. For example, students' recognition of Native Americans rarely being discussed in the media, and thus more easily portrayed in racist mascots (Lesson A), led them to read the short story as more than a one-time racist incident of a white police officer stopping a van of Native Americans and accusing the driver of drinking. After reading a character described as struggling "against his weight," a student noted, "I think they are talking about emotional weight," realizing that the weight was literal (the character is described as a 280-pound teenager) as well as symbolic of ongoing racism. Similarly, students initially considered the poem (Lesson B) racist, but focusing on certain language led to the idea that it might be a message to Black people not to be like White people. Ultimately, a student noted that the last stanzas were not about racism and began to identify with the people of the text: "The author says all these things that make us who we are. He's like, 'Black people are flutes, the warriors and survivors through this situation.' Like we never gave up." Her focus on the explicit language of Black voice and expression allowed for personal identification with the poem as well as reflection on its broader message.

Significance

Overall, this work indicates the value of allowing space for student experience, emotion, and expertise in making sense of texts and the importance of teachers leveraging these understandings and connections as ways to clarify, extend, and deepen meaning making and transaction.

References

Applebee, A. N., Langer, J. A., Nystrand, M., & Gamoran, A. (2003). Discussion-based approaches to developing understanding: Classroom instruction and student performance in middle and high school English. *American Educational Research Journal, 40*, 685–730.

Lee, C. D. (2007). *Culture, literacy, and learning: Taking bloom in the midst of the whirlwind.* New York, NY: Teachers College Press.

Lee, C. D., Goldman, S. R., Levine, S., & Magliano, J. (2016). Epistemic cognition in literary reasoning. *Handbook of epistemic cognition,* 165-183.

Levine, S. (2014). Making Interpretation Visible With an Affect-Based Strategy. *Reading Research Quarterly, 49*, 283–303.

Mar, R. A., & Oatley, K. (2008). The function of fiction is the abstraction and simulation of social experience. *Perspectives on psychological science, 3*(3), 173-192.

Mar, R. A., Oatley, K., Djikic, M., & Mullin, J. (2011). Emotion and narrative fiction: Interactive influences before, during, and after reading. *Cognition & emotion, 25*(5), 818-833.

Sosa, T., Hall, A. H., Goldman, S. R., & Lee, C. D. (2016). Developing symbolic interpretation through literary argumentation. *Journal of Learning Sciences, 25, 93-132.*

Frictional Patterns in the Design of Games for Learning

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Abstract: This work presents a case study of a game-based learning prototype to define *frictional design patterns* – design decisions that knowingly impede some specific user interaction – as a type of pattern to support learning with games. We evaluate frictional design patterns by applying the concept to a game focused on scientific argumentation in order to examine the balance between data collection requirements and players' access to information required for certain in-game epistemic performances.

In this paper, we advance the concept of *frictional design patterns*. A pattern in general is a reusable solution to a common design problem, whereas a frictional one, as we define it here, is one that knowingly and necessarily makes some specific user interaction more cumbersome. Frictional patterns may be seen as one way to design desirable difficulties – challenging circumstances that "trigger encoding and retrieval processes that support learning…" (Bjork & Bjork, 2011, p. 58). The goal of using frictional patterns is to explicitly document design decisions made to facilitate or detect learning outcomes, yet which also negatively impact users' experiences in some way, ideally so these impacts can be mitigated elsewhere or accounted for in analyses of players' behavior.

Defining frictional patterns

Many fields of design, such as software and interaction design, distinguish between design principles and design patterns to communicate different forms of design knowledge (Gamma, Helm, Johnson, & Vlissides, 1995). In this scheme, *principles* are abstract rules presumed to be useful across most contexts. *Patterns*, on the other hand are reusable solutions to frequent, concrete design problems (e.g., creating an adapter to let two ordinarily incompatible components interface with one another). Respectively, designers may also refer to *anti-patterns*, or common solutions to design problems that may seem appealing at face value, but which are actually counterproductive or detrimental. User interaction designers have also recently classified *dark patterns*, which are those that are "used intentionally by a game creator to cause negative experiences for players which are against their best interests" (Zagal, Björk, & Lewis, 2013, p. 45). The design requirements of games for learning suggest a need for a special class of patterns, which we call *frictional patterns*, that serve to reconcile competing aims that arise from educational and game design best practices, and which serve as explicit reminders of design compromises selected. We define a frictional pattern as *a pattern that is used in a designed experience which resembles a typical user-centered experience, where fulfilling a design requirement necessitates holding some proximate user interest in abeyance*. This definition acknowledges that users have a set of expectations on the basis of their prior experiences with other similar designs; we generalize the field of applicability beyond digital games, however, as frictional patterns may be used in traditional games, as well as in non-game-based computerized learning environments. This definition furthermore differentiates frictional patterns from dark patterns. While both types of patterns advance designers' interests in favor of users' interests, a frictional pattern is at worst a minor or temporary setback in users' goals and does not violate their long-term aims or autonomy.

Frictional patterns in practice

Researchers working in the sub-field of epistemic cognition have identified a need for designs that elicit evidence of learners' knowledge and justifications (e.g., Sandoval, 2012). Moreover, Chinn, Rinehart, and Buckland (2014) have argued that scholars must find evidence of learners' aims in order to interpret their epistemic practices. Consequently, a constraint adopted for the present work was to *design interactions that would render changes in players' attention more directly observable during the course of play* without requiring specialized hardware or clinical testing environments. This general technique was used by Danielak and colleagues (2014) in an early prototype of a museum-based game focused on engineering, where players had to explicitly open a modal window in the interface in order to review their progress. This action was logged on players' devices, allowing the study's authors to make inferences about players' goal orientations during play. It was therefore conjectured that using a similar pattern for actions that are performed frequently could provide one source of data regarding the trajectory and cadence of players' epistemic aims in a game.

The game used in this case study is a hybrid digital/tabletop game focused on paleobiology, where two players cooperate to uncover features of a specimen and are rewarded for using these features to make inferences about other features the specimen might have. Players use a companion app on touchscreen devices

to create mathematical models relating these features, and they can use these models to warrant arguments they make about the specimen. The app also serves as a personal reference, where players can inspect technical terms on-demand. While good game design traditionally calls for providing explicit information just-in-time (Gee, 2003), information essential for model evaluation was intentionally obfuscated behind interface elements in order to generate more unambiguous data regarding what players are looking at, how much time they spend looking at it, and so on. As such, the app's model browser displays confidence ranges for a predicted characteristic under different input conditions, but players must touch and hold on affordances in the interface to view detailed descriptions of the confidence ranges, as well as to see the *strength* values the model confers (the latter of which is the only piece of mechanically relevant information in the context of the game).

The data in the pilot test covered here come from two adults who regularly play games with one another. Data collected include audio and video recordings of the participants, video recording of the game board, as well as screen recordings and log data from players' touch screen devices. Neither the sample nor this study is intended to be representative of a broader population. Rather, we provide an example of how a *frictional design pattern* can impact players' learning and activity in a game.

At the beginning of the game, Player 1's utterances focused primarily on victory points and strength values, indicating a proximate aim of advancing her state in the game. The log and video data revealed that her reading of model descriptions in the app was fairly cursory during this period, focused on skimming to find strength values. However, when she created an argument with zero strength (a move not explicitly disallowed in the rules), there was some disagreement regarding how to interpret her model. For example, Player 1 suggested that the model indicated that "the likelihood of these two features leading to a predator is not...strong." to which Player 2 replied "the way I interpreted what it said was that it just doesn't have enough evidence to make the case that it is strong or not." Player 1 puzzled through this interpretation aloud, tentatively agreeing that "there's not enough evidence to, to predict one or the other." After this exchange, Player 1 spent longer periods of focused time interpreting descriptions in the app when creating new models. This shift, as evidenced by identifiable jumps in her cumulative time spent reading model descriptions following this event, reflected changes in her play strategy and hence her orientation from simply *how to score points* in accordance with the rules to *how to make a coherent argument*. The culmination of this effort occurred three turns later when she produced an argument to her satisfaction, exclaiming "Finally! I did something right."

Conclusions

The example discussed here shows how one low-level interface decision can explicitly deviate from traditional usability standards while generating evidence required to understand player activity. Characterizing this decision as a *frictional pattern* allows us to clearly document the expected impacts on usability and user comprehension. By explicitly defining frictional patterns in design work, it becomes possible to better qualify the positive value of specific impairments to usability in design-based research.

References

Bjork, E. L., & Bjork, R. (2011). Making things hard on yourself, but in a good way: Creating desirable difficulties to enhance learning. In M. A. Gernsbacher, R. W. Pew, L. M. Hough, & J. R. Pomerantz (Eds.), *Psychology and the real world: Essays illustrating fundamental contributions to society* (1st ed., pp. 55–64). New York, New York: Worth Publishers.

Chinn, C. A., Rinehart, R. W., & Buckland, L. A. (2014). Epistemic cognition and evaluating information: Applying the AIR model of epistemic cognition. In D. N. Rapp & J. L. G. Braasch (Eds.), *Processing inaccurate information: Theoretical and applied perspectives from cognitive science and the educational sciences* (pp. 425–453). Cambridge, Massachusetts: MIT Press.

Danielak, B. A., Mechtley, A., Berland, M., Lyons, L., & Eydt, R. (2014). MakeScape Lite: A prototype learning environment for making and design. In *Proceedings of the 2014 Conference on Interaction Design and Children - IDC '14* (pp. 229–232). Aarhus, Denmark.

Gamma, E., Helm, R., Johnson, R., & Vlissides, J. (1995). *Design patterns: Elements of reusable object-oriented software*. Boston, Massachusetts: Addison-Wesley.

Gee, J. P. (2003). *What video games have to teach us about learning and literacy*. New York, New York: Palgrave Macmillan.

Sandoval, W. A. (2012). Situating epistemological development. In *The future of learning: Proceedings of the 10th international conference of the learning sciences* (Vol. 1, pp. 347–354). Sydney, Australia: International Society of the Learning Sciences.

Zagal, J. P., Björk, S., & Lewis, C. (2013). Dark patterns in the design of games. *FDG 2013 - 8th International Conference on the Foundations of Digital Games*, *1*(312), 39–46.

BioSCANN: A Collaborative Learning Platform That Scaffolds Scientific Inquiry in the Context of Interrupted Case Studies

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Abstract: We present BioSCANN, a collaborative learning platform that scaffolds scientific inquiry in the context of Interrupted Case Studies. This technology-enhanced curriculum engages students by integrating experimental design and career awareness in the context of drug discovery. It supports teacher orchestration of scientific argumentation and builds student conceptual understandings, career awareness, and self-efficacy. Preliminary results from six classrooms will be presented, providing insights into facilitating learning and career awareness both with and without technology.

Science, technology, engineering, and mathematics (STEM) education has experienced a shift away from the memorization of facts, figures, and procedures toward engaging students in more authentic science practices and scientific argumentation. In response to this challenge, scholars have advanced the methods of collaborative problem-based learning (PBL) as a pedagogical framework to increase student understanding of science and long-term retention of content, as well as to improve their critical thinking skills, metacognition, willingness to assume difficult tasks, persistence, motivation, and transfer of learning to new situations (Fortus, Krajcik, Dershimer, Marx & Mamlok-Naaman, 2005; Kolodner et al., 2003; Strobel & van Barneveld, 2009). In our own prior research (Jacque, 2015), we have advanced a more structured model of case-based learning using *interrupted case studies* (ICS) that scaffold evidence-based argumentation from scientific data given in piecemeal, building risk assessment skills critical for 21st-century health literacy in high school biology classrooms. By structuring cases into a clear progression, we provide "interruption points" that allow teams of students to stay in sync and give teachers an opportunity for planned or spontaneous whole-class discussions. This format also allows teachers multiple opportunities to pose questions, review student responses, and to use those responses to address student conceptions and to model answering questions appropriately (Herreid, 2005).

The ICS approach can be challenging for teachers and to address this we have developed a web-based interactive learning environment called *BioSCANN* that scaffolds *ICS-based* learning scenarios that engage high school students in collaborative scientific inquiry and argumentation. The BioSCANN technology environment can be used to author a unique workflow for an ICS that allows students to progress through set points of reflection. At each step in the ICS, students use the Question-Method-Data-Conclusion framework to assess their scientific argumentation. Students document their thinking and work in BioSCANN's collective knowledge space and use this to discuss and debate issues. After making a decision based on data, the team then elects the next path to take, allowing for a choose-your-own-adventure, game-like feel that inspires ownership. In this way, BioSCANN responds to the challenges of enacting ICS by: (1) allowing for multidirectional decision making – in which students can choose their own path of inquiry; (2) providing distinct content to each group to encourage classroom discourse; (3) utilizing interactive technologies for group decision-making and reporting to the class; (4) creating a common data and results archive that supports teacher facilitation of scientific argumentation (SA). *BioSCANN* provides scaffolding that mimics the step-by-step iteration of scientific discovery and practices, while providing instructors with opportunities to manage discourse.

In its current iteration, the BioSCANN curriculum is a five-day experience in which high school students are placed in teams that each play a distinct role as a member of a drug discovery team (animal care technician, financial consultant, research scientist, and medicinal chemist). The curriculum challenges students to work together in groups to design a new drug to combat HIV.

The BioSCANN web platform facilitates the three phases of the ICS process: Exploration: Student groups use career-relevant information (roles) in the context of the specialized experimental methods and data and are asked to solve the challenge of the day. Each group has only a small piece of the data needed to reach a comprehensive class-wide conclusion. In this phase, the teacher takes on the role of 'guide at the side'. Discourse: The entire class then coheres as a knowledge community to critique, debate and revise explanations, and make decisions guided by the teacher. In this phase the teacher takes on the role of 'mentor at the center,' orchestrating class-wide student discourse while, modeling the process of SA. Synthesis: Students then utilize evidence (data), to draw conclusions and explanations to select the next step they will take as a design team. In this phase, the teacher reprises their 'guide at the side' role as students return to their groups to synthesize findings and ideas and

to formulate the questions that will form the foundation of the next iteration of the three phases of the ICS. In short, BioSCANN acts as a scaffold for scientific argumentation via ICS and is a tool to facilitate the community's inquiry process.

The major research goals of this project are to better understand a) how to engage a broad range of students in STEM-cognate careers and 2) to increase their skills in data interpretation and evidence-based problem solving. In the first year of the project, we worked towards this goal by adapting a measure of career interest and goal setting, Social Cognitive Career Theory (SCCT), provided to us by Dr. Robert Lent, one of the scholars who created the theory. This new tool measures Self Efficacy (SE), Outcome Expectations (OE), Interests, and Career Goals, with the addition of items that target bioscience career awareness and awareness of education and training pathways for bioscience careers. We used a similar process to develop an instrument to measure corresponding factors in teacher participants. For example, we believe that how a teacher perceives their student's capacity might correlate with student's self-perception

We administered the SCCT instrument as a pre- and post-test with a sample of 19 high school students who participated in a summer 2017 pilot. Knowing that the student participant's in the pilot are self-selected, we also compared their responses to a group of age-matched high-school students who did not participate in the pilot. We found that in all cases, the pilot participants reported significantly higher SE, OE, and Interest than the comparison group (unpaired t test, $p =$ SE $<.0001$, OE 0.0002, Internest 0.003). This is expected given the self-selecting nature of recruitment for the pilot study. Importantly, we did not see a significant difference between the pre-tests scoring of Goals of the pilot student participants and the comparison group (unpaired t test, $p = .83$). However, there was an increase in pre-to post Goals following participation in the pilot (paired t test $p = .039$). When looking at items from the new construct - Bioscience Career Awareness (CA), we saw the most dramatic patterns and effects. Students showed significant gains in pre-post awareness of a number of other bioscience careers and an increase in their overall awareness as well (paired t test, $p = <.001$).

This poster is directly related to the conference theme of "*exploring learning in real-world settings in an interdisciplinary manner in order to understand how learning may be facilitated both with and without technology*" by showcasing impacts on students participating in BioSCANN. Our development of BioSCANN has not only highlighted the challenges of such pedagogical technology environments, it has also revealed vital new opportunities for engaging teachers in the orchestration of a classroom learning community. Therefore, it will unpack the role of technology in providing students with instructional "scaffolding" and a set of tools that promote team-based discourse and knowledge building that resemble the iterative nature of scientific discovery and practices. We will also address a key challenge when using this approach: there is a danger that the teacher's role will be subsumed by ensuring that the technology functions smoothly and students are staying "on task." Moreover, from classroom evaluations of BioSCANN we have come to recognize that much of the underlying pedagogy of ICS is hidden from teachers - implicit within the technology environment. Thus, teachers may not fully exploit the ICS format as they guide the exploration, discourse and synthesis phases of the ICS.

References

Fortus, D., Krajcik, J., Dershimer, R. C., Marx, R. W., & Mamlok-Naaman, R. (2005). Design-based science and real-world problem-solving. *International Journal of Science Education, 27*(7), 855-879.

Herreid, C. F. (2005). The interrupted case method. *Journal of College Science Teaching, 35*(2), 4-5.

Jacque, B., Malanson, K., Bateman, K., Akeson, B., Cail, A., Doss, C., . . . Roundtree, E. (2013). The Great Diseases Project: A partnership between Tufts Medical School and the Boston public schools. *Academic Medicine: Journal of the Association of American Medical Colleges, 88*(5), 620.

Jacque, B., Koch-Weser, S., Faux, R., & Meiri, K. (2015). Addressing health literacy challenges with a cutting-edge infectious disease curriculum for the high school biology classroom. *Health Education & Behavior, 43*(1), 43-53.

Kolodner, J. L., Camp, P. J., Crismond, D., Fasse, B., Gray, J., Holbrook, J., … & Ryan, M. (2003). Problem-based learning meets case-based reasoning in the middle-school science classroom: Putting learning by design (tm) into practice. *The Journal of the Learning Sciences, 12*(4), 495-547.

Lent, Robert, Brown, Steven B., Hackett, Gail (August 1994). "Toward a Unifying Social Cognitive Theory of Career and Academic Interest, Choice, and Performance". *Journal of Vocational Behavior, 45, 79-122.*

Slotta, J. D. (2010). Evolving the classrooms of the future: The interplay of pedagogy, technology and community. In K. Mäkitalo-Siegl, F. Kaplan, J. Zottmann & F. Fischer (Eds.). *Classroom of the Future. Orchestrating collaborative spaces*, pp. 215-242. Rotterdam: Sense.

Strobel, J., & Van Barneveld, A. *(2009). When is PBL more effectie? A meta-synthesis of meta analyses comparing PBL to conventional classrooms. *Interdisciplinary Journal of Problem-based Learning, 3, 4.*

Characterizing Digital Contexts of Collaborative Learning:
An Updated Classification of Computer-Mediated Communication

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Abstract: The learning sciences is concerned with studying how learners interact with each other in technologically-mediated environments, but core similarities and differences among tools are rarely addressed, limiting our ability to build a collective knowledge base. To address the issue, we present a revised version of Herring's (2007) scheme for classifying technological contexts of communication, updated for current technologies and their uses.

The learning sciences has a long tradition of carefully documenting learner interactions in technologically-mediated environments, with patterns in communication connected to specific affordances of the tools and the ways they are taken up in the context of established or emergent practices. However, in attending to the particulars of design, we often lose sight of fundamental technological characteristics that play a role in shaping activity. Characterizing common aspects of tools can offer a language with which to discuss computer-mediated communication (CMC) across tools and contexts. Drawing on literature from communication, linguistics, informatics, and sociology, Herring (2007) presented a scheme for such classification (see Table 1a). No element is deterministic, but each describes a key characteristic that can influence the structure and substance of online talk. While Herring's scheme has been used extensively in other fields, there has been limited uptake in the learning sciences. At the same time, there have been dramatic changes in the technological capabilities of CMC and socio-cultural practices surrounding its use, creating a need to update the original elements. The revised scheme is shown in Table 1b. Some elements have merged with others, some were added in response to new technological capabilities, and some retained their name but changed greatly in the underlying description.

Table 1: (a) Original and (b) Updated Technological Characteristics of CMC Contexts

Original Technological Characteristics
Synchronicity
Message Transmission (1-way vs. 2-way)
Persistence of transcript
Channels of communication
Size of message buffer
Anonymous messaging
Message format
Private messaging
Quoting
Filtering

(a)

Updated Technological Characteristics	
Timing	Synchronicity
	Simultaneity
	Persistence
Messages	Communication Channels
	Message Size
	Storage Structure & Display Format
People	Identity Markers
	Community Markers
Controls	Privacy
	Filtering, Searching & Sorting

(b)

Timing. *Synchronicity.* Historically there was a clear line between systems intended for synchronous (same-time) and asynchronous (time-separated) use, but over the last decade there has been convergence of these modalities (Herring & Androutsopouluos, 2015). Traditionally synchronous tools (e.g. chat) now store messages to support asynchronous use, while the pervasiveness of internet connectivity supports synchronous use of traditionally asynchronous tools (e.g. email). In large groups, latency in message creation, receipt and reply can differ across individuals as well. Synchronicity is now thus best considered as a continuum and one which depends both on the technology and how it is used. Differences in synchronicity have effects on reply latency, message length, formality and complexity. *Simultaneity.* Previously discussed as one- versus two-way transmission, the broader concept of simultaneity refers to the technical possibility for overlap in communication. Systems that support near-simultaneity require a comment to be composed in its entirety before it is transmitted to others. The system may or may not provide an indicator the composition is occurring (e.g. "Jo is typing"). In contrast, systems that support high-simultaneity transmit messages as they are composed on a character-by-character basis, allowing for interruption and overlapping talk. The degree of simultaneity possible and indicators of message composition influence turn-taking, interruptions and how comments are interleaved. *Persistence.* Persistence describes how many messages remain stored in a system for how long. Traditionally asynchronous media have effectively everlasting persistence. Traditionally synchronous mediums were in part used this way because the length of the transcript retained was limited, with new comments replacing the old

(Herring, 2007). However, as described above, persistent transcripts have now become a feature of formerly synchronous tools leading to their hybrid use. At the same time, some tools (e.g. SnapChat) have made time-limited persistence (intentional ephemerality) a feature by deliberately capping the duration for which a message is stored. The anticipation (or absence) of persistence has implications for what learners will say to each other.

Messages. *Communication Channels.* While CMC tools traditionally used text as the primary communication channel, visual and audio channels are often now supported, and in some cases designated as preferred (e.g. Instagram). Traditional analysis has focused primarily on textual communication, but the increased use of alternate channels requires incorporation of new analysis techniques, for example methods for analyzing visual communication. Many CMC tools also include additional communication channels via the application of pre-determined or user-generated tags (e.g. "likes" "up-votes" "#greatpoint"). When available, such tags can take the place of messages that would have been written, thus need to be considered as such in analysis. *Message Size.* Allowed message size typically refers to an explicit restriction on the number of characters in the textual portion of a message. While many CMC systems are effectively without cap, other tools are strongly constrained, for example Twitter's well-known character limit. Textual content embedded in images can also be implicitly limited due to restrictions on image size and the need for readability. Limits on allowed message size can lead to the use of abbreviations and particular discourse strategies. Tools can also tie display properties to message length, thereby affecting their use; for example Facebook currently "amplifies" (shows in large colored text) posts of 85 characters or less. *Storage Structure & Display Format.* Storage structure refers to relationship(s) between messages, while display format indicates the way in which messages and these relationships are presented to learners. Storage structures can be single stream, threaded, or networked and constrains, but does not determine message display (e.g. chat tools add new contributions to the bottom of a list while blogs place newest entries at the top). In addition, organization of thread display by topic or by para-content (e.g. views, up-votes and likes) can influence what messages are read and replied to. This is important to consider when making claims about the construction, popularity or importance of particular portions of online talk.

People. *Identity Markers.* Some CMC systems allow learners to mask their identity when sending messages either by not logging in (true anonymity) or while logged in (system-protected anonymity). This can support self-disclosure and/or anti-social behavior (Herring, 2007). A variant is the use of pseudonyms through systems that allow (or require) learners to select a handle different from their name. Pseudonyms support continuity across messages, providing support for identity play. At the other end of the spectrum, systems such as Facebook attempt to limit users to a single account that is tightly tied to their real world identity. Such systems can force learners to reconcile different aspects of themselves, either through accepting the mingling, regulating their disclosure, or through careful use of privacy controls. *Community Markers.* The rise and evolution of social networking has brought about new sets of features with affordances for activity that can play a role in online talk (Herring & Androutsopouluos, 2015). These include establishing linkages between messages or user accounts (e.g. two-way "friends" or one-way "followers"). Traversing such connections makes it more likely that learners will encounter messages shared by certain people, thus affecting how online talk proceeds and making it difficult to claim that people have innate (rather than induced) affinity for certain kinds of content.

Controls. *Privacy.* Early CMC tools included the basic ability to send messages publicly or privately. Recent tools offer complex systems of privacy controls for "public" messages (e.g. share comments only with those in your network or segmented subpopulations of this). This can lead different streams of talk to have distinct, limited groups of potential participants and result in participants each seeing a different, partial, version of a conversation. This splintering of experience impacts inferences that can be drawn about a conversation existing as "shared" among a group. *Filtering, Searching & Sorting.* Complementary to privacy controls by message authors, these tools give learners control over what messages from others they see. Current systems offer a wide variety of options for message inclusion, including searching by learner or keyword. Sorting can also be done based on timing or learner-created para-data (e.g. "likes"). Application of hashtags to denote thematically related content provides an additional (privileged) vocabulary for filtering. Together these tools can create amalgamations of messages that are read by learners as in relation to each other even if not created in this way.

References

Herring, S. C. (2007). A faceted classification scheme for computer-mediated discourse. *Language@ Internet, 4*(1), 1-37.

Herring, S. C., & Androutsopoulos, J. (2015). Computer-mediated discourse 2.0. In *The handbook of discourse analysis, 2nd ed*. (pp. 127-151). Chichester, UK: John Wiley & Sons.

"My Favorite Part Is When We Tell the Truth": Identity and Agency in Middle School Youth's Climate Science Digital Storytelling

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Abstract: The Green Ninja Film Academy middle school curriculum combines climate science, art and English Language Arts to promote youth voice through youth-created films that situate learners and communities in the social, cultural and environmental impacts of climate change. In this iterative design-based research study, data sources include surveys of climate science proficiency and identity and agency with respect to climate science (N=316), as well as case studies from classroom observations, interviews and curricular artifacts of one focal sixth grade classroom. Analyses suggest youth used filmmaking as a tool of identity negotiation and performance as they played with possible science and social trajectories.

Introduction

Preparing youth and communities to equitably address the impacts of a changing climate is perhaps the most pressing educational challenge of the current century. However, the perspectives, experiences, resources and needs of non-dominant communities are underrepresented in climate science and climate decisions, making foregrounding voices from these communities a priority for equitable climate action (Cook, 2015). In this work, we explore the efficacy of a middle school curriculum, the Green Ninja Film Academy (GENIE), to support youth voice on climate science issues. The GENIE curriculum combines the traditional processes of storytelling (selecting and researching a topic, writing a script and developing an interesting story) with a technology-rich experience. This study addresses the following research question: To what degree does participation in the GENIE unit, including creating and sharing Green Ninja films, inform students' perceptions of and identification with climate science, as well as personal and collective action to mitigate climate change impacts?

Theoretical framing

We conceptualize and position youth as change agents and cultural historical actors in their community (e.g., Gutiérrez 2008). We take a sociocultural perspective to examine youth science identity construction and agency with respect to climate action and participation in social and scientific communities. We consider filmmaking as a mediator of identity construction, and explore youth-constructed "horizons of choice" - a picture of their possible futures - within the confines of the structures in place, such as gender, ethnicity, and social class (DeWitt & Archer, 2015, p. 2174). Here, we examine how film creation was used as a tool of identity construction and consider how learners position themselves as historical actors and/or change agents, and played with imagined futures, characters and selves in films.

Methodology

GENIE is a six-week middle school unit which includes lessons in climate science, storytelling and filmmaking. The second pilot of GENIE took place in four schools in the Western and Midwestern United States in February-May 2017 (N=316). Data sources include survey assessments of science, identity and agency, films and culminating science portfolios for all students, and video recorded observations of class meetings (~35 hours), interviews, and qualitative field notes for one focal sixth grade classroom. Survey responses were analyzed for changes between pre and post for all students who completed both assessments (N=296). Qualitative case studies were prepared for students at Manzanita School, a K-8 inclusive school with a predominately Hispanic, low-income student population. Interview and classroom observations were transcribed and coded using a grounded theory methodology (Lofland & Lofland, 1995) to identify processes the mediated youth identity work, and instances in which youth navigated identity, agency or scientific content and practice.

Major findings

Pre- and post-assessments

Analysis of the science assessment for the full student population (N=296) show gains in several areas, including identifying correct characteristics of greenhouse gases, distinguishing between climate and weather, identifying characteristics of the carbon cycle, identifying actions to reduce carbon footprint, defining the

greenhouse effect, and selecting characteristics of cradle-to-cradle design. No significant changes were seen pre/post in the identity/agency instrument for the full student population, a result attributable in part to large student variance. However, segmenting students according to their initial interest in and identification with the environment as measured by Environmental Index (EI), a subset of the survey questions, revealed a negative correlation (R^2=0.31) between EI and change in EI over time (i.e. students with low initial environmental interest increased EI while those with high interest decreased). Students with low initial EI reported higher levels of recognition by peers for their scientific accomplishments in the post assessment ($p<0.05$).

Case study: The Sapphire Table

The Sapphire Table encompassed five students: Lena, Natasha, Jacklyn, Alexis and Eva. The group's filmmaking process was characterized by tension over leadership of the group, authorship of the story, as well as significant humor and engagement in the theatricality of the filmmaking process. The narrative of the film was based mainly on stories by Lena and Natasha, and these stories related to their own identity work and ideas of climate agency. Lena was a trilingual aspiring mechanical engineer whose story delved into reciprocal relationships between good/bad and environment/technology. Her climate story centered on "good" and "bad" twins, and focused on dichotomous tensions that resonated with her ongoing negotiation between being good at school and engineering and valuing this academic success, and disengaging during episodes of frustration and anger. In her survey and interview, Lena used characters from her story to express her own personal characteristics and relationship with the environment, suggesting that the filmmaking space was an opportunity for her to play with possible selves or variations of self in her science identity work.

Natasha drew on her aunt's experience with cancer in her story, a narrative of how a woman became more environmentally friendly during recovery from an illness and was able to travel to the past. Natasha told us that after her cancer diagnosis, her aunt "turned her life around …one of the things that she did, she helped the environment at the same time." Natasha reframed this personal story as one of agency over climate solutions, connecting a meaningful family experience and the science content. Natasha and Jacklyn agreed that their favorite part of making their film was having the opportunity to "tell the truth" about climate change. Jacklyn stated, "My favorite part is when we tell the truth and … make the environment healthy again," and Natasha agreed: "Telling the truth about the environment." Natasha constructed a personally consequential analogy to her life through her film that empowered her to speak "the truth" about climate impacts.

Discussion and significance

Analysis to date suggests that students on average demonstrated gains in scientific content related to climate scinece and data analysis, as measured in the science assessment through the GENIE unit. In addition, the identity and agency survey suggests that there varied experience for youth with an initially high versus low interest and affiliation with science and the environment. Preliminary analyses demonstrate that case study students drew on ideas and values that were of personal, family and community consequence to construct their narratives, and that social dynamics within the group shaped the resulting film and story, as students negotiated for positions of authoring and power within film construction. This supports an initial assertion that the holistic, multidisciplinary GENIE filmmaking experiences allowed learners to actively situate themselves in roles and pathways as they authored identities in relation to personal and societal changes across time and space in ways that supported hope, agency and engagement. Further the suite of possible pathways and roles was at times shaped, constrained or afforded through negotiation with peers and instructors.

References

Cook, K. (2015) Grappling with wicked problems: exploring photovoice as a decolonizing methodology in science education. *Cult Stud of Sci Educ*, *10*, 581-592.

DeWitt, J., & Archer, L. (2015). Who aspires to a science career? A comparison of survey responses from primary and secondary school students. *International Journal of Science Education*, 37(13), 2170-2192.

Gutiérrez, K. D. (2008). Developing a sociocritical literacy in the third space. *Reading Research Quarterly*. 43(2). 148-164

Lofland, J., & Lofland, L. H. (1995). Developing Analysis. Analyzing Social Settings: A Guide to Qualitative Observation and Analysis (pp. 181-203). New York: Wadsworth.

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Examining the Role of Unpacking 3-Dimensional Teaching and Learning in Museum-Based Professional Development

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Abstract: The purpose of this study is to examine changes in teachers' attitudes and behaviors towards three-dimensional instruction after participation in a Museum-based professional development program. The study design includes a pre- and post-survey measuring attitudes towards three-dimensional instruction along with observation rubrics and facilitators' field notes. A preliminary analysis of early data is used to describe implications of applying the "backwards design" model in professional development.

Introduction

The international shift towards three-dimensional (3D) teaching and learning (NGSS Lead States, 2013), requires using and applying knowledge, skills, and abilities to make sense of scientific phenomena and/or design solutions to problems (National Research Council, 2012). Central to this transition is the view that disciplinary core ideas, science and engineering practices, and crosscutting concepts are intertwined and work together to advance students' learning through 3D instruction. Accordingly, teachers need guidance to (re)develop their classroom pedagogy to better align with the newer demands of teaching science. To address this need, a large, urban science museum has developed and facilitated professional development (PD) courses for teachers to (1) gain information about 3D instruction and (2) develop strategies directly relevant to the process of unit/lesson planning for a next generation science classroom. The purpose of this study is to better understand the change in participants' attitudes and behaviors towards teaching aligned with three-dimensional practices, upon participating in the PD. Our research question is, "What impact does participation in a science-museum based PD program have on its participants' attitudes towards key concepts and subsequent behaviors aligned with three-dimensional instruction?"

Literature review

Science-focused PD for teachers is central to student achievement and ensuring overall successful science education reform. High quality professional development will produce superior teaching in classrooms, which will, in turn, translate into higher levels of student achievement. Informal science education institutions, such as museums, are increasingly active in providing teacher PD (NRC, 2009). Providing teachers a space to construct knowledge and develop skills and abilities that align with new reforms is important for achieving successful student outcomes. While there are a few professional development opportunities being developed to support 3D teaching and learning, many offer educators resources without a process/strategy to achieve lasting changes in teachers' practical knowledge.

The Understanding by Design framework provides guidance for curriculum planning process/strategy through a three-staged approach also commonly known as *backwards design* (Wiggins & McTighe, 2005). This process emphasizes (1) identifying desired results, (2) highlighting acceptable evidence, (3) planning learning experiences and instruction to meet the goals. Engaging in these steps allows educators to align activities and assessments with learning performances, as learning goals, to gain a better understanding of "knowledge in use", a key idea in the learning science (Krajcik, McNeill & Reiser, 2007)

Methods

The studied teacher PD program takes place at a large urban science museum for six day-long sessions spread across an academic school year. Participants were selected according to school need and requested to attend in groups. This cohort consists of 3-4 teachers and one school administrator from 12 primary schools in the USA. The PD focused on unpacking 3D learning standards and then rebuilding domain and practical knowledge into three-dimensional, conceptually coherent unit and lesson plans using the principles of backwards design. An example of the process used to model this approach with participants appears in Figure 1.

Data collection

A pre survey addressing science related attitudes, teaching behaviors, and three-dimensional (3D) instruction was administered prior to the start of the course. Items related to 3D instructional practices were taken from an instrument developed by Hayes et al. (2016) to measure the use of 3D teaching and learning with in-service teachers (hereafter: 3D scale). Attitude and behavior specific items on the survey were adopted from the Dimensions of Attitude towards Science (DAS) instrument (van Aalderen-Smeets & van der Molen, 2013). All four sections of the survey consist of items in a five-point Likert format. A post survey will be administered after the last session in March and data will be analyzed prior to the conference proceedings. Additionally, observation rubrics were designed to understand the facilitators' process of explaining the unpacking model during the PD and to identify potential learning barriers. The rubric included categories associated with each item in the Hayes, et al. (2016) survey. A researcher observed the first 2 sessions and took field notes. (The final session will be observed prior to the conference proceedings.) Following a design-based research (DBR) process (Barab & Squire, 2004), data from the observation rubrics and facilitators' notes informed an iterative design process employed by the program facilitators who made continuous research based design changes to the PD. The notes were open coded to identify themes in the changes made in the iterations.
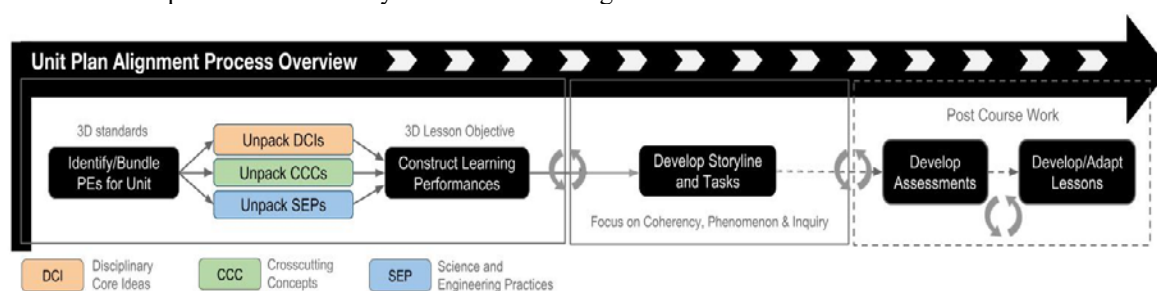
Figure 1. PD model to explain unpacking process.

Preliminary results

The observation rubrics and field notes reflect five major themes in the changes made during the course iterations: increasing scaffolds, tapping into prior knowledge, modeling instruction/providing examples, increasing collaboration within teams and outsourcing additional resources. Each of these evidence-based ideas are known to reinforce learning and may improve teachers' ability to understanding and apply the process described in Figure 1. in their classroom.

Fifty-four participants completed the pre-survey, representing 12 schools. 7 were administrators and 47 were teachers. Pre-survey composite scores were aligned with the prior year's study of a similar PD course that did *not* have a focus on 3D instruction, indicating the population of this program is similar to traditional PD populations at this institution. With the post-survey results in hand, we will be able to determine what impact the 3D-specific changes described here had on overall attitudes of teachers.

Implications

3D teaching and learning presents a challenge for supporting teachers through PD, and little research exists on that specific PD focus (Hayes, et al., 2016). In this paper we report on a PD that was iteratively developed using backwards design methods, and which is aimed at providing teachers with the skills to use backwards design with 3 D standards. We expect that once we collect post-survey data, findings from this study will show how unpacking 3D standards to (re)build aligned unit/lesson plans using a backwards design approach can promote 3D instruction. This PD model may provide a principled approach for addressing the complexities called for by new visions for science education.

References

Hayes, K. N., Lee, C. S., DiStefano, R., O'Connor, D., & Seitz, J. C. (2016). Measuring science instructional practice: A survey tool for the age of NGSS. *Journal of Science Teacher Education*, 27(2), 137-164.

National Research Council. (2012). A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas. National Academies Press

van Aalderen-Smeets, S., & Walma van der Molen, J. (2013). Measuring primary teachers' attitudes toward teaching science: Development of the dimensions of attitude toward science (DAS) instrument. *International Journal of Science Education*, 35(4), 577-600.

The Impact of a Lego Exhibit on Awareness of the Roles and Identities of Engineers

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Abstract: This study measures the impact of exposure to an engineering exhibit on children's awareness of the roles and responsibilities of engineers. We studied 250 children, aged 8-16, in a quasi-experimental design. Results indicate the exhibit did not have a major impact in children's perceptions of who engineers are but did positively impact what they knew about what engineers do as part of their job.

Keyword: Engineering, Lego, Informal Learning, Museums

Introduction

Many children have little exposure to engineering and may not have access to the subject in their school. Informal science institutions can help fill in the gap by creating engineering curriculum and exhibits (Engineering is Elementary, 2017). This study is about one such exhibit that incorporates engineering curriculum with a popular childhood toy: Lego bricks. Our guiding research question was, "What is the impact of visiting the exhibit on guest awareness of the roles and identities of engineers, designers, architects and builders?"

Literature review

There is a current need to increase the number of students prepared for careers in science, technology, engineering, and math (STEM) (U.S. Department of Education, 2015). Previous research suggests that students do not have a strong awareness of what engineers do and conceptualize them mainly with fixing, building, and working on things (Capobianco, Dux, Mena, & Weller, 2011; Cunningham, Lachapelle, & Lindgren-Streicher, 2005). Informal science experiences can improve science understanding and increase participation in scientific activities and awareness of scientific careers (Bell, Lewenstein, Shouse, & Feder 2009; Banks et al., 2007). But despite a growing number of engineering-based museum exhibitions, there is little research on the impact these opportunities have on visitors' understanding of engineering careers.

Methods

We collected data through guest assessments. Families with children 8-16 were recruited as they passed a common area near the exhibit entrance and exit. Those who had previously attended the exhibit were grouped into the treatment condition, while those that had not yet attended were placed in the control group. While the children completed their assessments, the parents completed a demographic background survey. One hundred and thirty guests were recruited into the treatment condition and 120 in the control. The overall gender distribution was 54% male and 46% female. The mean age was 10 (1.9 SD). The top three self-identified racial groups were White (84%), Asian (8%), and African American (5%). About 12% identified as Hispanic.

The child assessment consisted of two sections. The first was modeled after the Draw an Engineer (DAE) instrument that asked children to draw an engineer at work and write a short description of what they are doing (Knight & Cunningham, 2004). The second assessment was based on the What is an Engineer (WIE) instrument (Cunningham, Lachapelle, & Lindgren-Streicher, 2005). The WIE consists of 16 icons that show someone at work, with a small description below them. The child is asked to circle the icons that represents engineers at work.

Drawings from the DAE instrument were analyzed by researchers using the rubric described by Weber, Duncan, Dyehouse, Strobel, & Diefes-Dux (2011). The rubric utilizes 24 items to encapsulate the different aspects of each of the drawings. T-tests reveal the 'train' and 'fixing' variables were the only significant differences between the control and treatment. For the WIE instrument we found differences between the conditions on 6 of the 16 icons, significance was tested using independent samples t-tests (Table 1).

Table 1: "What is an Engineer"

"What is an Engineer?" Instrument

	Engineering Task		
Icon Label	(Y/N)	Treatment	Control
Read about Inventions*	Y	.42	.28
Design Ways to Clean Water**	Y	.52	.32
Work as a Team***	Y	.78	.57
Test Things***	Y	.67	.42
Repair Cars	N	.59	.69
Design Things***	Y	.85	.67
Clean Teeth*	N	.08	.02

Note. Percentages reflect number of responses that circled the icon. Each icon had an image with the label beneath it.

Conclusion

Results suggest that the exhibit was successful in increasing awareness of roles an engineer but did not strongly impact their conceptions of who engineers are. Using the rubric, the DAE only had 2 differences in drawings between the control and treatment, "train" and "fixing", in both cases the control group drew these items more frequently. This ties into other studies finding strong associations between engineers and trains when using the DAE (Capobianco, Diefex-Dux, Mena, & Weller, 2011; Knight & Cunningham, 2004; Fralick, Kearn, Thompson, & Lyons, 2009; Karatas, Micklos, & Bodner, 2011). In those studies, it is generally thought that trains are commonly drawn due to the term engineer being used to describe train crew. However, the WIE had significant differences in 6 icons (Table 1). All but one of these categories are aligned with what an engineer would do in their job. Not surprisingly, the exhibit provides opportunities for children to take part in activities related to these categories. This study provides evidence about strengths and limitations for using an exhibit-based informal learning space to introduce children to engineers.

References

Banks, J., Au, K. H., Ball, A. F., Bell, P., Gordon, E. W., Gutierrez, K. D., . . . Zhou, M. (2007). *Learning in and out of school in diverse environments: Life-long, life-wide, life-deep.* Seattle, Washington: The LIFE Center.

Bell, P., Lewenstein, B., Shouse, A. W., Feder, M. A. (2009). *Learning Sciences in Informal Environments: Peoples, Places, Pursuits.* Washington, DC: The National Academies Press.

Capobianco, B.M., Diefes-Dux, H. A., Mena, I., & Weller, J. (2011). What is an Engineer? Implications of Elementary School Student Conceptions for Engineering Education. *Journal of Engineering Education, 100*(2), 304-328.

Cunningham, C. M., Lachapelle, C., & Lindgren-Streicher, A. (2005, June). *Assessing elementary school students' conceptions of engineering and technology.* Paper presented at the ASEE Annual Conference and Exposition, Portland, OR.

Engineering is Elementary. (2017). *About Us.* Retrieved from https://www.eie.org/about-us

Fralick, B., Kearn, J., Thompson, S., & Lyons, J. (2009). How middle schoolers draw engineers and scientists. *Journal of Science Education and Technology*, *18*(1), 60-73.

Karatas, F.O., Micklos, A., & Bodner, G.M. (2011). Sixth grade students' views of the nature of engineering and images of engineers. *Journal of Science Education Technology*, *20*(2), 123-135.

Knight, M., & Cunningham, C.M. (2004, June). *Draw an engineer test (DAET): Development of a tool to investigate students' ideas about engineers and engineering.* Paper presented at the ASEE Annual Conference and Exposition, Salt Lake City, UT.

U.S. Department of Education (2015). *Science, Technology, Engineering and Math: Education for Global Leadership.* Retrieved from https://www.ed.gov/stem

Weber, N., Duncan, D., Dyehouse, M., Strobel, J., & Diefes-Dux, H. A. (2011). The development of a systematic coding system for elementary students' drawings of engineers. *Journal of Pre-College Engineering Education Research (J-PEER)*, *1*(1), 6.

Community Science Identity: Becoming Community Scientists in a Museum-based Genetics of Taste Program

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Abstract: A museum genetics lab, following an apprenticeship model, scaffolds volunteers' participation in laboratory activities through interactions with other lab members. As volunteers interact and complete activities in the lab they connect prior memories and experiences to present and imagined future experiences. Using a sociocultural analytic framework for trajectories of identification, we examined (1) how volunteers were scaffolded in lab participation and (2) how participation directly affects trajectories of identification by analyzing prolepsis, positioning, and agency.

Keywords: Community Science, Citizen Science, Informal Learning, Identity

Research problem

Community science, or Public Participation in Science Research (PPSR) (Bonney, et al., 2009), is an exciting and growing avenue whereby members of the general public contribute meaningfully to the scientific enterprise, while simultaneously learning science. While community science offers opportunities for PPSR, how those opportunities are scaffolded and received by the scientific community, and how those opportunities are successfully and unsuccessfully accessed remains unclear. The purpose of this paper is to describe how trajectories of identification emerge for community scientists as they participate in different ways in a volunteer museum-based genetics lab program, and how age, gender, prior experience in science, and elements of participation affect identity and future participation in science. This will ultimately be used to understand barriers and constraints to continued participation as a community scientist.

Theoretical and methodological approach

We theorize that volunteer participants in community science hold projected identities, or *trajectories of identification,* which direct how they participate in the lab and thus in science. In this study, we examined (1) how volunteers are scaffolded in their participation and (2) how their participation directly affects identity and *trajectories of identification* by analyzing *prolepsis, positioning*, and *agency* of participants, as they occur in real time and in narrative. Using the *trajectories of identification* framework (Polman & Miller, 2010), we theorize participation and identity as dynamic and co-constructed through social interactions and activities.

To further analyze *trajectories of identification*, we looked at the following elements of participation: prolepsis, positioning, scene, and agency. The distance measuring the individual's actual identity to a future possible identity imagined by self and others is represented by the Zone of Proximal Identity Development (ZoPID; Polman, 2010). Using the ZoPID—similar to Vygotsky's Zone of Proximal Development (ZPD)—we view identity development as tied to the participant's past positioning and positioning by self and others during social activities. The ZoPID for each community scientist includes trajectories of identifications (from self and others) which "impact their participation in the learning environment on a moment-to-moment basis, and which lead to their longer term development of identity" (Polman, 2010, p.129). We focus on three different planes of sociocultural activity— community/institutional, interpersonal, and personal—for developmental analysis of participants involved in sociocultural activities and practices. Rogoff (1995) refers to the interpersonal process as *guided participation,* whereby "people manage their own and others' roles, and structure situations (whether by facilitating or limiting access) in which they observe and participate in cultural activities" (pp. 147-148). As participants move through this functioning apprenticeship they are guided in their participation and appropriate skills and knowledge to participate in the community as a more knowledgeable peer. Thus, our analytic approach "requires considering how individuals, groups, and communities transform… together" (Rogoff, 1995, p.161).

Methods and data sources

This study was conducted in a museum-based genetics of taste lab, and all community scientists were invited to participate in the study. 35 participants consented. All participants were given pseudonyms. Using an ethnographic approach, we completed participant observations and observations of the community science program in the genetics lab beginning in July 2016 until December 2017. Observations consisted of recorded actions and

interactions occurring in real time. Participant observations were conducted once a week for six months prior to observations. Each participant observation was 4.5 hours, the length of one volunteer shift. After six months, researchers transitioned to roles as observers of community scientists as they participated in lab activities and during social and public interactions in the lab; ethnographic observations of lab shifts continued for ten months. Formal and informal interviews were also conducted, as well as exit interviews when community scientists left the program due to career and life transitions. Lastly, informal events such as symposiums, workshops, outreach events, and appreciation dinners, offered by the museum to volunteers, were observed to understand more fully the types of interactions and forms of participation occurring for community scientists outside the lab.

We deductively coded and thematically analyzed (Erickson, 1986) all field notes and interviews. Using the ZoPID (Polman, 2010) and trajectories of identification framework (Polman & Miller, 2010), we looked at elements of participation and identification to build individual case studies describing trajectories of identification, based on types of participation in the lab, career and life stages, and association to social categories. Career and life stage were divided into pre-professional, early/mid-career, or late-career/retired. Pre-professional career volunteers are in high school or college, while those in their early to middle career stages are either working, obtaining a higher degree, or in transition. The late-career/retired volunteers are those who are fully or semi-retired. In addition, we coded thematically for motivation/satisfaction for volunteering, lab and scientific practices, science content, and for characteristics of the community/social environment.

Major findings

Lab volunteers are trained during volunteer shifts by the lab staff and other volunteers, oftentimes using lab protocols and procedures from lab binders; thus functioning as an apprenticeship (Lave & Wenger, 1991; Rogoff, 1995). Upon entering the lab, all community scientists are positioned as novices to the lab, yet are expected to successfully contribute to scientific research. Our overall analysis has revealed primary categories of positioning used by community scientists about themselves and other sub-categories which have emerged during laboratory moments and interactions. Many of these have predictable relations to career and life stages, and position community scientists in different lab roles. We found that volunteers in the lab fall under "retiree" (or self-described "geezer"), "resume builders", and "more knowledgeable peer (MKP)" categories, and those identities are related to more sophisticated levels of scientific participation. We also found that unique communities formed across the different shifts.

Conclusion and further implications

Evidence from this study contributes to our understanding of how identifications associated with life stages and aspirations contribute to the experiences of community scientists. Thus prolepsis, agency, and positioning (by self and others) directly contributes to the level and type of participation exerted by the volunteer and contributes to social categories emerging from laboratory interactions that further reflect life stage and volunteer task preference.

References

Bonney, R., Ballard, H., Jordan, R., McCallie, E., Phillips, T., Shirk, J., & Wilderman, C. C. (2009). Public Participation in Scientific Research: Defining the Field and Assessing Its Potential for Informal Science Education. A CAISE Inquiry Group Report. Available: https://eric.ed.gov/?id=ED519688

Erickson, F. (1986). Qualitative Methods in Research on Teaching. In *Handbook of Research on Teaching [3rd edition]* (pp. 119–161).

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. New York: Cambridge University Press.

Polman, J. L. (2010). The zone of proximal identity development in apprenticeship learning. *Revista de Educación*, 353 (Sep-Dec), 129-155. http://www.revistaeducacion.educacion.es/re353_05.html

Polman, J. L., and †Miller, D. (2010). Changing stories: Trajectories of identification among African American youth in a science outreach apprenticeship. *American Educational Research Journal, 47*(4), 879-918.

Rogoff, B. (1995). Observing sociocultural activity on three planes: Participatory appropriation, guided participation, and apprenticeship. In Wertsch, J. V., del Rio, P., & Alvarez, A., *Sociocultural Studies of Mind* (pp. 139–164). New York: Cambridge University Press.

Acknowledgements

Bridging Multiple Ecologies to Support and Research Learning in Contested Spaces

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Abstract: This poster presents a theoretical and methodological framework for studying complex phenomenon and organizing for learning in contested spaces. A contested space challenges assumptions about power, privilege, and possibility. Our early-stage work is designing a family maker space in a minimum-security prison to support STEM pathways for incarcerated women and their children. In order to design for - and research learning - from an equity perspective, multiple "ecologies" are drawn from that we argue are applicable to other contested spaces, further supporting learning for vulnerable and marginalized populations.

Introduction and background

Our early-stage research project, STEM Ecologies of Learning for Families (SELF), foregrounds the expertise of currently incarcerated women as both makers and mothers as we develop a family maker space in prison. A women's prison is a highly-contested space challenging the scope of STEM-for-all initiatives; it challenges both our notions of who "deserves" education and whose voices are privileged in designing learning opportunities. For Learning Scientists who want to move forward with "equity-oriented" making practice and expand the work being done (e.g., Vossoughi, Escudé, Kong, & Hooper, 2013; Schwartz & Gutiérrez, 2015) to other contested spaces and for vulnerable populations, our theoretical framing and methodological approach to learning research and design must reflect the complexity, power, and possibility inherent in these spaces. This poster presents our framework for undertaking such an endeavor.

Ecologies of STEM, cognition, and research

SELF has three key ecological frameworks that reflexively support each other: ecologies of STEM, cognition, and research. We use the term "ecology" to represent how all learning processes are interrelated and dependent on the people, tools, and disciplinary practices under investigation.

First, this project is focused on creating a STEM ecology that recognizes both horizontal and vertical movement within STEM activity. Horizontal movement refers to the ways in which everyday practices can be leveraged toward more expansive forms of learning (Engeström, 1987; Gutiérrez & Vossoughi, 2014). We examine how incarcerated women can connect their and their children's everyday practices to STEM practices, widening the possibilities for what can be seen as STEM. At the same time, opening the possibility for a range of STEM practices, also allows women and their children to take interest in particular STEM activities and support their movement into more focused and deeper learning in particular practices, or the vertical dimension of learning (Engeström, 2003).

Second, SELF is grounded in sociocultural theories of learning in that we view learning as socially organized, dialogic, and relying on cultural tools. While the role of individual cognition has been deemphasized in social practices theories of learning, we argue that cognition plays an important role in the mutual construction of persons and practices (Packer, 2010). Tools, including making activities, are cognitive artifacts that carry and elaborate information for us (Norman, 1991), they are also reflections of our thinking. Neither the tool, nor our thinking can be separated from the cognitive ecology under study (Hutchins, 2010). It is important to recognize how people shape and are shaped by their technology use (Bowker, et.al, 1997; Hollan, Hutchins, & Kirsh, 2000). Tools not only afford participation, they can potentially limit the identities available in a practice.

Lastly, our project represents an ecology of research. As researchers, we are aware that dominant forms of research often reproduce power-laden relationships between the researcher and "the researched" that need to be interrogated for whom – and with what consequences – the knowledge gained from research is generated (Gutiérrez & Penuel, 2014; Esmonde & Booker, 2016). We draw on principles from participatory design research (Bang & Vossoughi, 2016) to acknowledge the expertise of our participants including incarcerated women, STEM professionals, and the researchers. Our ecology of research is a partnership with all involved to "extend the notion of the so-called 'expert' to encompass a wider range of stakeholders" (Dimitriadis, 2008). For this reason, not only are our research questions jointly negotiated with our participants, our participants are co-designing family maker activities, as well as constructing and analyzing research data.

Discussion and significance

Enlisting incarcerated women as co-researchers is not new (e.g. Fine et al., 2003); however, leveraging the expertise of incarcerated women as makers and mothers is. This project has implications for research involving making and the underrepresentation of women and vulnerable populations in STEM disciplines, as well as the ways to support STEM identity development. However, we argue that our theoretical and methodological framing extends to all spaces where dominant ideas regarding disciplinary learning, cognitive agency, and the researcher as epistemic expert are present. Furthermore, if we interested and committed to designing for learning in a truly equitable manner, as many of the STEM-for-all initiatives claim, then our theories and methods must encompass this as a possibility. In our work, we are attempting to create an equitable design of learning locally for incarcerated women and their children that will extend to other communities more broadly (Gutiérrez & Penuel, 2014). Understanding the foundations for how this is accomplished supports other equity through learning endeavors.

References

Bang, M., & Vossoughi, S. (2016). Participatory design research and educational justice: Studying learning and relations within social change making.

Bowker, G., Star, S.L., Turner, W., & Gasser, L. (Eds.) (1997). *Social science, technical systems and cooperative work: Beyond the great divide*. Hillsdale, NJ: Erlbaum

Dimitriadis, G. (2008) Series Editor Introduction. In Cammarota, J., & Fine, M. (Eds.). *Revolutionizing education: Youth participatory action research in motion*. Routledge.

Engeström, Y. (1987). *Learning by expanding: An activity-theoretic approach to developmental research*. Helsinki, Finland: Orienta-Konsultit.

Engeström, Y. (2003). The horizontal dimension of Expansive Learning: Weaving a Texture of Cognitive Trails in the Terrain of Health Care in Helsinki. In F. Achtenhagen & E. G. John (Eds.), *Milestones of Vocational and Occupational Education and Training, Volume 1: The Teaching-Learning Perspective*. Bielefeld: Bettlesmann.

Esmonde, I., & Booker, A. N. (Eds.). (2016). *Power and privilege in the learning sciences: Critical and sociocultural theories of learning*. Taylor & Francis.

Fine, M., Torre, M. E., Boudin, K., Bowen, I., Clark, J., Hylton, D., & Upegui, D. (2004). Participatory action research: From within and beyond prison bars. *Working method: Research and social justice*, *95119*.

Gutiérrez, K. D., & Penuel, W. R. (2014). Relevance to practice as a criterion for rigor. *Educational Researcher*, 43(1), 19-23.

Gutiérrez, K. D., & Vossoughi, S. (2010). Lifting off the ground to return anew: Mediated praxis, transformative learning, and social design experiments. *Journal of Teacher Education*, *61*(1-2), 100-117.

Hollan, J. D., Hutchins, E. L., & Kirsh, D. (2000). Distributed cognition: A new theoretical foundation for human-computer interaction research. *ACM Transactions on computer-human interaction*, 174-196.

Hutchins, E. (2010). Cognitive ecology. *Topics in cognitive science*, *2*(4), 705-715.

Norman, D. A. (1991). Cognitive artifacts. In J. M. Carroll (Ed.), *Designing interaction: psychology at the human-computer interface* (pp. 17-38). New York: Cambridge University Press.

Packer, M. J. (2010). Educational research as a reflexive science of constitution. *Learning Research as a Human Science*, *109*.

Schwartz, L., & Gutierrez, K. (2015). Literacy studies and situated methods: Exploring the social organization of household activity and family media use. In J. Rowsell & K. Pahl (Eds.). *The Routledge Handbook of Literacy Studies*. New York: Routledge.

Vossoughi, S., Escudé, M., Kong, F., & Hooper, P. (2013, October). Tinkering, learning & equity in the after-school setting. In *annual FabLearn conference. Palo Alto, CA: Stanford University*.

Learning to Think Computationally: Comparative Outcomes of a Robotics Workshop for Girls

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Abstract: This paper reports quantitative results derived from a larger exploratory case study devoted to examining the development of computational thinking (CT) in students during a one-day, all-girl robotics workshop. Here we report on the relationship of CT conversations to programming outcomes. Results indicate that groups who engaged in more frequent algorithmic thinking and debugging conversations attempted more difficult missions than those who engaged in these conversations less frequently.

Dearth of women in computer science

Due to societal bias, girls and women have less exposure, access, and experience with important domains of learning, such as computer science (Cheryan, Ziegler, Montoya, & Jiang, 2017). Therefore, their entrance into these fields is hindered. Indeed, the lack of women entering the field of CS in college and as a career is a well known phenomenon (National Science Foundation, 2015). Providing girls with opportunities to achieve personal accomplishments in the area of computer science is an important means of supporting their entrance into the field. Moreover, developing a clear understanding of how girls learn in computer science based learning environments, such as robotics, is a key aspect of creating meaningful opportunities for them. Here we examine girls' computational thinking as they work in collaborative groups to solve robotics missions in the context of a one-day introduction to the FIRST LEGO League ® workshop. Our overarching research goal in this work is to identify which aspects of computational thinking novice girl programmers engage with as they "do" robotics and examine how these ideas develop, collaboratively, over time.

Computational thinking and doing with robotics

Robotics kits are computational manipulatives that enable student engagement in computational thinking and doing (Sullivan & Heffernan, 2016). Students working with robotics, typically enact a troubleshooting cycle (TSC) that consists of designing, programming, testing, and debugging their creations (Sullivan, 2011). Engagement in this TSC is the essence of computational thinking and doing for students and includes the creation of algorithms and systems analysis (Sullivan, 2008).

Methods

Research design, participants, and data collection

This observational case study took place at a one-day, all-girl introduction to robotics event called "Girls Connect." The workshop featured the FLL's 2011 challenge: "Food Factor." This challenge features 11 missions of varying degrees of difficulty. The students were allowed to select the mission(s) they wished to solve. The participants in this study included 17 girls, ages 8-13 (M = 11.725) who attended 5 different schools in New England. The students were divided into six teams (five teams of 3 and one team of 2); girls from the same schools were on the same team and wore t-shirts of the same color. We collected audio and video data at the one-day event. Each group of girls had their own worktable, a LEGO Mindstorms EV3 robotics kit and a laptop computer. Two challenge arenas were set up in the room so that the girls could test their solutions. We created a video and audio recording of each group's activity and discussion for the day as they moved between their individual worktables and the challenge arenas. We also ran a screen capture program on each groups' laptop. In this way, we collected all of the robotics programming activity engaged in by each group. This data includes the final robotics program(s) created by each group.

Data analysis

This study features three units of analysis, including the TSCs the students enacted, the utterances that were spoken during each TSC, and the final programs created by each group. We first segmented the data into TSCs, we then coded student talk in each TSC using a CT coding scheme derived from our own prior research (Sullivan, 2008; Sullivan, 2011) and from definitions of computational thinking created by other researchers as

summarized in Grover and Pea (2013). Simple interrater reliability was calculated at 94% between two raters. Next we developed a rubric to score student programs. This rubric is based on the difficulty of the mission tasks presented on the FLL challenge arena. Once we had segmented, coded, and scored the data, we tabulated the instances of the CT codes in each TSC for each group. In the next step, we focused on examining the relationship between the frequency of the discussions that are the most relevant to computational thinking and the overall difficulty scores for the groups.

Results and discussion

Our results are encapsulate in this scatter plot, which visualizes the relationship of student scores on their final programs (y-axis) and the amount and type of CT talk each group engaged in during each TSC (x-axis). The scatter plot is presented in Figure 1.
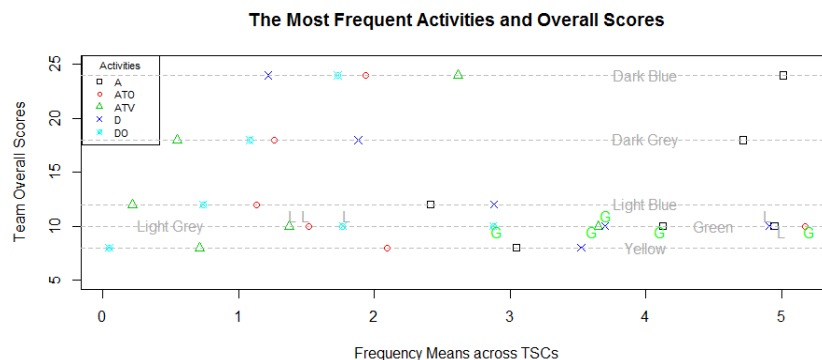
Figure 1. Scatter Plots for the Most Frequent CT Codes and Program Scores

The scatter plot indicates that the dark blue team, who had the highest programming score, also had the highest mean for the analysis and algorithmic thinking variable codes. They also had the second highest means for both algorithmic thinking operation and debugging operation codes. The dark blue team had the lowest mean related to discussion of the physical design of the robotic device. We also notice that the dark blue group discussed variables at a higher level than operations, in terms of algorithmic thinking. We argue this is significant, as discussion of the variables indicates increasing conceptual understanding of the programming block being used. Our next steps with this data set is to examine the nature of the actual conversations of each group to identify the qualities of the conversations that support conceptual understanding.

References

Cheryan, S., Ziegler, S.A., Montoya, A.K., & Jiang, L. (2017). Why are some STEM fields more gender balanced than others? *Psychological Bulletin, 143*(1), 1-35. http://dx.doi.org/10.1037/bul0000052.

Grover, S. & Pea, R. (2013). Computational thinking in K-12: A review of the state of the field. *Educational Researcher, 42*(38), 38-43, DOI: 10.3102/0013189X12463051.

National Science Foundation, (2015). *Women, minorities and persons with disabilities in science and engineering 2015.* National Center for Science and Engineering Statistics. Retrieved from http://www.nsf.gov/statistics/wmpd/

Sullivan, F.R. (2008). Robotics and science literacy: Thinking skills, science process skills, and systems understanding. *Journal of Research in Science Teaching, 45*(3), 373-394.

Sullivan, F.R. (2011). Serious and playful inquiry: Epistemological aspects of collaborative creativity. *Journal of Educational Technology and Society, 14*(1), 55-65.

Sullivan, F.R., & Heffernan, J. (2016). Robotic construction kits as computational manipulatives for learning in the STEM disciplines. *Journal of Research in Technology Education, 49(*2) 105-128. doi: 10.1080/15391523.2016.1146563

Acknowledgements

Measuring Maker Mindset: Establishing Content Validity With Card Sorting

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Abstract: This poster describes the development of an instrument to measure maker mindset and establishes its content validity. We identified five component constructs of maker mindsets and developed an instrument that asks participants to respond to vignettes related to each construct. To establish content validity, a group of maker professionals (*n*=17) completed a card sorting task in which they grouped the 25 vignette-based items based on the maker mindset attribute that they thought each item was intended to measure. Analysis of the results revealed 16 items that were grouped in one of three clusters that largely aligned with the five original constructs after collapsing some constructs. We conclude that the 16 remaining items have content validity.

Introduction

Recently, researchers have identified and defined the problems, constructs, challenges, and opportunities associated with the infusion of maker principles and technologies into education. Much of that body of research has identified constructs—often aggregated into the concept of a *maker mindset* (further defined below)—that represent the cognitive characteristics important to making. We believe that maker research has advanced to the point at which it is now time to apply the lessons learned through this type of exploratory research to the development of a methodologically rigorous psychometric scale that measures maker mindset. We therefore describe the first stage of development of the Maker Mindset Instrument (MMI), a scale designed to measure component factors of a maker mindset. To develop a scale for maker mindset, we identified a set of constructs to serve as sub-scales because although we expect an individual's maker mindset to holistically represent his or her approach to making environments and activities, we also expect certain features of the mindset may be more or less relevant to certain students, in certain environments, and when attempting certain activities.

Maker mindset constructs

Via a thorough literature search, we identified a set of five constructs to include in the MMI through a review of the literature on making, which is the upper limit of the number of constructs that should be measured with one scale. For our first construct, we grouped together resilience, grit, and "can-do" attitude into a general **resilience** construct. The next construct is **growth mindset**. This construct likely contributes to resilience but is a distinct set of beliefs about aptitude and intelligence (Dweck, 2006). Our third construct is **creativity**. Makerspaces remove many barriers between ideas and implementation. Therefore, creativity is central to a maker mindset. Our fourth construct combines several related constructs: curiosity about how things work, playfulness in trying new things, iterative practices, and a do-it-yourself attitude. All of these aspects are subsumed into the **willingness to tinker** construct. Researchers have characterized tinkering as including some of the problem-solving and iterative design-focused behaviors as engineering, but with a more playful, experimental orientation (Martinez & Stager, 2013; Resnick & Rosenbaum, 2013; Vossoughi, Escudé, Kong, & Hooper, 2013). The fifth construct is a **collaboration orientation**, which combines disposition to share and collaborate with an interdisciplinary approach to challenges.

Scale development

We wrote five situational vignettes per construct, for a total of 25 vignettes. Vignettes allow respondents to reveal their own mindset by answering a question about a fictitious character without requiring potentially biased self-reporting (Wallander, 2009). Following each vignette, respondents are tasked with answering how much they agree with a statement about the vignette character's mindset. For each vignette, i.e., item, the scale of agreement was the same—a 7-point Likert scale, anchored between strongly disagree and strongly agree. An example of a vignette follows:

Sadik built a fort out of sticks. He built it to play in with his friends. It took him a while to build it. It's not very stable, but it hasn't fallen down. Sadik wants the fort to stay standing for a long time. He thinks he knows a way to make it more stable. He decides to tear it down and rebuild it with a new design. How much do you agree with the following statement: *It's worth Sadik's time to rebuild the fort, even though it hasn't fallen down yet.*

Participants

Twenty-one individuals responded to our recruitment. We excluded 4 of the 21 total responses for being incomplete or completed incorrectly. Nine of the 17 respondents (53%) identified as male, and the remaining 8 (47%) identified as female. One of the respondents (6%) identified as Hispanic or Latino. Fourteen of the respondents (82%) identified as white, 2 (12%) identified as Black or African American, and 1 (6%) identified as Asian. Fourteen of the respondents (82%) reported speaking English at home, and 3 (18%) reported speaking English and/or another language at home.

Procedure

The card sorting task was conducted online. In an open card sorting task, participants are presented with a number of stimuli (in this case, the 25 vignettes) and are asked to sort them into piles based on some criteria established by the researchers. Participants started by watching a brief, one-minute instructional video that introduced the task. Participants were instructed to read through the vignettes, then sort them into 3-7 groups based on what construct/attitude the participant felt the vignettes were attempting to measure. Once participants completed sorting all of the cards, they named each group and submitted their answers.

Validation results and discussion

To quantitatively analyze the groups that participants had created, we used multidimensional scaling (MDS). To compare participants' categories to the constructs, we made agreement matrices for each participant. In the agreement matrix, the matrix was organized by construct, and we indicated which cards were grouped together.

These matrices were then analyzed using ALSCAL to determine the number of dimensions present in the data and the coordinates of each card in p dimensional space (i.e., to determine which cards clustered together). Based on the analysis, we determined that three unique dimensions were represented. Young's S-stress was .299 with a single dimension. With two dimensions, S-stress (.166) improved by .132. With three dimensions, S-stress (.143) improved by .023, which is a small improvement, but, based on inspection of the coordinates for each item, was meaningful. With four dimensions, S-stress improvement was only .006 and, therefore, not meaningful enough to justify the inclusion of a fourth dimension.

Based on the first dimension, cards 3-8 were separate from the others. These cards are supposed to represent resilience and growth mindset, which are related theoretically, so we called this dimension **Resilience/Growth Mindset**. Based on the second dimension, cards 21-25 clustered closely and are supposed to represent collaboration orientation, so these items represent the dimension **Collaboration Orientation**. The last dimension is harder to parse, which makes sense based on the .023 S-stress improvement that it contributes. It roughly accounts for the creativity and willingness to tinker constructs, though, which are fundamental to maker mindset, so it makes sense that expert makers would group them with other constructs frequently. We called this dimension **Tinkering** and retained cards 11-12, 14-16, and 18 because they clustered closely.

References

Dweck, C. (2006). *Mindset: The new psychology of success*. New York, NY: Random House.
Martinez, S., & Stager, G. (2013). *Invent to learn: Making, tinkering, and engineering in the classroom*. Torrance, CA: Constructing Modern Knowledge Press.
Resnick, M., & Rosenbaum, E. (2013). Designing for tinkerability. In M. A. Honey & D. Kanter (Eds.), *Design, make, play: Growing the next generation of STEM innovators* (pp. 163–181). New York, NY: Routledge.
Vossoughi, S., Escudé, M., Kong, F., & Hooper, P. (2013). Tinkering, learning & equity in the after-school setting. In *FabLearn 2013*. Stanford, CA. Retrieved from http://fablearn.stanford.edu/2013/wp-content/uploads/Tinkering-Learning-Equity-in-the-After-school-Setting.pdf
Wallander, L. (2009). 25 years of factorial surveys in sociology: A review, *Social Sci. Research, 38*, 505-520.

Preparing Students for Learning Statistics with Adventure Game: Learning Cycle Model of Gaming, Watching, and Practicing

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Abstract: Learning statistics is challenging for non-major students. Prior research suggests engaging students in some preparatory activity for them to explore statistical problems with a video game and tangible simulation before providing formal learning resources leads to larger learning gains than the other order. The present study extends this line of theoretical discussion by demonstrating *adventure game* as another suited format for such preparatory activity as part of a learning cycle combined with collaborative formal practice.

Introduction

Learning statistics is challenging for non-major students, and it is a significant goal to develop such instructional theory that helps a wide range of students without a strong mathematics background learn statistics effectively. Literature suggests engaging students in some form of inquiry as a promising approach; some emphasize engaging students in scientific practices (e.g., Lehrer, Kim & Schauble, 2007); some emphasize engaging students in informal statistical inference (ISI) (e.g., Makar, Bakker, & Ben-Zvi, 2011). Another line of research engages students in some preparatory activity for them to explore statistical problems with a deliberately designed video game and tangible simulation designed to prepare them for future learning before providing formal learning resources (e.g., Arena & Schwartz, 2013; Schneider & Blikstein, 2015).

Conceptual framework

Bransford and Schwartz (1999) discussed a point of view of transfer to solve new problems given relevant resources in *Preparation for Future Learning* (PFL). Schwartz and Martin (2004) engaged students in an "invention" activity that they first attempt to invent their own solution for a statistical problem before its brief lecture and individual practice, and demonstrated that students in such condition outperformed those in the "tell-and-practice" condition. Later, Arena & Schwartz (2013) designed an invader game that visualizes probability distributions of invaders and demonstrated consistent results by engaging participants in playing the game and reading expository texts. Schneider and Blikstein (2015) designed a tabletop simulation of permutations and combinations and demonstrated that the "table-and-video-lecture" condition outperformed the "video-lecture-and-table" condition. These suggest that PFL can be characterized by the preparatory stage that engage students in some exploratory activity *before* providing formal learning resources (FLRs). In this study, we propose an *adventure game* as an alternative format for designing such PFL activities combined with another collaborative formal practice (CFP) step after the "PFL-and-FLR" sequence as part of the unit of learning cycle.

Adventuregame for PFL followed by formal learning resource and practice

Adventure game is a popular category in video, computer, and mobile games, which can present various, both real and virtual, and context-rich scenarios to users and engage them in a sequence of questions and answers in the form of problem solving. In the present study, we designed an online adventure game in which students can explore such statistical-problem-solving scenarios (Figure 1). First, users choose a scenario and they are given a background context and its problem such as "Is your friend's coin deceptive?" and "Which store has the longest waiting time?" with answer options aimed to engage them in informal statistical reasoning (Table 1). To solve the problems, users go to the investigation mode in which they collect sample data by choosing a sample size (N=10, 100, or 1000) and interpret the histograms from randomly varied but computationally controlled population distributions. Based on their own reasoning with the graphs, users choose their answer and the subsequent story acknowledges them if and how their choice was correct in the scenario context or not. After exploring the probabilistic phenomena and activating their prior knowledge, they are provided with FLR such as lectures and the videos, and this "PFL-and-FLR" sequence is expected to lead to better learning gains than the other order as discussed in aforementioned studies. In addition, we also stress the third step of CFP as part of the unit of learning cycle. CFP refers to such activity that students collaboratively work on conceptual and mathematical tasks that help students practice their formal knowledge and skills after the FLR step (Figure 2).

Such collaborative exercise step has not been stressed as part of the unit of learning cycle in prior studies, but it will help students develop their conceptual understanding and its application skills through the exercise step.
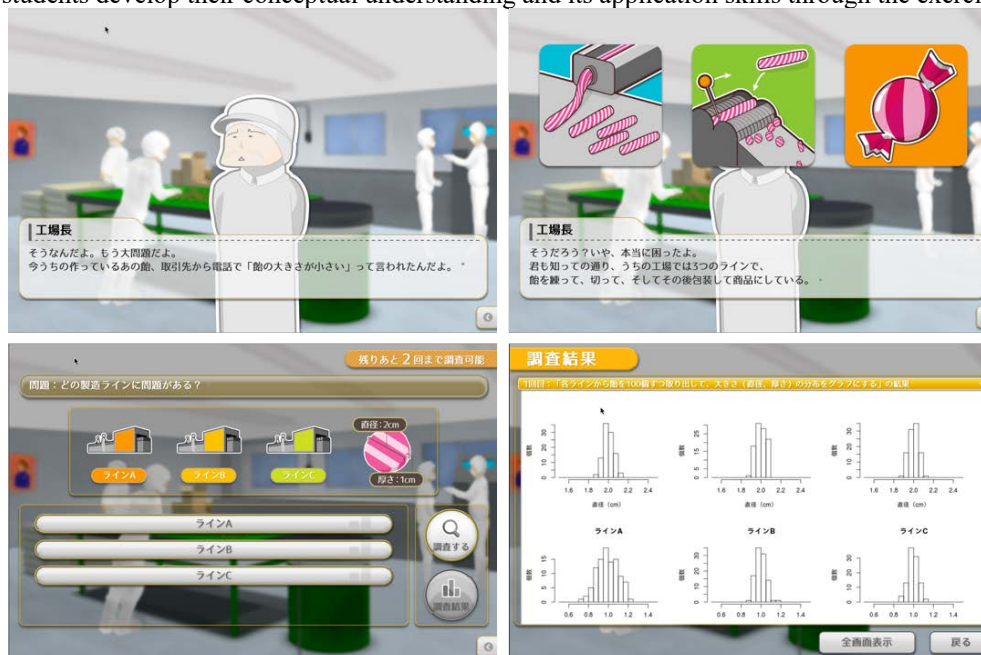
Figure 1. Screen Captures of the Adventure Game—top left and right: presenting the background context (candy factory scenario), bottom left: presenting the problem and answer options (Line A, B, and C), and bottom right: histograms in the diameter and thickness of a candy (Line A has a larger variance in thickness than other lines).
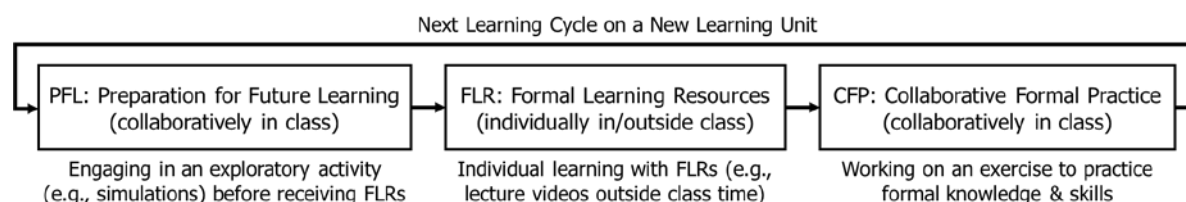
Figure 2. The Learning Cycle Model of PFL, FLR, and CFP Steps Drawing from the PFL Framework

Future work

The present study illustrated a learning cycle model with the adventure game followed by formal learning resource and collaborative practice. This study is still in a preliminary stage and a comparative experiment is going to be held to test effects of the adventure game on learning gains and processes in the near future.

References

Arena, D. A., & Schwartz, D. L. (2013). Experience and explanation: Using videogames to prepare students for formal instruction in statistics. *Journal of Science Education and Technology*, 23(4), 538-548.

Bransford, J. D. & Schwartz, D. L. (1999) Rethinking transfer: a simple proposal with multiple implications. *Review of Research in Education*, 24: 61-100.

Lehrer, R., Kim, M., & Schauble, L. (2007). Supporting the Development of Conceptions of Statistics by Engaging Students in Measuring and Modeling Variability, *International Journal of Computers for Mathematical Learning*, 12(3), 195–216.

Makar, K., Bakker, A., & Ben-Zvi, D. (2011) The Reasoning Behind Informal Statistical Inference, *Mathematical Thinking and Learning*, 13, 152–173.

Schneider, B. & Blikstein, P. (2015) Flipping the Flipped Classroom: A Study of the Effectiveness of Video Lectures Versus Constructivist Exploration Using Tangible User Interfaces, *IEEE Transactions on Learning Technologies*, 9(1), 5-17.

Schwartz, D. L. & Martin, T. (2004) Inventing to Prepare for Future Learning: The Hidden Efficiency of Encouraging Original Student Production in Statistics Instruction, *Cognition and Instruction*, 22:2, 129-184.

Recounting Counting: Self-Appraisal in Math-Adjacent Discourse

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Abstract: This study illuminates how women position their relationship to everyday textile craft practices (e.g., knitting, sewing, crocheting) and to mathematics. We employ discursive psychology and conversation analysis to analyze interviews with crafters. Rather than just (not) being "math people," preliminary findings reveal that speakers discursively orient to mathematics as consisting of both "lower-level" and "higher-level" categories, and speakers appraise their own mathematical abilities with regard to each.

Keywords: math, gender, discourse

Background

This study focuses on how women position their own competence in mathematics to illuminate when and how institutional environments erect barriers to participation. We focus on self-appraisals of mathematical ability made by women who engage in textile crafting practices and contrast this with their appraisals of their abilities in math in formalized schooling environments. Textile practices have been recognized as sites where rich mathematical reasoning occurs (Harris, 1997), as well as sites with historically deeply engagement from women (Barber, 1994). However, it is likely that both crafters and non-crafters have inadequately recognized the math inherent in crafting to be "legitimate" or "real," and therefore not capitalized on the potential of crafting to open up trajectories that lead to success in formal math learning environments.

Methodological approach and methods

The learning sciences has historically focused on the role of discourse in mathematics learning (e.g., Sfard & Cobb, 2014). In this study, we analyze 13 interviews with women who have experience with weaving, sewing, crocheting, or knitting, in which participants were asked to discuss their textile crafting practices and make connections to mathematical thinking. We focus on the interactive and discursive features of the interview, drawing upon discursive psychology (Edwards & Potter, 1992) and conversation analysis (Heritage, 1984). Our goal is to explore the questions: (RQ1) How do crafters position math as "school math," "craft math," or in some other way, and (RQ2) How do crafters position themselves in relation to these various sorts of math?

Initial findings

As a case instance, in the following extract, "Bianca", a crafter with experience sewing, knitting, and crocheting, and the interviewer are discussing the mathematical nature of crafts in an online video-conferencing platform. Before the extract, Bianca explained how she made some stuffed animals. Bianca begins by assessing the mathiness of knitting. In so doing, she quickly makes a distinction between counting and higher math and qualifies her experience with each of these two types of math ("I" is short for "interviewer").

A.1	I:	Do you find that you need mathematics to make those crafts, or
A.2		does that seem just sort of (.2) uh (.6) not so (.2) so: obvious.
A.3	Bianca:	Well I mean I think knitting is kind of at its base it is mathematical
A.4		cus it's all about counting (.2) um and not (.) sort of any sort of
A.5		higher math or or I I've never really done any sort of (1.2) like
A.6		math-based patterns that you know. (1.4) like I I'm kind of <u>aware</u>
A.7		of it, (.2) but you do have to keep counting.
A.8	I:	[Right]
A.9	Bianca:	[Um] (1.0) and I know that there are people who do design patterns
A.10		that are <u>based</u> on math. [which]
A.11	I:	[right]
A.12	Bianca:	think are <u>cool</u> erm but I've never: (.2) yknow either sought them
A.13		out or made my own patterns or anything like that

In this extract, the interviewer asks Bianca if her craft (knitting) tends to "need mathematics" (A.1). This is set up as a choice between finding that math is necessary or that math's presence is less obvious—thus the preferred response is agreement that math is present, and in practice the question is more about how obvious this mathematics is. Bianca offers that knitting is mathematical "cus it's all about counting" (A.4), which constructs counting as a part of mathematics. Furthermore, counting and mathematics are established as having a strong correlation as knitting is "all" about counting (A.4). The language of "at its base" (A.3) functions to demonstrate how inseparable the math and the counting are. Bianca elaborates without prompting that the knitting has "not…any sort of higher math" (A.4–A.5). She presents a non-counting kind of math that is both "higher" (more difficult) and not present in knitting, which in turn may function to establish why a knitter might not be expected to be competent in this kind of higher math. While noting that she has never done any "math-based patterns" (A.6), Bianca would be contradictory had she been referring to math as counting, so "math" is interpreted here as referring to the amorphous "higher math." The language of "base" and "based" (A.3, A.6, emphasized on A.10) position math as something that underlies or is fundamental to knitting, rather than as something that sits on top of or is extraneous to knitting. Although Bianca has "never" (A.5, A.12) used math-based patterns, she emphasizes that she is aware of them (A.6), which places a qualifier on her inexperience and serves to position her as not entirely incompetent with this topic. In summary, Bianca does note that knitting has counting and possibly not "any sort of higher math," thus constructing counting and higher math as two opposing kinds of math (RQ#1). She goes on to carefully explicate her experience with each of the two, noting that the former is necessary to her knitting "at its base," while the latter is something she is "kind of aware of" but has "never really done" (RQ #2).

Discussion

A key finding of this study is that the women crafters interviewed appraised their own mathematical competency by separating math into multiple parts (e.g., higher and lower) and positioning themselves relative to each. Constructing two kinds of math functions to allow speakers to position themselves in variable ways with regard to math. It is possible that this in turn allows speakers to (a) account for their self-appraisal as less capable in higher-level math or (b) position themselves as especially competent since they are capable at both types of math. In so doing, speakers may tacitly or implicitly resist simplistic identities as "math people" or "not math people." These findings have deep implications for the study of mathematical self-appraisal. Rather than simply treating people as "math people" or as having a stable-low or stable-high mathematical self-appraisal, a discursive psychology (DP) approach revealed much deeper complexity in how and why speakers construct a representation of mathematics as a subject and their own abilities therein. By focusing on what speakers do in talk, DP can reveal flexible, occasioned, and fluid understandings of mathematical ability. These findings also have potential implications for the design of learning environments that seek to encourage learners to engage with mathematical concepts and thus broaden participation in STEM. Learning environments should explicitly call attention to the depth of the mathematical work being done therein, illustrating to learners that they are engaging in "higher" math when they are. Relatedly, these environments might also seek to reposition productive, useful kinds of math— like the kind of "basic" arithmetic that powerfully can be used to accomplish textile crafting—as not necessarily being of a "lower level" than more abstract kinds of math (Papert, 1980). This approach in turn may invite learners to position themselves as legitimate participants in deeper mathematical practices.

References

Barber, E.W. 1994. *Women's work - The first 20,000 years: Women, cloth and society in early times.* New York: W.W. Norton.

Edwards, D. & Potter, J. (1992). *Discursive psychology.* Sage Publications.

Harris, M. (1997). *Common Threads: Women, Mathematics, and Work.* Trentham Books.

Heritage, J. (1984). *Garfinkel and ethnomethodology.* John Wiley & Sons.

Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas.* Basic Books, Inc.

Sfard, A., & Cobb, P. (2014). Research in mathematics education: What can it teach us about human learning?. *The Cambridge Handbook of the Learning Sciences*, 545-63.

Acknowledgments

Beyond Copy Room Collaboration: A Case Study of Online Informal Teacher Professional Learning

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Abstract: With the ubiquity of social media and the access to information instantly, teachers, like the rest of society, are turning to the internet for support. This study investigates how a public Facebook group mediates contextually relevant professional learning. Using a qualitative case study research design, a Facebook group tailored to mathematics education is analyzed based on 1) how group members share knowledge, and 2) the use of discourse structures to support professional learning.

Teaching is a dynamic profession with many factors influencing change and growth. There are new standards every decade, new students every year, and new technology adopted before full integration of old technologies. Teachers must regularly develop to keep up with change. Unfortunately, when teachers reflect on their professional development, only 25% report satisfaction with what their schools offer (Gates Foundation, 2014). They are dissatisfied with the insufficient time included for professional development during the school year, and the content of professional development is not contextually relevant (Gates Foundation). To combat inadequate development, teachers look outside of their school for learning opportunities.

Teachers often enter online environments to find professional learning opportunities. They are finding communities where they can participate in critical reflection of their practice, learn about new methodologies, access experts outside their personal network, and develop their teaching identity through discussion (Macia & Garcia 2016). Through these virtual interactions, teachers are expanding their social network, finding connections to professional learn communities, and combating isolation often felt in their day-to-day practice. When reflecting on professional development opportunities for teachers online, when do we know learning is possible? Ball and Cohen (1999) emphasize teacher learning occurs when discourse is centered in teacher practice, learning activities consist of investigations of teaching practice, and learners engage in intentional professional discourse structures. Using the characteristics outlined by Ball and Cohen, this paper seeks to better understand the discourse structures available to teachers within online environments.

Methods

This research project is approached using a qualitative revelatory case study design (Yin, 2003). A revelatory case study is used to illuminate the interaction among a group of individuals that have rarely been studied or have not been examined through the current theoretical lens. The case study is intended to illuminate detailed examples of discourse among teachers within a public Facebook group intended to support mathematics education.

The group used in this study, is a public Facebook group intended to support mathematics teachers. All posts, comments, interactions, and member activity were collected in October 2016, which was 39 months of activity for the group. There are 1476 original posts to the group, which included 5950 comments. With the intention of looking for instances of teacher's help seeking, the data set was initially partitioned into questions and non-questions. Questions posed by members were indicators of a member's desire to tap into the collective knowledge of the group and are used for this analysis.

Findings

Four discourse structures were identified during the coding process and are detailed in the cases below.

Case #1: Provide desired help – Collecting online math games. The first type of discourse observed was in direct response to what was requested. Interactions that fall in this discourse category provide the teachers with exactly what they asked. A majority of the responses are short and directly tied to what is requested, rarely do individuals ask clarifying questions of the requester. This discourse structure often occurred when an individual requested a list of resources such as the following teacher, *"I am writing a P.D. on Math Games to support Learners. What might be some good online games that support a more constructivist pedagogy? Thank you!"*

Case #2: Reframe help – Deficit-minded request. The second discourse structure occurred when ideas offered by group members is not what the requester asked for, but rather, it is what the community feels the requester should have requested. Requests such as *"I teach 7th grade math at a small private school. This class scores very low in number sense. I would like to find an appropriate assessment that I can administer periodically to measure their growth in this area. Any suggestions?"* produce discourse structures that attempt to reframe help. The responder, after evaluating what has been requested, decides to offer an alternative piece of knowledge that

can meet the same outcomes desired by the requester. In the above example, members join the discussion to reframe how the teacher is addressing building number sense and both recommend not using assessment, but rather use activities that have students practice these skills. While this interaction only includes three individuals, it highlights how the community quickly responses to a deficit-minded comment and reframes knowledge that they want to share.

Case #3: Challenge help - Deconstructing a Common Core standard. The third type of professional discourse move that occurs within this public Facebook group includes instances when group members challenge or debate the requester's, or other responder's, ideas. Often times in these interactions, the challenger, along with highlighting what is wrong, will also provide a countering idea to help redirect the conversation, as in the reframing move. The challenge move often results in a debate among multiple members of the group. In one post, the original requester is looking for help with aligning his old teaching practice with the new requirements of Common Core. The requester provides how he has taught the concept in the past, the teaching idea that he would like to enact moving forward, and also a case that might cause his new idea not to work. The thread starts with many responders agreeing with him and sharing his frustration. Then, a challenger highlights that many respondents are providing shortcuts to teaching simplifying expressions without teaching conceptual understanding. His challenge is countered by two other members who believe that their way of teaching helps students "read" the mathematics. The debate lasts for 12 comments.

Case #4: Collaborative help – Building understanding of a resource. Collaboration between members was the final type of professional discourse move observed within this public Facebook group. This interaction occurred when individuals worked together to build a common understanding of an idea. It could be that an individual asked a clarifying question of a previous responder, or they could provide additional information to develop a better understanding of a previous proposed idea. One interaction between five individuals as they discuss enrichment activities for elementary mathematics exemplifies this discourse pattern. One respondent offers an activity by brand name including that they use it with students to make the mathematics visible. Following this response, another member joins the conversation and agrees with the resource and mentions that they enjoy using the app on the iPad. The first responder did not know an app existed and reflected that it would be a great activity to use on an iPad. This is an example of how the community collaborated to build a more complete understanding of a resource.

Conclusion

Through this case study of a public Facebook group focused on mathematics education, interactions among group members provide opportunities for professional learning. The final characteristic of teacher learning, and the focus of this study, highlighted by Ball and Cohen (1999) reflected that the interactions among members of the group should sustain professional discourse. Questioning, investigating, analyzing and criticizing are types of discourse that are reflective of a community of teacher learners. These discourse moves provide a learning environment that is centered on thoughtful discussion, which allows for individual reflection and co-construction of knowledge. With only 25% of teachers satisfied with the current professional development offered by their schools, online collaboration platforms, like the Facebook group studied, can become places where teachers network together virtually to build communities of learners. The findings of this study highlight the existence of informal teacher learning online providing proof that teachers can find their own professional learning opportunities outside the confines of school offered professional development.

References

Ball, D. L., & Cohen, D. K. (1999). Developing practice, developing practitioners: Toward a practice-based theory of professional education. *Teaching as the Learning Profession: Handbook of Policy and Practice*, *1*, 3–22.

Gates Foundation (2014). *Teachers know best: Teachers' views on professional development*. Seattle, WA: Bill & Melinda Gates Foundation.

Macia, M., & Garcia, I. (2016). Informal online communities and networks as a source of teacher professional development: A review. *Teaching and Teacher Education*, *55*, 291–307.

Yin, R. K. (2003). *Case study research: Design and methods*. Thousand Oaks, Ca: Sage Publications.

Learning Engineering Practices Through Drones: Iterative Design of an Informal Learning Curriculum

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Abstract: Informal learning programs provide youth with additional opportunities to engage in STEM. Here, we report on an informal engineering program for low-income youth. We describe how a curriculum was modified to reflect the instructional shifts outlined in the *Framework for K-12 Science Education* and how these changes enhanced youth interests and engagement in engineering practices.

Introduction

Afterschool programs are an important part of the science, technology, engineering, and mathematics (STEM) ecosystem, providing youth with opportunities to spark or deepen their interests in STEM, engage in science and engineering practices, and understand the value of STEM for society and future employment. In formal educational settings within the United States, science learning in classrooms is undergoing profound changes, motivated by the *Framework for K-12 Science Education* (NRC, 2012) and the *Next Generation Science Standards* (NGSS Lead States, 2013). There have been numerous studies examining the implementation of new curricula designed to support the instructional "shifts" described in these documents in formal educational settings (see, for example, Severance, Penuel, Sumner, & Leary, 2016). However, there have been fewer studies examining how these shifts influence the design of STEM curricula in informal learning settings. We report on the development and implementation of an afterschool program designed to engage low income, middle school youth in engineering experiences in atmospheric and related sciences.

Theory and prior work

Supporting the instructional shifts in the *Framework* and NGSS are central to our approach. The *Framework* advocates for using phenomena to drive instruction in science as a means of sustaining student interests and promoting 3D learning. With this approach, the focus of learning is about figuring out how to explain a phenomenon not learning about a set of topics. Within science, the goal is to build and refine models to explain and predict phenomena, based on evidence (Lehrer & Schauble, 2006). Within engineering, the goal is to engage youth in designing solutions to problems, using evidence of their design's efficacy to inform and motivate iterative improvements. A core premise of this approach is that through "figuring out" youth will be guided to engage in 3D learning, where their knowledge of disciplinary core ideas and cross cutting concepts (such as patterns or cause and effect) is developed through deep engagement with science and engineering practices. Ideally, when asked what they are doing and why, youth should be able to describe how their learning activities are helping them to solve their engineering problem. The ability of youth to understand the purpose behind discrete activities is one way of operationalizing student-centered measures of curriculum coherence. Researchers have proposed storylines as a promising approach for developing coherent curriculum (Shwartz, Weizman, Fortus, Krajcik, & Reiser, 2008). A storyline is a way to represent sequence of lessons where each lesson is driven by youth questions and each activity helps youth to make progress on explaining an anchoring phenomenon.

Context, methodology, and analysis

Engineering Experiences is an afterschool engineering curriculum based on Unmanned Aerial Vehicles (UAV/Drones). Participating youth learn how to fly drones and how to use them as platforms for scientific investigations. Figure 1 shows the design of iteration three of the curriculum, where we focused on coherence around a driving question for the semester. This program was studied over the course of three iterations following a design-based research methodology. The first and second iterations were at a middle school that serves youth in grades 6 – 8; 40% of the students at this school are Hispanic while 50% are Caucasian. Almost 45% of the students qualify for free-and-reduced lunch (FRL). The third iteration took place at a PK-8 School where 84% of the students are Hispanic, 12% are Caucasian, and 83% qualify for FRL.
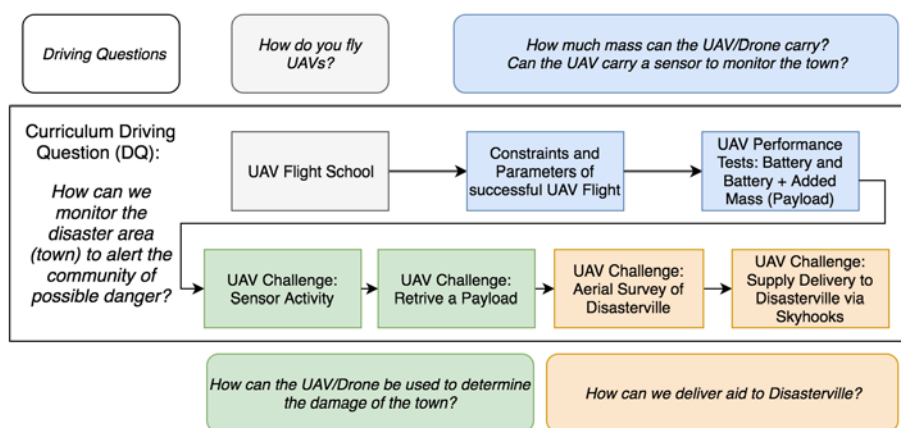
Figure 1. Curriculum Design around a Driving Question in Iteration Three.

In each iteration, we collected data using journal prompts, project artifacts, observations, and interviews with youth and adult participants. We used "flight logs" as an unobtrusive journaling notebook for gathering evidence about youths' interests, engagement, and knowledge. In survey questions and interviews, we asked youth to reflect on their interests, performance expectations, relevance of the program to their lives, and their use of engineering practices. Our session observation protocol focused on observing the degree to which youth were engaged in different activities and enacted engineering design practices, as well as how the participating adults supported the youths' experiences. Analysis was conducted collaboratively by the research team.

Results and discussion

Our results suggest that using phenomena and design problems to drive instruction can help sustain student interests. In all three iterations, participating youth reported that their main reason for attending was their interest in drones – 57% of youth noted that the drone content was pretty important in iteration three. However, in earlier iterations, this interest did not sustain their participation, with attendance declining through the duration. In iteration three, nearly all youth completed the 14-week program, which was longer in duration and intensity than the previous iterations. We observed that youth were deeply engaged in the activities for majority of the sessions. In earlier iterations, youth would disengage from activities and passively observe. Our observations also revealed differences in youth engagement with engineering practices. Youth were engaging in more testing of specific designs, more iterations of their designs, and ultimately creating more sophisticated designs. In the earlier program iterations, youth were limited in their ability to iterate due to the short durations of each session and interviews with youth revealed that they were not motivated to iterate as they perceived their designs to be "good enough."

We hypothesize that the curriculum's new emphasis in version three on engaging in argument from evidence helped youth to convince themselves that more work was needed to improve their designs. For instance, during interviews, youth often discussed the need to collect data to justify their decisions or processes. One youth stated, "*I would use some research data and say if I tested it on my own processor or designer city I made on my own. So, I would show them evidence and anything else that I used to do with the drone*" [T1]. Thus, building on the framework helped us to create an in-depth afterschool program that built on student interest while engaging them in significant science and engineering practices.

References

Lehrer, R., & Schauble, L. (2006). *Cultivating Model-Based Reasoning in Science Education*. Cambridge University Press.

National Research Council(NRC) (2012). A framework for K-12 science education: Practices, crosscutting concepts, and core ideas. National Academies Press.

NGSS Lead States. (2013). *Next Generation Science Standards: For States, By States.* Washington, DC: The National Academies Press.

Severance, S., Penuel, W. R., Sumner, T., & Leary, H. (2016). Organizing for teacher agency in curricular co-design. *Journal of the Learning Sciences*, *25*(4), 531-564.

Shwartz, Y., Weizman, A., Fortus, D., Krajcik, J., & Reiser, B. (2008). The IQWST experience: Using coherence as a design principle for a middle school science curriculum. *The Elementary School Journal*, *109*(2), 199-219.

Towards a Critical Sociocultural Theory of How Teachers Understand Inequity, Power, and Oppression

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Abstract: Teacher educators and researchers argue that teachers must understand inequity, power, and oppression. Critical sociocultural theories suggest that teacher learning is enmeshed in systems, that it either reproduces or contests oppressive power relations, and that resistance is an infinite praxis. However, a review of teacher education literature illustrates that by contrast, teachers' "understanding" of inequity, power, and oppression is typically conceived as being an individual trait, an achievable state, and transferable. This poster calls for more teacher education research to use critical sociocultural theories to conceptualize teacher learning and relatedly, teachers' ability to disrupt oppressive systems.

Keywords: equity, teacher education, critical consciousness, sociocultural, critical theory

Introduction

Teacher educators and scholars have long argued that the world we live in is rife with inequity, and teachers must recognize this and act accordingly. As Alcoff (2007) argues, however, the structures and systems in our society often conceal the mechanisms and the oppressive power relations that produce and maintain inequity. Consequently, those who seek to disrupt the status quo must find ways to perceive what is hard to perceive in order to prevent the reproduction of existing patterns of oppression. But what does it mean for teachers to "understand" inequity, power, and oppression in this way?

Theoretical framework

Educational researchers have long used sociocultural theories of learning to frame phenomena such as teaching practice, teacher identity, and teacher learning (for a review, see Russ, Sherin, & Sherin, 2016). Sociocultural theories of learning foreground the dynamic social, cultural, historical, and political contexts in which learning happens, making them well-suited to the analysis of teachers' "understanding" of inequity. Critical theories additionally center the role of power relations in organizing and structuring social contexts. As a result, learning scientists are increasingly integrating sociocultural theories with critical theories that elucidate the role of power and systems of oppression in learning (e.g., Enyedy, 2016).

Drawing on the work of these scholars, I highlight three ideas that illustrate the promise of critical sociocultural theory to support research into teachers' "understanding" of inequity. First, teacher learning is enmeshed in systems of actors and artifacts, which carry histories embedded with power. Therefore, studies of teacher learning must study systems, and must account for relational histories and situational contexts in learning (e.g., Esmonde & Booker, 2017). Second, power relations within these systems are either reproduced or resisted (e.g., Philip, 2011). Activity that does not resist existing power relations legitimizes the social order, so there is no neutral ground. Third, resisting is an infinite praxis; not only is the status quo too complex to simply overthrow once and for all, but also, transformation requires a constant struggle and a constant effort at provisional action (e.g., Butler, 2005; hooks, 1994). Figure 1 shows the first of these ideas in the two upper sections, the second idea at the bottom, and the third idea represented by the cyclical nature of the diagram.
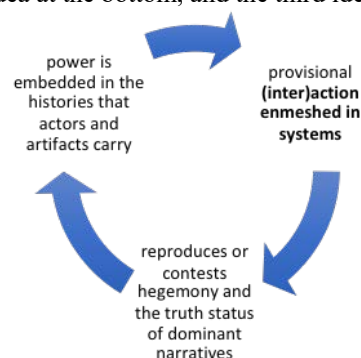
Figure 1. A critical sociocultural theory of teachers' understanding of inequity.

Methods

To determine how "understanding" is conceptualized in existing teacher education literature, I conducted a representative but not exhaustive review of empirical studies that made claims about how K-12 teachers learn to "understand," using search terms such as "critical consciousness" and "teacher education." Three-quarters of the 45 studies described interventions in university-based teacher education courses, and the remainder were mostly observational or action research studies with in-service teachers. I coded studies for their desired outcomes, research design, and evidence of learning (what was learned and by whom?), among other features. Then, I synthesized these codes into themes summarizing how researchers conceptualized teacher "understanding."

Findings

Although exceptions certainly existed, the majority of reviewed articles conceptualized teachers' "understanding" of inequity, power, and oppression as an *individual* trait, as an *achievable* state, and as *transferable* across contexts and situations. Table 1 offers a brief summary of these prevailing assumptions.

Table 1: Typical conceptualizations of teacher understanding

Theme	Evidence in studies	Limitations
Individual trait	Reliance on individual surveys or self-reported statements such as "I realized" and "now I am aware"	Overlooks teachers' historicized selves (Gutiérrez & Jurow, 2016), the teacher educator's positionality, and artifacts
Achievable state	Describing teachers as being "changed" or "transformed" or as gaining "newfound awareness"	Partitions understanding into discrete levels; does not allow for partial or situational understanding
Transferable	Claims of universal ("children in all places") or general ("I know what racism really is") understanding	Assumes that teachers who "understand" in one interaction, situation, or context will "understand" forevermore

Conclusion

Applying a critical sociocultural theory of teacher learning to studying teachers' "understanding" of inequity, power, and oppression calls for greater attention to the systems and situational contexts of teacher learning in action, to the histories and power dynamics involved, and to moment-to-moment interactions rather than static understandings that can be acquired and applied. Accordingly, teacher educators must seek pedagogies that engage teachers in this active, ongoing, and important work.

References

Alcoff, L. (2007). Epistemologies of Ignorance: Three Types. In S. Sullivan & N. Tuana (Eds.), *Race and Epistemologies of Ignorance* (pp. 39–57). Albany, NY: State University of New York Press.

Butler, J. (2005). *Giving an account of oneself*. New York, NY: Fordham University Press.

Enyedy, N. (Ed.). (2016). Participatory design research and educational justice: Studying learning and relations within social change making [Special Issue]. *Cognition and Instruction*, *34*(3).

Esmonde, I., & Booker, A. N. (Eds.). (2017). *Power and privilege in the learning sciences: Critical and sociocultural theories of learning*. New York, NY: Routledge.

Gutiérrez, K. D., & Jurow, S. (2016). Social Design Experiments: Toward Equity by Design. *Journal of the Learning Sciences*, *4*, 565–598.

hooks, b. (1994). Engaged Pedagogy. In *Teaching to transgress: Education as the practice of freedom* (pp. 1–22). New York, NY: Routledge.

Philip, T. M. (2011). An "ideology in pieces" approach to studying change in teachers' sensemaking about race, racism, and racial justice. *Cognition and Instruction*, *29*(3), 297–329.

Russ, R. S., Sherin, B. L., & Sherin, M. G. (2016). What Constitutes Teacher Learning? In D. H. Gitomer & C. A. Bell (Eds.), *Handbook of research on teaching* (5th ed.). Washington, DC: American Educational Research Association.

Acknowledgments

Learning Scientific Practices Through Participation as a Volunteer Community Scientist

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Abstract: An ethnographic study of community scientist volunteers in a museum-embedded genetics lab clarifies how participants are afforded or constrained in opportunities to learn scientific practices through an apprenticeship-model program. Guided participation in the lab results in participatory appropriation of scientific practices by volunteers. Community scientists enter as newcomers, then gain experience through opportunities to observe and engage in a range of scientific practices associated with studies on genetics of taste and everyday lab support tasks.

Keywords: community science, citizen science, apprenticeship learning, informal learning

Introduction

Over the last two decades, there has been an increased focus on the participation of members of the general public in aspects of scientific research, commonly referred to as citizen science. These types of volunteer programs, also referred to as Public Participation in Scientific Research (PPSR, Shirk et al., 2012) or "community science," generally provide opportunities for volunteers to contribute to various aspects of scientific research. While the availability of volunteers to collect data is of clear benefit to science researchers, there is an ongoing question as to the benefit of such participation to the volunteers themselves. Too often, volunteers can be relegated to the role of "databots" guided in collecting rigorous data following protocols, without an understanding of the scientific issues that render it meaningful (Pea, et al., 1997). What benefit do the community scientists themselves derive from their participation in such practices and others designed into community science programs? We examine one program in detail to answer the question: How do individuals volunteering as community scientists in a museum-embedded genetics lab learn scientific practices through their participation in ongoing studies of the genetics of taste?

Theoretical framework

We draw on Rogoff's (1995) framework of learning through participation on three planes of sociocultural activity: apprenticeship, guided participation, and participatory appropriation. The broadest plane is the community level of activity, which Rogoff refers to as *apprenticeship*, as newcomers to the community learn new skills through first-hand participation (Lave & Wenger, 1991). The next plane of activity focuses on the interpersonal level of participation – *guided participation* – which describes how multiple individuals interact within the context of the mutual activity. The final plane of activity narrows the focus to an individual's process of learning new tasks and using new skills to participate in activities in more knowledgeable ways. Rogoff refers to this plane as *participatory appropriation*. Community scientists are positioned as novices within the community, embedded within existing institutional systems that proscribe engagement in the activity, with tasks directed by more experienced individuals. In this way, we identify learning as a change in participation in practices, looking for evidence of learning within and through the three planes of analysis.

Methods

This study took place inside a genetics lab embedded within an exhibit on the human body in a large natural history museum in the Western U. S. The work of the community scientists who volunteer in this lab is directed on a day-to-day basis by a lab manager and three museum staff members. The community scientists in the lab are responsible for daily maintenance tasks related to the exhibit-associated experiment area as well as enrolling museum guests in ongoing genetics studies and other study-related tasks.

We took an ethnographic approach, engaging the first and second author in participant observations of lab operations. The researchers participated in the normal onboarding process for all museum volunteers. Over the course of 16 months, they completed 52 observations (>156 hours) across all 14 volunteer shifts. All community scientist volunteers were asked to consent to being observed while working in the lab, with a purposive sub-sample asked to participate in interviews. For analytic purposes, based on our observations of

learning opportunities, we partitioned community scientists into one of three groups based on career phase: pre-professional, early/mid-career, or late-career/retired.

Primary sources of data included detailed observation notes of all consented community scientists (N=35), interviews of a subset of participating community scientists (N=13), exit interviews of five departing community scientists, demographic survey results, and associated artifacts. Observation notes and interview transcripts were coded using both inductive and deductive codes (Miles, Huberman, & Saldana, 2013).

Findings

On the community and institutional plane, the volunteer program represents a small community of volunteers whose formation is supported by the larger volunteer program in which it is embedded. This natural history museum has over 1800 volunteers each year, representing 230,000 person-hours or 114 full-time positions. The volunteers are treated by the institution as valuable and necessary to the successful operation of the museum.

On the interpersonal level of participation, novice volunteers in the genetics lab are apprenticed into the community, supported and mentored by both lab staff and more experienced community scientists as they engage first-hand in the everyday tasks of the lab through a process of guided participation. One frequently observed example is how novice community scientists learn how to micropipette, a scientific skill requisite for activities such as DNA extraction and analysis, by being shown how to use a micropipette, then being observed by a skilled lab member while practicing, followed by opportunity to practice independently with a follow-up.

On the final plane of activity, novice community scientists demonstrate participatory appropriation through use of learned scientific practices both in and out of this particular lab. For example, we observed Kaitlyn [early/mid career] using her micropipette skills to extract DNA from the previous genetics of taste study, and Aiden [pre-professional] reported using his new micropipetting skills during a lab at his high school.

However, despite ample observations of community scientists engaging in the learning of new scientific practices, we identified patterns of participation that were often mediated by the career phase of the participants in ways that afforded or constrained their participation. For example, pre-professional community scientists such as Aiden were not able to enroll participants because they were not yet 18 years old, so they were relegated to non-study related lab tasks. Early/Mid career community scientists were often focused on acquiring new marketable science skills and as such, were often offered more opportunities to learn such skills. Late-career/retired community scientists frequently identified the purpose of their participation as more socially-oriented and were mainly happy to complete rote tasks rather than engage in learning new scientific practices.

Conclusions and implications

Overall, we found that ample opportunities to learn about scientific practices are embedded as part of regular participation in the ongoing activities in this genetics lab. Community scientist programs need to be designed to provide meaningful opportunities with enough flexibility to support the goals of diverse individual participants. This is a challenging balance to strike, particularly within the context of institutional guidelines and while maintaining rigorous protocol standards.

References

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge Univ Press.

Miles, M. B., Huberman, A. M., & Saldana, J. (2013). *Qualitative data analysis: A methods sourcebook*. SAGE.

Pea, R. D., Gomez, L. M., Edelson, D. C., Fishman, B. J., Gordin, D. N., & O'Neill, D. K. (1997). Science education as a driver of cyberspace technology development. In K. C. Cohen (Ed.), *Internet links for science education: Student–scientist partnerships* (pp. 189–220). New York:Plenum Press.

Rogoff, B. (1995). Observing sociocultural activity on three planes: Participatory appropriation, guided participation, and apprenticeship. In Wertsch, J. V., del Rio, P., & Alvarez, A., *Sociocultural studies of mind* (pp. 139–164). New York: Cambridge University Press.

Shirk, J., Ballard, H., Wilderman, C., Phillips, T., Wiggins, A., Jordan, R., ... & Bonney, R. (2012). Public participation in scientific research: a framework for deliberate design. *Ecology & Society*, *17*(2), 29-48.

Acknowledgements

Mobility, Diversity, and Openness: Design Principles for Equitable Makerspaces

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Abstract: As makerspaces become ubiquitous, they need to remain equitable environments for teaching and learning. Building on inquiry of diverse makerspaces, we identified three design principles of equitable environments (i.e., mobility, diversity, and openness) and leveraged them for one of the first university school of education makerspaces. We present the design principles, their application, and implications for the design of future makerspaces, particularly those that support pre-service teacher education.

Keywords: makerspace, school of education, design principles, pre-service teachers

Roots of making and a pedagogy for teacher education

Embodying the do-it-yourself ethos and celebrating technological innovation, makerspaces have surged over the past decade, rapidly spreading in schools, libraries, museums, and after-school centers (Peppler, Halverson, & Kafai 2016). This surge may be too brisk to keep pace with innovative educational design needs, as there is underdeveloped certainty about how these spaces can avoid repeating prior inequities in STEM-based environments. Higher-education-based makerspaces are important because they present opportunities to model high-quality educational practice for future teachers placed in a multitude of schools and afterschool programs. Makerspaces promise a real opportunity for more inclusive teaching and learning, provided we build them using appropriate design principles, humble theories that guide affordances toward improved learning (Rook, Choi, & McDonald, 2015). Makerspaces have been aligned with principles of constructionism (Resnick & Rosenbaum, 2013), an approach to learning in which learners come to know the world through design as they create personally meaningful projects that can be publicly shared (Papert, 1993). As makerspaces move into schools and teachers facilitate content knowledge through maker activities (Peppler, Halverson, & Kafai, 2016), there is a need for pre-service education that supports future teachers to explore constructionist learning before entering the profession. Aspects of successful preparation of future teachers and professional development opportunities of in-service teachers include the creation of contexts that are conducive for reflecting on practice and developing new approaches to teaching and learning (Vescio, Ross, & Adams, 2008). Despite the urgency for teachers to be able to use emergent technologies and the promise of makerspaces to support this exploration, the design of learning environments in pre-service teacher education remains under researched.

Methodological approach

Our makerspace design approach builds on design-based research, a methodology in which researchers and practitioners collaborate to iteratively analyze, design, develop, and implement learning experiences in real-world settings (Wang and Hannafin, 2005). One pillar of design-based research is the distillation of *design principles*, localized guiding theories that improve learning (Rook et al., 2015). This poster focuses on design principles to guide the development of new makerspaces that promote equity through a two-phase process.

Phase 1 adopts a qualitative contextual inquiry. We surveyed 51 and observed 10 makerspaces that encourage equity through educational practices and materials and serve diverse demographics. Based on qualitative observations and in-depth interviews with mentors and youth, we distilled design principles through a reversed conjecture mapping process (Sandoval, 2014). Phase 2 is comprised of testing and refining the design principles through research-based design (Leinonen et al., 2008). We analyzed how the design principles and their form impacted pre-service education throughout the first year in which the makerspace was open.

Design principles and development of the makerspace

The makerspaces we observed included a wide range of materials and exhibited a range of youth projects. All makerspaces were situated inside of open studio spaces where youth could see what others were engaged with. Ceiling electricity, mobile tables, and concrete floors supported the setup of workstations that flexibly accommodated project needs presupposed that makerspaces change over time as projects evolved and new materials entered the space. Based on these commonalities, we distilled three guiding principles: (1) *Mobility* to arrange workstations according to learning needs, (2) *diversity* of materials to support a broad range of

approaches to making, and (3) *openness* of access to materials for youth of all ages. To test the design principles, we used them to guide the spatial arrangement of the university makerspace as a way to spark possibilities particularly for pre-service teachers for modelling community-based and open-ended learning.

To support *mobility*, we ordered height-adjustable tables, custom storage units that tucked under counters or generated work surfaces, exposed the concrete floor to move furniture with less friction, and installed metal pegboard along walls for continuous space rearrangement. To invite *diverse* approaches to making, we made the space wheelchair accessible. We engaged material historicity (Buchholz et al., 2014) by considering participants' gender and age, stocking the space with a range of materials, and established faculty grants that included allocations for material purchase. As architectural plans were created, we focused on *openness* to make materials, projects, and practices visible and accessible for people both familiar with and unfamiliar with making. This led us to tearing down walls and instantiating an open door policy.

Once the space opened, design continued. People created projects, moved furniture, and asked for additional materials. We observed how the design principles and their material implementation acted within the institutional space of the school of education. Against our expectations, the mingling of materials did not happen as frequently. For instance, most 3D printed models remained on the right side of the space while most laser cut projects were displayed on the left side. Assumptions about learning that were embedded into the institutional setting, such as working on individual projects in designated seats and all classrooms to be of similar sizes and shapes, were challenged through new maker materials that called to move across the space and to share work openly with others. The variety of materials visibly accessible at the makerspace invited people to try new tools and techniques, resulting in a variety of projects, including laser-cut dinosaur puzzles, a 3D model for teaching Tai Chi, and art and science education tools. Faculty grants broadened material diversity, as projects brought in toys and gluten-free playdough. The makerspace was rearranged frequently, as people shifted the tables and storage carts across the room to create unique workspaces. The ceiling-mounted electrical cords were pulled towards workspaces to maintain and break existing setups, underscoring the mobility of space, and allowing for continued adjustment. The design principles allowed for the space to take shape quickly while being open for rearrangement in the future. Removing the pre-existing wall and built in cabinets, adding countertops, affixing pegboard, and installing glass walls produced an open rectangular space that passersby could peek into.

Discussion

The design principles of mobility, diversity, and openness guided the makerspace setup and facilitated adaptability. The principles have utility to the design of new learning spaces, including schools, libraries, and museums. They can help recognize possible inaccessibility, obstruction, immobility. and homogeneity through small and big changes, such as adding wheels to a cart. We envision spaces all across learning settings that are open and accessible at odd hours, that value a diversity of approaches, and that allow for spatial arrangement to be part of the creative learning process. This has implications for how we conceive of design of educational settings that are established in existing institutional settings as a longer-term process in which materials take on an active role in the shaping of continuous learning possibilities. This calls for practical consequences for tracking continued material design and tensions when contending assumptions of learning meet.

References

Leinonen, T., Toikkanen, T., & Silfvast, K. (2008, October). Software as hypothesis: research-based design methodology. *In Proceedings of the tenth anniversary conference on participatory design 2008* (pp. 61-70). Indiana University.

Papert, S. (1993). *The children's machine: Rethinking school in the age of the computer*. New York: Basic Books.

Peppler, K., Halverson, E., & Kafai, Y. B. (Eds.). (2016). *Makeology: Makerspaces as learning environments (Vol. 1)*. New York: Routledge.

Resnick, M., & Rosenbaum, E. (2013). Designing for tinkerability. M. Honey & D. Kanter (Eds.) *Design, make, play: Growing the next generation of STEM innovators*, 163-181. New York: Routledge.

Rook, M. M., Choi, K., & McDonald, S. P. (2015). Learning theory expertise in the design of learning spaces: Who needs a seat at the table?. Journal of learning spaces, 4(1).

Sandoval, W. (2014). Conjecture mapping: An approach to systematic educational design research. *Journal of the learning sciences*, 23(1), 18-36.

Vescio, V., Ross, D., & Adams, A. (2008). A review of research on the impact of professional learning communities on teaching practice and student learning. *Teaching and teacher education*, 24(1), 80-91.

Wang, F., & Hannafin, M. J. (2005). Design-based research and technology-enhanced learning environments. Educational technology research and development, 53(4), 5-23.

Developing Interdisciplinary Competencies for Science Teaching and Learning: A Teacher-Researcher Professional Learning Community

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Abstract: We describe a research project examining teacher knowledge and practice over a multi-year professional development project centered on assessment literacy in the context of the U.S. *Next Generation Science Standards.* The project supports teacher learning through professional learning community workshops (LCW) and collaborative design team (DT) meetings. Five dimensions of knowledge are posited as essential to effective implementation of the NGSS, including assessment design for formative purposes and science literacies inherent in the practices of developing, carrying out and reporting science investigations. Learning along these dimensions is being documented through close analyses of teacher talk in the workshops, design team meetings, at their school sites, in the classroom, and in the assessments they design, implement and revise. In this poster we report on the initial year of work with these high school science teachers.

Keywords: Assessment, collaboration, secondary, science, teacher.

Introduction

What to teach as well as how to teach and assess it are persistent questions that confront educational systems. The digital age has catalyzed a resurgence of these questions over the past 10 years, with new and/or revised standards in traditional content areas (e.g., mathematics, science, the language arts, social studies) as well as expanded emphases important to life-long learning (e.g., affective, dispositional). A clear theme across these efforts is the call for learners to be actively involved in the ways of knowing — in the disciplinary habits of mind and knowledge-generating inquiry and representational practices that characterize particular fields of knowledge (e.g., Pellegrino & Hilton, 2012). For teachers to provide learners with opportunities to develop such competencies, teachers themselves need opportunities to develop competencies to teach and assess these competencies (Goldman et al 2016; Ford & Forman, 2006; Kelly, 2014).

We report on an effort by researchers and teachers to co-create professional learning contexts that enable high school science teachers to develop instructional and assessment competencies to effectively implement one U.S. example of redefined standards, the *Next Generation Science Standards* (National Research Council, 2014; NGSS Lead States, 2013). The three-dimensional emphasis of these standards — disciplinary core ideas, crosscutting concepts, and practices — demand different lenses on the work of science teaching and learning, including making explicit the science "reading" literacies inherent in all aspects of scientific investigations (Goldman et al, 2016). Teachers need to shift their understanding of what science is, change their modes of engaging students, and implement new ways of assessing students. Drawing on multiple domains of learning sciences research, we hypothesized 5 learning dimensions to enable teachers to shift instruction and assessment practices in NGSS-consistent directions: Participation within collaborative design teams and professional learning communities; Instructional practices aligned with NGSS; Assessment literacy and practices; Assessment design practices aligned with NGSS; and Views of student roles in assessment practices.

Collaborating for learning

Over the 3-year project duration, we are collaborating with teachers (approximately 20 representing four different urban high schools and the typical range of science domains) to design and enact learning opportunities intended to engender growth along the 5 learning dimensions. Consistent with design-based implementation research (DBIR; Penuel et al., 2011), the design process includes ongoing review and reflection on how teachers take up aspects of these dimensions in their teaching and assessment practices (Popham, 2009).

Our collaborative activities occur in two settings: learning community workshops (LCW) with all teachers and researchers and design team meetings (DT) with representatives from each high school and the

researchers. Both the LCWs and the DT meetings amplify teachers' agency with respect to their own learning and that of their students, their instructional practices with the NGSS-aligned assessments they design, and within school collaborations. A major mechanism for promoting agency and participation in learning communities is through iterative cycles of design, implementation, reflection and revision at the local school site and at the monthly LCWs (Lave & Wenger, 1991). During the LCWs, teachers' work within school teams, across science domains, and within science domains to consider how the instructional and assessment activities they design invite students into meaningful science learning. Between LCWs, teachers implement their designs and bring their experiences doing so to school site and subsequent LCW meetings. Collaborative co-design with researchers is most strongly enacted in the DT meetings where the content and focus of subsequent LCWs are discussed, debated, and outlined (Severance et al., 2016). DT meetings begin with each representative using "mirror material" (Engeström, 2011, p. 612) for relating discussions at their school, including what is being learned from classroom use of designed artifacts, and questions and concerns school teams are raising. The DT then turns to selected video footage from the prior LCW for reflective review relative to the goals and activities of that workshop. These documented DT discussions guide the scope and content of the subsequent LCWs.

Sources of evidence and initial findings

Discourse and artifacts from the LCWs and DTs constitute the primary data sources for tracing movement along the five learning dimensions. For example, we carry out analyses of the assessment and instructional materials teachers design, discuss, use, and revise. These, along with the discourse around them, suggest how teachers increase their understanding of three-dimensional assessments as well as of the reading and production demands of their current assessments. Analyses of video of DT meetings and LCWs provide indications of specific collaborative experiences and fruitful discussions about the tensions and challenges that underlie this approach to science instruction. Other artifacts we are analyzing capture initial "locations" and movement along the five learning dimensions include: (1) Year-long curricular maps aligned with the NGSS disciplinary core ideas; (2) Alignments of the curricular maps with science and engineering practices, providing the basis for teachers design of multi-dimensional instructional activities and assessments; and (3) A checklist for validity, reliability, and fairness of assessments. In creating these products teachers engaged in unpacking NGSS practices and are in the process of examining the NGSS crosscutting concepts and developing criteria for informative rubrics.

References

Engeström, Y. (2011). From design experiments to formative interventions. *Theory & Psychology, 21*, 598-628.

Ford, M. J., & Forman, E. A. (2006). Redefining disciplinary learning in classroom contexts. *Review of Research in Education*, *30*, 1–32.

Goldman, S. R., Britt, M. A., George, M. A., Lee, C. D., Brown, W., Cribb, G., Greenleaf, C., Shanahan, C. & Project READI (2016). Disciplinary literacies and learning to read for understanding: A conceptual framework of core processes and constructs. *Educational Psychologist, 51,* 219-246.

Kelly, G. J. (2014). The social bases of disciplinary knowledge and practice in productive disciplinary engagement. *International Journal of Educational Research*, *64*(Supplement C), 211–214.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge, UK: Cambridge University Press.

National Research Council (2014). *Developing Assessments for the Next Generation Science Standards*. Washington, DC: The National Academies Press.

NGSS Lead States (2013). *Next Generation Science Standards: For States, By States.* Washington, DC: The National Academies Press.

Pellegrino, J. W. & Hilton, M. (2012). *Education for life and work: Developing transferrable knowledge and skills in the 21st century*. Washington, DC: National Academy Press.

Penuel, W. R., Fishman, B. J., Cheng, B. H. & Sabelli, N. (2011). Organizing research and development at the intersection of learning, implementation, and design. *Educational Researcher, 40*, 331–337.

Popham, W. J. (2009). Assessment literacy for teachers: Faddish or fundamental? *Theory into Practice*, *48*, 4–11.

Severance, S., Penuel, W. R., Sumner, T. & Leary, H. (2016). Organizing for teacher agency in curricular co-design. *Journal of the Learning Sciences, 25*, 531–564.

Acknowledgments

Europa Universalis IV the Grandest LAN Party: A Case Study

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Abstract: Although there is disagreement among researchers about when, how, and which digital games should be used in formal educational settings, digital games are already present in classrooms. Affinity spaces provide both a theoretical framework and methodology for addressing this issue. The "EUIV Grandest LAN party" was identified as a source of novel insight for educational researchers, teachers, and game developers interested in serious games, learning through affinity spaces, and scaffolding within online gaming communities.

Keywords: Affinity spaces, Games, Online communities, Informal learning, Transformative play

Introduction

Despite the abundance of research on digital games in educational settings, there remains a general lack of consensus among educational researchers on the topic. This may be due to the ever changing technological and digital gaming landscape or to the perpetual difficulty of describing the contexts suited for learning through digital games. "[H]ow can one theoretical framework account for both the moment-to-moment interactions that constitute gameplay (including the player's goals and interactions) while also accounting for the broader socio-cultural contexts that constitute the activity?" (Squire, 2002). Research on affinity spaces help to bridge the *context* gap in games by attempting to describe both physical and virtual informal learning. This research extends the theoretical framework of affinity spaces by identifying a particular online gaming community as an ideal example of learning through affinity spaces.

The EUIV Grandest LAN party was a 4-day live-action role playing (LARP) campaign where attendees collectively played Europa Universalis IV (EUIV), a historical grand strategy game, but negotiated diplomacy and collaboratively strategized in-person within the walls of a medieval castle. A local area network (LAN) party is when people come together in a physical space to engage in collective game play. This particular LAN party was advertised worldwide through EUIV's many social media websites and was designed by a LARPing company. The event was supported by EUIV's game developer, Paradox Interactive, and advertised authentic learning activities, such as fencing and workshops on history, statesmanship, and the art-of-war. Previous research on the second edition of Europa Universalis, EUII, resulted in empirical findings supporting the educational value of the game (Egenfeldt-Nielsen, 2012). Egenfeldt-Nielsen writes, "I believe that the game [EUII] has educational potential, and I have conducted a two month-long history course, teaching with the game in a Danish high school involving 85 students and two teachers" (2012). This study utilizes Egenfeldt-Nielsen's work on EUII to discuss the potential educational capabilities of EUIV and its unique affinity space. Additionally, this study adds to recent literature by describing the ways in which modern gamers interact with each other and how learning is facilitated through dynamic online networks. The EUIV LAN party serves as a bounded event in which to analyze how these online gamers designed an authentic learning experience for other EUIV gamers.

Games and learning in affinity spaces

Affinity Spaces are described as informal learning spaces where a common endeavor connects all participants, in this case a game, EUIV (Gee, 2004). These informal learning spaces are spread across physical and virtual environments including the game itself (which allows for multiplayer campaigns), online forums (Reddit, Steam, and Paradox forums), social media (Facebook and Twitter), and video sharing sites (Youtube and Twitch). Therefore knowledge in affinity spaces is dispersed throughout its many participants, online tools, and technology (Lammers, Curwood, & Magnifico, 2012). Digital games, computer and videogames, are particularly interesting for studying affinity spaces because gaming communities primarily are connected by online networks, these online networks leave a digital trail on the community's activities and interactions (Lammers et. al., 2012). Learning sciences focus on interactive systems activity, therefore the individual is only a piece of the context and researchers must also focus on the interactional structures of the social and material systems (Steinkuehler, 2004). Game-focused affinity spaces can therefore provide a more holistic description of how learning is facilitated by the game itself and through the affinity space.

Games are designed experiences that are extremely useful context to study cognition (Steinkuehler, 2006). Additionally, immersive game-based learning environments for transformative play have been used as successful curricular scaffolds (Barab, Scott, Siyahhan, Goldstone, Ingram-Goble, Zuiker, & Warren, 2009).

The EUIV Grandest LAN party was an informal learning environment that incorporated transformative play through LARPing. Transformative play in games allows students' identities to meld with the player identity, overcome challenges through problem-based, contextually meaningful decision-making, provide motivation and grounds learning, and embeds authentic resources and tools (Barb et. al., 2009). Therefore, "the educational value of the game-playing experiences comes not from just the game itself, but from the creative coupling of educational media with effective pedagogy to engage students in meaningful practices" (Squire, 2002). If the EUIV Grandest LAN party can be studied as a product of its affinity space and a designed experience for its participants, then this study can elucidate how participants are motivated to interact, teach, and learn within this space.

This ongoing project aims to establish a basis for further research into EUIV's gaming community and culture - how does participation in the affinity space lead to socially regulated learning and is that learning valuable for education? Three core questions are pertinent to this case study: 1) What does EUIV Grandest LAN party's affinity space look like? Specifically, what portals are available through the game's networks and how do participants contribute and partake of the content? 2) What are the social motivations that led an online community to meet up for a 4-day LAN party? Or rather, what was the desired product of participants? And lastly, 3) How do participants apply their game-knowledge to the real-world and is there awareness of co-construction of knowledge?

Research design

This exploratory case study expands on Lammer et. al. affinity space ethnographic methodology (2012). Preliminary research has been conducted to deconstruct the game (Aarseth, 2003), EUIV, to describe its affordances and constraints, and diagram the online networks and social media websites involved in the EUIV Grandest LAN Party's affinity space. Additional research will include in-depth interviews with the LAN party's attendees and discourse analysis of Youtube and Twitch videos of the event in order to illustrate the content and context of the experience. Attendees and participants of interest have been identified through social media networks. Participants of interest include two of EUIV's game developers who were special guests at the event, a historian and speaker for one of the workshops, and the LARPing company's CEO that hosted the event.

Implications

The potential of games for learning remains shrouded in questions about which games should be used, what content games teach, and how they should be implemented. "Affinity spaces are an important part of gaming practices, and participation within them can enable a powerful form of social learning" (Pellicone & Ahn, 2015). Additionally, affinity spaces must be studied in their entirety including their physical context, online websites, and social media networks. This case study draws on a special gaming community's live event that has shown great potential for: 1) researchers interested in motivation and socially shared-regulation of learning in affinity spaces, 2) teachers and teacher educators interested in designing meaningful gaming experiences for learning, and 3) game developers interested in game affordances that encourage player buy-in and affinity space mediated content support. This study aims to describe a designed experience and its application for formal and informal learning environments.

References

Aarseth, E. (2003). Playing Research: Methodological approaches to game analysis. In *Proceedings of the digital arts and culture conference* (pp. 28-29).

Barab, S., Scott, B., Siyahhan, S., Goldstone, R., Ingram-Goble, A., Zuiker, S. J., & Warren, S. (2009). Transformational play as a curricular scaffold: Using videogames to support science education. *Journal of Science Education and Technology*, *18*(4), 305.

Egenfeldt-Nielsen, S. (2012). EUROPA UNIVERSALIS II: Conquest, trading, diplomacy from the Middle Ages to Napoleon, *Well Played, Vol. 1, No. 3.* Pittsburgh, PA: ETC Press.

Gee, J. P. (2004). *Situated language and learning: A critique of traditional schooling.* Psychology Press.

Lammers, J. C., Curwood, J. S., & Magnifico, A. M. (2012). Toward an affinity space methodology: Considerations for literacy research. *English Teaching*, *11*(2), 44.

Pellicone, A., & Ahn, J. (2015). Building worlds: A connective ethnography of play in Minecraft. *Games and Culture*, 1555412015622345.

Squire, K. (2002). Cultural framing of computer/video games. *Game studies*, *2*(1), 1-13.

Steinkuehler, C. A. (2004). Learning in massively multiplayer online games. In *Proceedings of the 6th international conference on learning sciences* (pp. 521-528). Intl Society of the Learning Sciences.

Steinkuehler, C. A. (2006). Why game (culture) studies now?. *Games and Culture*, *1*(1), 97-102.

Revitalizing Japanese Lesson Study Through Shared Tools Embedded in Design-Based Implementation Research

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Abstract: In order to tackle the *persistent problem* revealed in a Japanese learning sciences project, we attempted to identify an effective design for pre-lesson study workshops that supports teachers to focus on students' cognitive processes. A set of tools for simulating students' learning processes enabled participant teachers to take learner-centered perspectives, which contributed to making their images of what and how the children will learn more concrete.

Introduction

This paper clarifies an effective scaffold for teachers to focus on students' cognitive processes in creating and revising their lesson plans. The context for this study is design-based implementation research (DBIR: Penuel *et al.*, 2007) in a Japanese learning sciences project for promoting collaborative learning using a lesson framework known as the Knowledge Constructive Jigsaw (KCJ: Miyake, 2013). Approximately 1,000 teachers of all subjects from the 1st to the 12th grade in collaboration with 30 regional boards of education participate the project. The project has formed professional learning communities of teachers who share the KCJ method and its "lesson study" (Lewis, 2002) as a *common tool* (one feature of DBIR) in order to first, improve the quality of students' learning as well as the teachers' learning of "how students learn", second, encourage networking among the teacher communities, and third, to clarify how to support such improvement and networking in a sustainable way. The project revealed a *persistent problem* (another feature of DBIR), which is many teachers lack the habitual practice of focusing on the cognitive processes of the students (i.e., "How will students make sense of this task and read this material?") when they develop lesson plans. Although Japanese "lesson study" is known to be an effective form of professional development (Lewis, 2002) in which teachers observe live classroom lessons, collect data, and collaboratively analyze such data, two trends do not successfully merge into scalable action research: one trend focuses on what and how teacher *should teach* and the other focuses on what and how students *learned*. Faced with a scaling-up issue where researchers cannot directly help teachers explore students' learning processes, we propose a set of scaffolding for teachers to constructively interact with one other at their local school in forming and testing hypotheses about student learning (how they *will* learn) in their own lessons. This small research would suggest that additional but simple tools embedded in DBIR can contribute to DBIR of a higher quality.

Methods

This paper tests the hypothesis that a set of DBIR and its shared tools effectively support teachers to *simulate* how students will learn, and enable them to make their own hypotheses about students' learning process in the lesson. Specifically, we created a tool which is a set of "simulation sheets" of students' learning processes in the lesson for a pre-lesson study and shared it with the above DBIR community. It is not easy for one teacher to have concrete images of the diverse processes of students, to which multiple teachers with different points of view can make vast contributions, especially in the DBIR community which shares a common vision and instructional framework.

We took three cases (see Table1) from a pre-lesson study workshop, which collected 37 teachers of a municipal board of education. In this workshop, three designated teachers brought their lesson plans, each of which was collaboratively scrutinized through a three-step process. In the preliminary step (45 min), the teachers experienced a lesson as students to grasp an outline of the plan. In Step 1 (45 min), teachers anticipated the learning processes of the best student and the poorest one in this lesson plan based on their experience as students: "What answers are they likely to write at the beginning of the lesson?" "What are they likely to talk about during their discussions?" and "What are they likely to write after the lesson?" In Step 2 (45 min), they revised the lesson plan based on the simulation of Step 1. In both Step 1 and Step 2, the teachers use lesson design study sheets (shared tools), discuss the lesson plan in small groups, and present their findings to other groups.

In order to show that the simulation of the students' learning processes was properly done in Step 1, we analyzed the presentations from each group, where the representatives of the groups gave summaries of their group discussions in Step 1. We divided the reports by sentence and compiled the percentage of sentences with "a learner" or "learners" as the subject (learner-subject-sentences) in the number of sentences with subjects. The more we find learner-subject-sentences in the reports, the more we can consider participants engaged in the

simulation activities. Second, in order to show that revision from the students' viewpoint also continued in Step 2, we categorized the content of the presentations into four groups by combining two axes: Content (C) versus lesson design (LD), and learner-centered (LC) versus non-learner-centered (N-LC). We mostly focused on how teachers' simulation can change from N-LC to LC.

Results and discussion

Table 1 shows the analytical results of Step 1 to demonstrate in what proportion the teachers used learner-subject-sentences. As shown in the table, the teachers used them in 76.5% out of 102 sentences. The results indicate that the teachers engaged in simulating students' learning as we had expected. Table 2 shows the analytical results of Step 2 to demonstrate in what proportion the teachers referred to the contents or lesson designs from a learner-centered perspective. As shown in the table, the teachers considered those perspectives in nearly 60% of their utterances in every lesson. The results also indicate that the teachers engaged in pointing out the problems and making proposals based on their simulation of students' learning.

Table 1: Effect of Step 1: In how many sentences did the teachers refer to the learner(s) as the subject?

Lesson Plan (Grade, Subject)	Number of participants (and groups)	Learner-subject-sentences
Water in nature (G4, Science)	17 (5)	41(82.0%)
Programing (G6, ICT)	10 (3)	18 (81.8%)
Speech technique (G9, English(ESL))	10 (4)	19 (63.3%)

Table 2: Effect of Step 2: In how many topics did the teachers refer to the learner(s) as the subject?

Lesson Plan	Number of topics	C/LC	C/ N-LC	LD/LC	LD/N-LC	Proportion of LC
Water in nature	17	6	2	6	3	70.6%
Programing	13	4	2	3	4	53.8%
Speech technique	11	3	4	4	0	63.6%

Each teacher improved her or his own lesson plan after this pre-lesson study workshop for the teaching of their lessons. In addition, some participants brought those tools back to their schools and tried this new style of lesson study with their colleagues. These results indicate that the teachers perceived the simulation of students' learning processes to be new and useful. Even though our tools are very simple and easy to use, they worked because of the help of a shared context created and sustained through partnerships among university researchers, boards of education and the teachers themselves. Sharing context enabled everyone to share visions and images of learning goals, to identify the task of how to realize such vision and learning, and to utilize the instructional framework as a means to solve the task. The framework, that is, the Knowledge Constructive Jigsaw, was simple enough for teachers to simulate what would take place in each step of learning. Therefore, this scaffolding, in other words, shared tools embedded in design-based implementation research, enables lesson study to be revitalized as a whole. We would like to examine how this type of lesson study will contribute to teachers' reflection upon the lesson conducted (post-lesson study), and whether we can train teachers to be able to facilitate these kinds of workshops instead of ourselves for further up-scaling.

References

Lewis, C. (2002). *Lesson study: A handbook of teacher-led instructional change.* Philadelphia: Research for Better Schools.

Miyake, N. (2013). Case report 5: Knowledge construction with technology in Japanese classrooms (CoREF). In P. Kampylis, N. Law, Y. Punie (Eds.), *ICT-enabled innovation for learning in Europe and Asia,* 78-90, European Commission, Joint Research Centre.

Penuel, W. R., Fishman, B. J., Yamaguchi, R., & Gallagher, L. P. (2007). What makes professional development effective? Strategies that foster curriculum implementation. *American educational research journal*, *44*(4), 921-958.

Acknowledgments

Improving Elementary Students' Literacy Through Knowledge Building

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Abstract: This study follows the Knowledge Building discourse of 4th graders in order to assess changes in literacy-related outcomes over the course of two semesters. Our analyses revealed that Knowledge Forum activities, such as use of scaffolding tools, increased over time and were positively correlated with improved essay writing, particularly for the low-performing group. Our findings add to the growing body of research that Knowledge Building pedagogy and Knowledge Forum technology together support the development of students' literacy.

Introduction

Knowledge Building (Scardamalia & Bereiter, 2014) is a pedagogical approach that aims to enculture students into authentic knowledge work. During Knowledge Building, students engage in collaborative discourse in order to advance ideas in the community knowledge. Knowledge Forum serves as the online environment to make ideas accessible to all, with supports in place for sustaining idea improvement (Zhang, et. al., 2011). Using Knowledge Forum, students read and write for each other to elaborate their thinking, seek clarifications, make connections, and improve their ideas together. Such complex, discursively-rich interactions involving high levels of reading, writing, and revision have been shown to be positively associated with literacy outcomes like vocabulary growth (Zhang & Sun, 2011; Chen et. al., 2015).

Study design

The current study aims to explore how Knowledge Building and Knowledge Forum can enhance literacy outcomes related to essay writing. More specifically, the research questions are: (1) Which forms of engagement in Knowledge Forum enhance students' online collaboration over time? and (2) Which online activities on Knowledge Forum correlate with their writing performance over time?. We examined the Knowledge Building discourse of a fourth-grade class (25 students) in Taiwan, where an experienced Knowledge Building teacher used a principle-based approach to improve her teaching practices and instructional design process over two semesters. The teacher encouraged her students to work collaboratively on KF, to share, build on, and improve ideas in order to advance the collective understanding of their Chinese textbook. In the second semester, the teacher aimed to deepen collaborative reading and writing in Knowledge Forum. She asked students to self-organize into dyads and triads to read KF notes online and discuss ideas together face-to-face, before building on other groups' ideas in KF again. Students had the option to create individual or co-authored notes.

At the end of each semester, we examined students' literacy-related activities in KF, which included basic online activities (e.g., note writing, reading, revising), use of scaffolding tools (e.g., uses of keywords and epistemic markers in notes) and social interaction (e.g., note-linking and note-reading). In terms of students' literacy-related outcomes, they wrote an essay at the end of each semester, which was scored by the teacher. We also explored the relation between students' Knowledge Building activities and writing activities to measure students' progress in terms of the amount of online activities from the first to the second semester.

Preliminary results

Students wrote a total of 645 notes in semester 1 (M = 25.8; SD = 7.67) and 692 notes in semester 2 (M =27.68, SD = 8.71). In semester 2, 92 collaborative notes were written (M = 22.6%, SD = 20.3%), with students gradually increasing the proportion of collaborative notes, despite given the option to create individual notes. A summary of students' online activities in Knowledge Forum are provided in Table 1. In order to investigate the relationship between students' Knowledge Building activities and their writing performance, we conducted Spearman correlation analysis. Students' essay writing is significantly correlated with their use of KF scaffolding tools ($\rho = 0.44$, $p < .05$), suggesting that their use of keywords and epistemic markers in notes were helpful to improving their writing skills.

Table 1: Summary of online activities in Knowledge Forum (N = 25)

KF activities		1st semester Mean (SD)	2nd semester Mean (SD)	Z
KF basic activities	# notes created	25.80 (7.67)	27.68 (8.71)	-1.20
	# notes read	171.28 (58.35)	104.64 (45.58)	-4.31***
	#build-on notes	15.00 (6.19)	14.56 (6.16)	-0.34
	# notes revised	7.32 (5.28)	3.76 (2.97)	-3.58***
Use of KF scaffolds	# of keywords in notes	20.24 (7.46)	22.92 (7.95)	-1.73
	# of epistemic markers	24.92 (8.15)	26.64 (9.09)	-1.31
KF social interaction	% of note-linking	57.00% (8.81%)	52.32% (20.25%)	-0.97
	% of note-reading	50.96% (18.61%)	39.40% (17.13%)	-3.52***

In order to understand the trajectory of students' improvement in writing, we compared three clusters (high-, medium-, and low-performing) based on the rank of their essay scores using the Kruskal-Wallis H test. The analysis indicated that in terms of their uses of KF scaffolding tools, there are significant differences between the three clusters ($X^2 = 6.99$, $p < .05$). While the writing performance for the high-performing and medium-performing clusters remained stable, the performance of students in the low-performing cluster improved over time, suggesting that the scaffolding tools (i.e., keywords and epistemic markers) in notes were especially conducive to fostering the writing abilities of students in the low-performing cluster.

Discussion and future directions

In this study, we examined the Knowledge Building activities and literacy development of fourth-graders in a Chinese language class over the course of two semesters. Several patterns emerged. First, students' online collaborative Knowledge Building activities, such as notes contribution and scaffolding tools use (e.g., keywords and epistemic markers) increased over time. Second, students' essay writing performance was improved, though no significant difference was found between the two semesters. Third, students' use of KF scaffolding tools was positively associated with their writing performance, with students in the low-performing group showing the greatest amount of improvement over time. Surprisingly, students' note-reading behaviours decreased over time, but it is likely due to the way collaborative notes were created in Knowledge Forum during the second semester. It should be noted that students' note-linking behaviours remained relatively stable.

Together, our findings suggest that when students engage in collaborative Knowledge Building activities and discussions with appropriate pedagogical and technological supports, all members benefit in a way that minimizes the gap between high- and low-achieving groups. This is of particular importance for literacy instruction where it is commonplace that the rich get richer, commonly referred to as the Matthew effect (Stanovich, 1986). Continued use of epistemic markers and keywords would help students sustain discourse that leads to continual idea improvement and progressively deeper understanding. Future work should aim to explore over extended periods of time the evolution of group knowledge processes that facilitate the development of students' multiliteracies during Knowledge Building.

References

Chen, B., Ma, L., Matsuzawa, Y., & Scardamalia, M. (2015). The development of productive vocabulary in knowledge building: A longitudinal study. In O. Lindwall, P. Hakkinen, T. Koschman, P. Tchounikine, & S. Ludvigsen (Eds.), *Proceedings of the Computer Supported Collaborative Learning (CSCL) Conference 2015*, Volume 1 (pp. 443-450). Gothenburg, Sweden: The International Society of the Learning Sciences.

Scardamalia, M., & Bereiter, C. (2014). Knowledge building and knowledge creation: Theory, pedagogy, and technology. In K. Sawyer (Ed.), *Cambridge Handbook of the Learning Sciences* (2nd ed.) (pp. 397-417). New York: Cambridge University Press.

Stanovich, K. E. (1986). Matthew effects in reading: Some consequences of individual differences in the acquisition of literacy. *Reading Research Quarterly*, *21*(4): 360–407.

Zhang, J., Hong, H.-Y., Scardamalia, M., Teo, C. L., & Morley, E. A. (2011). Sustaining knowledge building as a principle-based innovation at an elementary school. *The Journal of the Learning Sciences*, *20*(2), 262-307.

Zhang, J., & Sun, Y. (2011). Reading for idea advancement in a Grade 4 knowledge building community. *Instructional Science, 39*(4), 429-452.

Investigating the Use of Anchoring for Promoting Design Thinking

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Abstract: There has been an increased emphasis on integrating design thinking in every aspect of student learning at an early stage. However, teachers still lack the resources and scaffolds to facilitate such integration. In this paper, I present a way for scaffolding design thinking in middle school classrooms by using incomplete models as anchors. Findings show that the use of an incomplete seed model as an anchor evoked different responses from the student designers – some extending it immediately, some returning back to it after exploring other design options, and some likely referring to it implicitly. The incomplete seed model provided an example to the students for practicing design thinking and make tradeoffs. The incompleteness also allowed students to pursue different design trajectories.

Introduction

We are faced with a future where engineers have to increasingly make very complex design decisions, starting from determining how to build efficient autonomous vehicles, to designing secure artificial intelligence driven personal assistants and even building interplanetary settlements. These endeavors will require design thinking at every stage and it is best to start training as early as possible. In order to prepare students for this future, policy changes to the middle and high school standards require US school curricula to integrate design thinking in every aspect of student learning (NAE, 2009). However, this implementation has been slow to come primarily due to lack of age-appropriate resources and scaffolds for young students that might help them practice design thinking (Moore et al., 2014). In this paper, I address this gap and present a way for scaffolding design thinking in middle school classrooms by using incomplete models as anchors.

Framework

Models are simplified representations of complex systems that are frequently used as a thinking tool for understanding the system by manipulating various model parameters (Harrison & Treagust, 2000). Models help make reasoning and ideas inspectable amongst peers as well as evaluators (Lehrer & Schauble, 2000). In classrooms, models serve as tools for overcoming inert knowledge (Renkl, Mandl & Gruber, 1996) by anchoring instructions and discussions to a concrete representation of the system (CTGV, 1990). Anchoring using such models situates new knowledge "in the context of immediate application to a problem solution and not in an abstract, decontextualized way" (Renkl, Mandl & Gruber, 1996, p. 119). Models, in particular the incomplete ones that allow the user to fill in the gaps, have been found to be helpful during problem-solving tasks by encouraging self-explanations (Renkl & Atkinson, 2000). Thus, in this study I use incomplete models to drive students' problem-solving process using design thinking while they are working on a design challenge. Design thinking as the systematic iterative process of determining the goal or scope of a problem, generating ideas for optimizing the solution, evaluating the ideas by making tradeoffs and checking their fit in the solution space, and implementing the ideas to achieve the intended goal (Sheppard, 2003).

Method

This case study was conducted in an urban school in the Midwest US and spanned across 10 lessons, each 45-minute long. 12 students – grouped into 4 teams or "plumbing companies" – from the 6th grade worked on a design challenge using an incomplete model as the seed model. Every group was given the incomplete model that acted as an initiator for design ideas. Students had to optimize this seed model within the given constraints ($3000 budget and min 10 psi at each of the three taps A, B and C). Data sources included student conversations and models created by them. The incomplete model had a cost of $1203 and connected the source supply only to tap B. Three types of pipes were provided for completing the model, each having a certain cost and resulting in a specific pressure drop – 1-inch ($45, 1 psi drop), ¾-inch ($33, 4 psi drop) and ½-inch ($28, 12 psi drop).

Findings and discussion

Three ways of using the incomplete model emerged during the design process- delayed anchoring, immediate anchoring, and implicit anchoring. In the first instance, students demonstrated *delayed anchoring*. In the first iteration, after analyzing the seed model, Team B took it apart and reflected on the types of pipes that they had used; mostly 1-inch diameter pipes. S2 mentioned that they were trying to reduce the cost while satisfying the pressure constraint (10 psi). After this, the team revised their model by using different combinations of pipe

diameters. They also moved the placement of pipes to reduce the cost of the model and ensure adequate pressure at the taps. The team also used the seed model to reflect on their prior design decisions and brainstormed alternative paths that may reduce the cost while meeting the pressure requirement. The team finally settled on a design similar to the seed model's design since it had the least pipe bends and thus was their cheapest model.

In the second instance, students demonstrated *immediate anchoring*. Team C began their design session by analyzing the seed model - *"Just connect it using more pipes… but we have to get it cheap, under budget"*. The team then modified the model by simply adding more pipes to the seed model's design thereby extending it. They made tradeoff decisions, determining what diameter of pipes to use for extending the seed model and also figuring out whether they needed to replace any pipes in the seed model. They kept the pressure at tap B same since it satisfied the pressure constraint and went on to make sure that their cost was below the budget *("this premade one (seed model) is exactly 10. So, our psi is good. We just have to make sure our money is good")*. S9 used the given pressure of 10 psi at tap B to justify why they did not need to replace the ¾-inch diameter pipes of the seed model. However, he indicated that the team needed to worry about the cost, moving the team towards making tradeoffs between cost and pressure. The final model looked very similar to the seed model's design.

In the third instance, students demonstrated *implicit anchoring*. After analyzing the seed model during the first iteration, Team A concluded that the model could be improved for the "greater good" but at a higher price (more than the incomplete model's cost). The team then took apart the model and started rebuilding it. They discussed various ideas, gesturing where the pipes should go and, in the end, opted for a design that was very similar to the seed model. However, the team did not refer to the seed model explicitly in this case. S3 suggested using ¾-inch diameter pipes but realized immediately that it would cause a huge drop in pressure, thus using 1-inch diameter pipes instead of ¾-inch diameter pipes. S13 then cautioned S3 that using only 1-inch pipes would increase their cost, highlighting the tradeoff of using 1-inch diameter pipes. In response, S3 used ½-inch diameter pipe near the taps to keep the cost down. The final model looked very similar to the seed model's design.

The use of incomplete seed model as an anchor evoked different types of students' responses – some extending it immediately, some returning back to it after exploring other design options, and some likely referring to it implicitly. The seed model appears to have provided an example helping students engage in the design thinking process and make tradeoffs. Students were able to immediately apply their knowledge about relationship between system variables to improve the seed model's design, potentially avoiding the new knowledge from becoming "inert." Additionally, the incompleteness of the seed model seems to have offered different design trajectories to the teams who ultimately gravitated towards optimal designs. Thus, anchoring using such incomplete models provide an age-appropriate effective scaffold for introducing design thinking in middle school. Further research is needed to determine the generalizability of these findings as well as evaluate the far transfer effect of such scaffolds. Also, future work will explore software-based representation of incomplete models to further understand the effect of form factor of the models on scaffolding design thinking.

References

Atkinson, R. K., Derry, S. J., Renkl, A., & Wortham, D. (2000). Learning from examples: Instructional principles from the worked examples research. *Review of Educational Research*, *70*(2), 181-214.

Harrison, A. G., & Treagust, D. F. (2000). A typology of school science models. *Intl' J. Sc Ed, 22*(9), 1011- 1026.

Lehrer, R., & Schauble, L. (2000). Developing model-based reasoning in mathematics and science. *Journal of Applied Developmental Psychology*, *21*(1), 39-48.

Moore, T. J., Glancy, A. W., Tank, K. M., Kersten, J. A., Smith, K. A., & Stohlmann, M. S. (2014). A framework for quality K-12 engg. education: Research and development. *J. of Pre-college Engg. Ed. Res*, *4*(1), 2.

National Academy of Engineering and National Research Council of the National Academies. (2009). *Engineering in K–12 Education: Understanding the status and improving the prospects.* Washington, DC: The National Academies Press.

Renkl, A., & Atkinson, R. K. (2002). Learning from examples: Fostering self-explanations in computer-based learning environments. *Interactive learning environments*, *10*(2), 105-119.

Renkl, A., Mandl, H., & Gruber, H. (1996). Inert knowledge: Analyses and remedies. *Ed. Psych.*, *31*(2), 115-121.

Sheppard, S.D. (2003). A Description of Engineering: An Essential Backdrop for Interpreting Engineering Education, *Proceedings (CD), Mudd Design Workshop IV*, Claremont, Cal.: Harvey Mudd College.

The Cognition and Technology Group at Vanderbilt. (1990). Anchored instruction and its relationship to situated cognition. *Educational Researcher*, 2-10.

Acknowledgments

Learning Loops: Affordances and Challenges of Project Bloks

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Abstract: Programming for young children has gained significant traction in recent years. Although many learning tools have been created toward this end, research has focused primarily on older children, and few studies have documented young children's learning processes and difficulties during programming activities. Through task-based studies with first-grade children, we examine the design affordances of a tangible user interface, Project Bloks. For the scope of this paper, we focus on two coding puzzles where children engage with loops. Our findings reveal that the design affordances of the system are conducive to the learning of loops, and highlight some difficulties that children encounter with loops. We discuss the implications of these preliminary results for designers and educators, and propose ideas for future work.

Introduction

In recent years, efforts to teach computer programming in formal and informal learning environments have steadily grown. Programming for K-12 was first introduced in the 1960s with Logo (Papert, 1980), and we have seen a new wave of interest in promoting computational literacy (diSessa, 2000) and introducing computational thinking (CT) to K-12 students (Wing, 2006; Blikstein, 2018). This has been accompanied by the development of programming environments specifically for children, including visual programming languages such as Scratch (Resnick et al., 2009) as well as tangible user interfaces for very young learners, such as KIBO (Bers et al., 2013).

Despite the abundance of child-friendly tools for learning programming, there is little research on the use of such tools with young children and even less on the thinking and learning processes during programming activities (Lye & Koh, 2014; Fessakis et al., 2012; Bers et al., 2013). We conducted task-based studies with children using Project Bloks, a novel tangible programming platform designed by members of our team in partnership with industry, and digital coding puzzles. We focus on the last 2 puzzles, where children engage with loops, a type of control flow instruction and a key concept of CT (Brennan & Resnick, 2012). Our study investigates whether the affordances of the system are conducive to the perception of need and learning loops, and the types of difficulties children may encounter when learning about loops.

Methods

We conducted individual, task-based studies with 12 first-grade students (6 girls, 6 boys) at a suburban elementary school. We focus on the last 2 puzzles only (P10 and P11), where complex loops were required. Children used Project Bloks, a set of physical blocks and icon-based symbols, to program a "bee" avatar to navigate through a digital maze. The icons represent instructions for directions (top, down, left, right) and commands (get flower, make honey). The repeat functionality is expressed with open/close blocks that resemble opening and closing brackets, and physically encompass the blocks to be repeated. After a brief discussion about building activities, children were solved the series of 11 puzzles with limited guidance from the researcher. Puzzles were presented in order of increasing difficulty; at P8, the "repeat" blocks were introduced. After the puzzles, children were asked to reflect on their experience using a smiley-o-meter and a few additional questions.

Data and findings

We video-recorded and transcribed all sessions and captured all intermediary versions of the code at runtime. All 11 children (5 girls, 6 boys) who attempted P10 completed it, with an average of 4 runs (range: 1, 9) and an average duration of 4m28s (range: 1m43s, 8m54s). For P11, all 7 children (4 girls, 3 boys) who attempted it were successful, with an average of 4 runs (range: 1, 8) and an average duration of 3m34s (range: 1m55s, 6m05s).

Studies revealed that the limited number of physical blocks creates an opportunity for children to engage with loops, in a way that on-screen programming languages do not. We observed that indeed the limited-block design prompted children to think harder upon realizing that the full sequence could not be physically expressed with the available blocks. 6 of 11 children in P10 and 2 of 7 children in P11 made explicit verbalized a need for more blocks; i.e., "*I don't have enough blocks*" or "*Wait, we need more pads*!" When faced with this limitation, children started to consider solutions with control flow structures rather than just single-action blocks.

A common difficulty we observed resulted from the simple introduction of the "repeat" block. Because the prior puzzles initially repeated only a single command, 5 of 11 children were unsure about whether they could use the repeat with more than one command in P10, which needed to repeat a sequence of 4 commands.

An exemplary case of problem-solving is Mallory, who begins by placing blocks for the full sequence (Fig. 2a). Upon noticing that there are not enough blocks to continue this way, she asks, "*Does the repeat block do like…two different ones [blocks]? Or just one?*" Her inquiry demonstrates how the limited-block design triggered the need for a different type of control flow structure. She initially places the open and close repeat blocks around the first two blocks (Fig. 2b) and says, "*I don't think that would work. Because then I would keep repeating these, and not do any of these.*" Without further prompting, she puts the sequence of 4 blocks together (Fig. 2c) and places one hand each on the open and close repeat blocks. The simultaneous action of both hands demonstrates how the bracket design maps to Mallory's gestures. She is able to then run the program successfully, suggesting that the design affordances of Project Bloks are conducive to the learning of loops; the limited-block design requires her to use a loop where she otherwise might not have thought to at that point.

Figure 2a, 2b, 2c. Mallory solving P10.

Discussion

These studies, and our preliminary analysis of P10 and P11, illustrate the potential for children to learn complex CT concepts, such as loops, using tangible programming interfaces like Project Bloks. The limited-block design is a contribution to the research on programming tools for children; while it is intrinsic to tangible user interfaces, it is missing from digital programming languages, where blocks are of infinite quantity. The system demonstrates how the practical limitation of blocks can be turned into a feature, productively triggering the need for a loop structure and creating opportunities for children to learn a key CT concept.

We also described a key difficulty that children encountered with loops. Although we often assume that children should progress from simple to complex, we found evidence that this may not be the case in programming activities. Because the repeat block was introduced in a context that repeated only a single command, there was no indication for children that multiple commands could be repeated. Thus, when introducing a CT concept such as "loops," it is important to consider how the first action may bias users and prevent them from thinking of other ways to use it. We hypothesize that introducing loops with multiple blocks may be more productive, and that this principle of "complex first" might also apply to other constructs, such as conditionals and functions.

We acknowledge that our results are promising but also preliminary. We focus here on loops; however, our findings and larger dataset reveal patterns that may be applicable to other CT concepts, such as functions.

References

Bers, M., Flannery, L., Kazakoff, E., Sullivan, A. (2013). Computational thinking and tinkering: Exploration of an early childhood robotics curriculum. *Computers and Education*, 72, 145-157.

Blikstein, P. (2018). Pre-College Computer Science Education: A Survey of the Field. Mountain View, CA: Google LLC. Retrieved from https://goo.gl/gmS1Vm

Brennan, K., Resnick, M. (2012). New frameworks for studying and assessing the development of computational thinking. *Annual Meeting of AERA 2012*.

diSessa, A. A. (2000). Changing minds: Computers, learning, and literacy. Cambridge: MIT Press.

Fessakis, G., Gouli, E., Mavroudi, E. (2012). Problem solving by 5-6 years old kindergarten children in a computer programming environment: A case study. *Computers and Education*, 63, 87-97.

Lye, S., Koh, J. (2014). Review on teaching and learning of computational thinking through programming: What is next for K-12? *Computers in Human Behavior*, 41, 51-61.

Papert, S. (1980). Mindstorms. Children, computers and powerful ideas. New York: Basic Books.

Resnick, M., Maloney, J., Monroy-Hernández, A., Rusk, N., Eastmond, E., Brennan, K., Millner, A., Rosenbaum, E., Silver, J., Silverman, B., Kafai, Y. (2009). Scratch: Programming for all. *Communications of the ACM*, 52(11), 60-67.

Wing, J. M. (2006). Computational thinking. *Communications of the ACM*, 49(3), 33–35.

Acknowledgements

Architectures for Learning and Successive Processes of Scaling

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Abstract: This study examines how school-level learning architectures affect the scalability of an innovation by conceptualizing scalability as successive scaling-up processes from the scale-up of teacher reform capacity to the result of spread. A longitudinal qualitative two-case study was conducted at two different schools, in the context of developing self-directed learning practice. The results showed how components of learning architectures affected successive scaling-up processes. These are components to be monitored at the school level for innovation at scale.

Keywords: architectures for learning, scaling up, self-directed learning, teacher reform capacity

Introduction and background

Previous research studies suggest that scalability is affected by the design of an intervention (Clarke & Dede, 2009) and the construction of teacher community networks (Glennan & Resnick, 2004). Relatively less research has been conducted to examine what and how school contextual factors can significantly hinder scalability when schools have tried to enact reform initiatives.

This study examines the effect of school contextual factors on a school's scale-up progress within the period of project intervention, drawing on the concept of learning architectures (Wenger, 1998, Law, et al., 2015). It is in the context of a three-year government-funded project in Hong Kong to promote self-directed learning (SDL) in science education from 2014-2017. SDL presented an innovative practice as science teachers in Hong Kong have traditionally adopted the teacher-directed lecture approach.

Conceptual framework
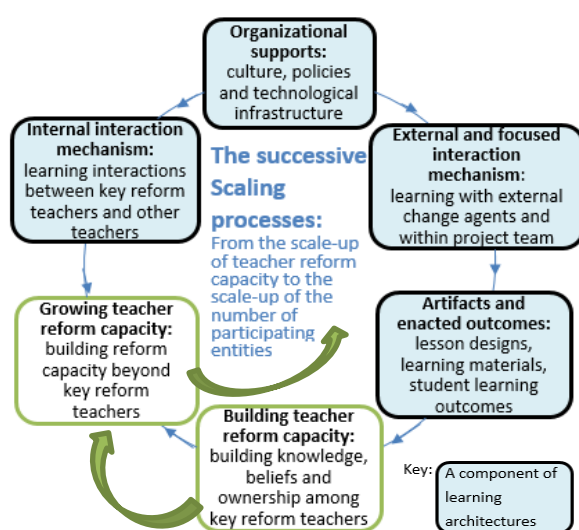
Figure 1. The successive scale-up model
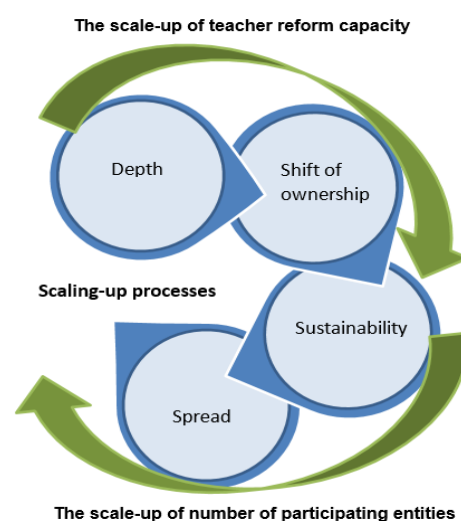
Figure 2. The successive scaling-up processes

This study develops a successive scale-up model (figure 1) to hypothesize the relationship between components of learning architectures at the school level with the scaling-up processes. In the model, scalability of an innovation is conceptualized as successive scaling-up processes (figure 2) from the scale-up of teacher reform capacity to the scale-up of the number of participating entities in the quality reform, building on Coburn's (2003) four dimensions in scalability: *depth*, *shift in reform ownership*, *sustainability* and *spread*. Teacher reform capacity is defined as the abilities of school teachers to accomplish a certain task, such as leading a school-innovation effort (e.g., adopting a SDL approach in primary and secondary school science education as is the case in the present study), embodying depth of reform knowledge, belief and ownership (Bandura, 1977; Gibbons, 2003). Law, et al. (2015) have proposed components for analyzing learning architectures. Building on their work, this study proposes four

major components of learning architectures for school level analysis: (a) organizational supports; (b) external and focused interaction mechanisms among key reform teachers; (c) artifacts and enacted outcomes as a result of teacher learning through external and focused interactions; and (d) internal interaction mechanism for growing teacher capacity beyond the project team.

Methods

A qualitative case study approach was adopted to understand each unit of analysis with an interpretation of data. Two schools A and B were sampled (table 1) because they showed significant differences in the progress of adopting SDL in science even though they joined the project in the same period for two years, working with the same university consultant, who is one of the authors. Data sources in the project included principal and teacher interviews, lesson observations, lesson artifacts, and student focus groups. Information and perspectives provided by different sources were compared. Data analysis was guided by the six components in the conceptual framework (figure 1).

Table 1: Information about the two selected schools

School	Joined the project at the same year?	Worked with the same University consultant?	No. of teachers enacting SDL in science		The grade-level with SDL in science	
			1st year	2nd year	1st year	2nd year
A	Yes	Yes	2	1 ↓	Grade 8	Grade 7
B	Yes	Yes	3	5 ↑	Grade 7	Grades 7 and 8 ↑

Findings and conclusion

Compared with school B, project teachers in school A had relatively weak organizational supports and sparse interaction mechanisms. Subsequently insufficient teacher reform capacity was developed and the scaling-up processes in school A broke down. The organizational supports in school B facilitated strong focused internal mechanism among project teachers for creating artifacts to perpetuate ideas. Hence, teacher reform capacity was built. Intense internal mechanism between project teachers and non-project teachers were strategically arranged for growing more reform-capable teachers and spreading SDL to more science classrooms. The two-case analysis with the successive scale-up model attests the impact of components of school-level learning architectures on the scaling-up processes. Schools are suggested to monitor these components for succeeding in building capacity to spread innovative practice.

With limited space, this study does not expand the focus to investigate how leadership affects the strength of components of learning architectures in the model. Principals and teacher leaders might be the architects, contributors and advisors of the school-level learning architectures, while at the same time they are also under the influence of it. Further research is needed to see whether the stronger components in school B is attributed to the involvement of the principal and the two teacher leaders in the team.

References

Bandura, A. (1977). Self-efficacy: toward a unifying theory of behavioral change. *Psychological review, 84*(2), 191.

Clarke, J., & Dede, C. (2009). Design for scalability: A case study of the River City curriculum. *Journal of Science Education and Technology, 18*(4), 353-365.

Coburn, C. E. (2003). Rethinking scale: Moving beyond numbers to deep and lasting change. *Educational researcher, 32*(6), 3-12.

Gibbons, M. (2003). *The self-directed learning handbook: Challenging adolescent students to excel*. John Wiley & Sons.

Glennan Jr, T. K., & Resnick, L. B. (2004). School districts as learning organizations: A strategy for scaling education reform. *Expanding the reach of educational reforms: Perspectives from leaders in the scale-up of educational interventions, 517-563*.

Law, N. W. Y., Yuen, J. K. L., & Lee, Y. (2015). Precarious school level scalability amid network level resilience: insights from a multilevel multiscale model of scalability. *In Annual Meeting of the American Educational Research Association, AERA 2015. Chicago, IL*.

Wenger, E. (1998). *Communities of practice: Learning, meaning, and identity*. Cambridge university press.

Collaborative, Multi-perspective Historical Writing: The Explanatory Power of a Dialogical Framework

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Abstract: When introducing students to the multi-perspective and interpretative nature of history within collaborative contexts, what are the relationships of individuals from conflicting groups with historical accounts that they produced as a group? How does the joint writing influence their historical understanding? We analyzed the joint accounts produced by post-primary Israeli students, Jews and Arabs, who collaboratively e-investigated events related to the Israeli-Palestinian conflict. Employing a thematic analysis and a Bakhtinian-inspired discourse analysis, we found that the joint texts were constructed of themes from both in-groups' perspectives. Students constructed a dialogic relationship between these themes, which enabled them to legitimize the other's voice, yet keep the voices unmerged. These texts reflect a new historical meaning and a better understanding of the nature of history.

Introduction

Within the history education community, interest in introducing students to the multi-perspective and interpretative nature of history is growing (Stradling, 2003). When these educational goals are pursued within collaborative contexts, what are the relationships of individuals from conflicting groups with historical accounts that they produced as a group? Wertsch's theoretical framework is often used to articulate the interaction of agents with historical presentations. According to Wertsch, our interaction with a historical presentation is bi-dimensional: (a) a cognitive dimension, or the mastering of a presentation; and (b) an affective dimension related to one's identity and sense of belonging, which promotes either the appropriation or resistance of a presentation. This framework is powerful in explaining situations in which a bias exists in students' interactions with historical presentations, caused by their appropriation and resistance of the in- and out-group narratives, respectively, e.g., why individuals often accept whatever supports their beliefs but meticulously examine and critique anything that contradicts them (Wertsch, 2000).

In a previous work, we investigated the interactions within 26 foursomes of Israeli post-primary students, Jews and Arabs/Palestinians who collaboratively investigated events related to the Israeli-Palestinian conflict. As expected, most discussions were disputatious. Yet, 15 disputatious groups produced a group account with a historical presentation agreed upon all group members. What historical perspective is manifested in the joint essay? What is the relationships between the historical perspective manifested in the joint text and the participants' perspectives on the event?

The experiment

The historical event was Britain's issuance of the Churchill White Paper in 1922. The British explained that they wanted to settle "[t]he tension which [had] prevailed from time to time in Palestine". One assignment was How did both sides (Arabs and Jews) respond to this document, and why? In phase1, students worked in ethnically homogenous pairs. They read all the sources and uploaded their answers to the assignment questions. In phase2, they work in bi-ethnic foursomes. They read and commented on each other's answers, and then conduct a synchronous textual e-discussion, aimed at producing a joint written summary of the event.

We analyzed the essays produced in phase1 and phase2 of all 15 groups who produced a joint essay. We employed a historical content analysis (Peck et al, 2011) in order to identify the students' perceptions of the three major historical agents: British, Arab (i.e., Palestinian), and Jewish. We employed the Bakhtin-inspired (1981; 1984) method of discourse analysis in order to identify the voices that the students integrated into their utterances and the interactions between them (Kamberelis & Scott, 1992). One interaction type is *hidden polemic*, which refers to cases when users' use of words (previously used by another voice) influences the original goal of the original speaker, thereby expressing the user's disagreement or it introduces tension with the original goal of the utterance.

Results and discussion

Wertsch's (1998) two-dimensional framework of mastery and appropriation/resistance was forceful in articulating the interaction of students with their in- and out- group narratives when producing the pairs' essays. In line with the vast empirical work conducted on students' interactions with multiple historical representations

(e.g., Wertsch, 2000), the pairs chose to integrate into their essays those themes that aligned with their in-group narrative and ignore those that aligned with the Other-group narrative. In fact, we observed a dichotomy in the frequencies of the themes in the essays of the Arab/Palestinian pairs (APs) and the Jewish pairs.

The discourse analysis revealed that in all the joint essays share several characteristics: (a) they are composed of bits of pre-existing (pairs') perspectives; (b) they are compatible with both the Zionist and Palestinian historical narratives; and yet (c) they create a whole new meaning regarding the historical agents' actions and the complex interests and constraints, in which they played a role. The two contrasting perspectives neither disintegrated nor fuses into one. These characteristics are demonstrated in the following example. Table 1 presents text segments from one group essay and the matching segments from the pair's essays.

Table 1: The response of the Arab historical agent to the issuance of the White paper in 1922

The AP's essay	The JP's essay	The group essay
The response of the Arab side was negative. They were angry because their lands were taken from them.	The Arab population did not agree with the White Paper because they interpreted in an exaggerated way the promises made to the Jews in the White Paper.	The Arab population did not agree with the White Paper because it was perceived as the beginning of a process whereby their lands would be taken [from them].

Both JP's and AP's original voices are evident in the group utterance, that the AP "perceived it as the beginning of the process of taking their lands". The idea regarding taking lands resembles the AP's essay. However, it is altered, from past tense ('were taken') to future tense ('would be taken'). This phrase is concatenated to "the beginning of a process". The change of the original AP's text allows the JP to maintain a *hidden polemic* interaction with AP's original idea. "The beginning of the process" means that this agent still had time to change its destiny, which is compatible with the Zionist perspective that this agent was non-pragmatic. Putting the issue of taking land in the Arab historical agent's perception also helps the JP to express their disagreement with this idea. Therefore, this text is compatible with both the Zionist and the Palestinian perspectives. It is unlikely to assume that these students did not understand that the text can be read differently. The AP choose not to mention anything about the end of the process as they did in the pair essay and JP did not mention the Jews' right to the land. The hidden polemic enabled the students to live peacefully with the text, although while being aware of the other's possible interpretation of it. Hence, students' interaction with the different narratives is beyond merely mastery or appropriation/resistance.

Nevertheless, the joint text reflects an improvement in students' historical understanding of the event. The combination of voices brings about a new reason for the Arabs' disagreement with the White paper, different from what was claimed by both AP and JP in their pair essays. Moreover, in the joint essay participants describe a historical process and avoid emotional empathy (as in AP's text) and moral judgment (as in JP's text) vis-à-vis the historical agent. In conclusion, students' interaction with their in- and out-group voices in the joint texts is more dialogical than is their interaction with these voices in the pair essays. This is in line with Humanities education's goal of humanizing students, i.e. assisting them in re-examining how they perceive themselves and others, and the limitations of their understanding of the world (Wineburg, 2001).

References

Bakhtin, M. (1981). The dialogical imagination: Four essays. (C. Emerson and M. Holquist, Trans.). Austin: University of Texas Press.

Bakhtin, M. M. (1984). *Problems of Dostoevsky's Poetics.* Edited and translated by Caryl Emerson. Minneapolis: University of Minnesota Press.

Kamberelis, G., & Scott, K. D. (1992). Other people's voices: The coarticulation of texts and subjectivities. *Linguistics and Education*, *4*(3-4), 359-403.

Peck, C., Poyntz, S. R., & Seixas, P. (2011). 'Agency' in students' narratives of Canadian history. In D. Shemilt & L. Perikleous (Eds.), *What does it mean to think historically*? Nicosia, Cyprus: Association for Historical Dialogue and Research.

Stradling R. (2003). *Multiperspectivity in history teaching: a guide for teachers,* Strasbourg:Council of Europe.

Wertsch, J. V. (1998). *Mind as action*. NewYork NY: Oxford University Press.

Wertsch, J. (2000). Is it possible to teach beliefs, as well as knowledge about history? In P. Stearns, P. Seixas, & S. Wineburg (Eds.), *Knowing, teaching, and learning history* (pp. 38–50). New York: New York University Press.

Wineburg, S. (2001). *Historical thinking and other unnatural acts: Charting the future of teaching the past.* Philadelphia: Temple University Press.

Eye Tracking Students' Gazes on Feedback in a Digital Assessment Game

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Abstract: This study tracked the eye movements of n = 24 undergraduate students while they played an assessment game, Posterlet. Students designed digital posters and then they received three pieces of constructive critical (negative) or confirmatory (positive) feedback on each of the posters. Total eye gaze duration analyses revealed that students spent significantly more time attending to the critical rather than to the confirmatory feedback they received. They also dwelled more on each word and letter of critical rather than confirmatory feedback. Finally, they also revisited critical feedback more often than confirmatory feedback. Implications of these results and future research directions are discussed.

Introduction

Feedback is one of the most impactful factors for learning (Hattie & Timperley, 2007). The feedback literature differentiates between positive (confirmatory) and negative (critical) feedback. Recently, eye movement research attempted to gain an insight into cognitive processes by tracking participants' eye gazes in real time and measuring two types of eye movements: fixations and saccades. Specifically, fixations are short gaze stops of approximately 200 milliseconds (ms) that are used to infer mindful cognitive processing (Bolzer, Strijbos, & Fischer, 2015), while saccades are fast gaze moving actions (Rayner, 1998). However, the eye tracking literature on feedback processes is scarce (Timms, DeVelle, & Lay, 2016). This research aims to gain an insight into the mechanisms of feedback processing by examining students' eye gazes on feedback while they play a digital game in which they design posters. Informed by prior research, this study hypothesizes that students dwell longer on critical than on confirmatory feedback when they are assigned feedback following a task.

Methods

A total of 24 university students (9 males and 15 females), ranging from 18 to 29 years of age, with a mean age of 21.79 years (SD = 3.1), took part in this study. Participants were recruited from a large North American university from a subject pool program. They received course credit for their participation. They signed an electronic consent form prior to joining the study and were tested individually in one session lasting approximately 45 minutes. The first 5 minutes were used to calibrate the eye tracker using a five-point calibration sequence. To calibrate and validate the eye tracker, participants had to follow a dot that appeared at five different locations on the computer screen. This procedure was repeated until the average deviation of the visual angle between the calibration was one degree. Participants played the Posterlet computer game for about 15-20 minutes. After completing the game, participants completed a post-test for about 20 minutes.

The study employed three instruments: (1) a computer-based assessment game, Posterlet (Cutumisu et al., 2015); (2) an eye tracker to capture students' gazes superimposed on the game; and (3) a post-test survey of background information, including demographic information. An alternative game version was designed as part of a larger yoked-study design. Players do not have a choice regarding the valence of their feedback in this version of Posterlet. Instead, they are assigned the feedback valence choices of participants who played the original Posterlet version. Eye movements were recorded using the SR Research EyeLink 1000 Plus desktop remote-mode system. The Screen Recorder software was employed to record participants' gazes onto the Posterlet game. Then, participants filled an online post-test survey.

Critical Feedback measures the number of critical feedback ("I don't like") messages that the participants encountered across the game. Gazes on Critical Feedback counts the number of critical feedback boxes where a participant's gaze was recorded across the three posters. Each of the critical feedback boxes was coded with 1 if there was a gaze ever detected on that box and with 0 otherwise. Mean Gaze Duration per Letter of Critical Feedback approximates the average time that participants spend looking at each letter of critical feedback across the Posterlet game. This measure is important, as it enables a fair comparison of the time participants took to attend to each feedback valence. Several steps are taken to compute this measure for each feedback valence. First, the sum of all the individual fixation durations on each feedback box, including the durations of the

regressions on that box, is computed. Then, this measure is divided by the length (i.e., the number of letters, including spaces) of the feedback message in that box. Then, these values are added for all the boxes of each valence and divided by the Gazes on Critical Feedback to obtain an estimate of the average time spent per letter of feedback valence. Mean Gaze Duration per Word of Critical Feedback measures the average time a participant spent looking at each word of critical feedback across the game. Mean Number of Fixations on Critical Feedback represents the average number of a participant's gaze fixations on the critical feedback boxes across the game, ranging from 3 to 14. Mean Number of Regressions on Critical Feedback represents the average number of times a participant revisited the critical feedback boxes across the game, ranging from 0 to 2. These measures were further refined according to the length of feedback and the number of words of feedback.

Results

Do students spend more time actively looking at critical rather than at confirmatory feedback when feedback is assigned? The mean gaze duration across the game was significantly larger [$t(20) = 4.93$, $p < .001$] for critical (M=2387.42 ms, SD = 581.44 ms) than for confirmatory (M=1873.07 ms, SD = 637.74 ms) feedback. Analyses revealed that participants spent more time attending to critical feedback per letter [$t(20) = 3.87$, $p < .01$] and per word [$t(20) = 3.67$, $p < .01$] than to confirmatory feedback. On average, participants read critical feedback (M=.0062, SD=.003) at a slower pace [i.e., less words per millisecond; $t(20)=-2.11$, $p=.048$] than they read confirmatory feedback (M=.0085, SD=.005). The more the participants encounter critical feedback, the more they dwell on it per letter and per word, but there is no association between gazes on critical feedback and dwell time per letter and per word on confirmatory feedback.

Is there a difference in the mean number of gaze fixations on feedback between valences when feedback is assigned? A paired-samples t-test analysis showed that the mean number of fixations on critical feedback boxes (M = 9.37, SD = 2.47) was larger [$t(20) = 5.97$, $p < .001$] than the mean number of fixations on confirmatory feedback boxes (M = 6.71, SD = 1.95). This suggests an overall closer attention paid to critical than to confirmatory feedback. Participants also read critical feedback (M = .18, SD = .05) more closely per letter [$t(20) = 4.87$, $p < .001$] than confirmatory feedback (M = .13, SD = .04). They also read critical feedback (M=.85, SD=.23) more closely per word [$t(20)=4.57$, $p < .001$] than confirmatory feedback (M = .65, SD=.19).

Is there a difference in the mean number of feedback revisits between feedback valences when feedback is assigned? A paired-samples t-test analysis revealed that the mean number of regressions on critical feedback boxes (M=.85, SD=.61) was significantly larger [$t(20)=4.10$, $p<.01$] than the mean number of regressions on confirmatory feedback boxes (M=.40, SD=.41). This finding confirms the results of the previous analyses in this section, suggesting that, overall, participants attended to critical feedback boxes more often than to confirmatory feedback boxes. Participants also revisited critical feedback (M=.0157, SD=.01) more often per letter [$t(20) = 3.93$, $p<.01$] than confirmatory feedback (M=.01, SD =.01). They also revisited critical feedback (M=.08, SD=.05) more often per word [$t(20)=3.89$, $p<.01$] than confirmatory feedback (M=.04, SD=.04).

Conclusions and educational implications

Results suggest that students attended to critical feedback significantly more often and more closely than to confirmatory feedback. The dwell time (per letter and per word) was significantly larger for critical rather than for confirmatory feedback. This research may inform the design and the delivery of feedback, so that students could attend more to the type of feedback that helps them improve their outcomes the most.

References

Bolzer, M, Strijbos, J.W., & Fischer, F. (2015). Inferring mindful cognitive-processing of peer-feedback via eye-tracking: role of feedback-characteristics, fixation-durations and transitions. *Journal of Computer Assisted Learning, 31,* 422-434. doi:10.1111/jcal.12091

Cutumisu, M., Blair, K. P., Chin, D. B., & Schwartz, D. L. (2015). Posterlet: A game-based assessment of children's choices to seek feedback and to revise. Journal of Learning Analytics, 2(1), pp. 49-71.

Hattie, J., & Timperley, H. (2007). The power of feedback. *Review of Educational Research, 77*(1), 81-112.

Rayner, K. (1998). Eye movements in reading and information processing: 20 years of research. *Psychological Bulletin, 124*, 372-422.

Timms, M., DeVelle, S., & Lay, D. (2016). Towards a model of how learners process feedback: A deeper look at learning. *Australian Journal of Education, 60*(2):128-145.

Acknowledgments

Promoting Cognitive Processes of Knowledge Integration

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Abstract: Knowledge integration (KI) is an important ability by which learners relate the ideas from prior knowledge and new knowledge to come up with a well connected and coherent understanding of a topic. We present a qualitative investigation done around a student-question-posing (QP) based learning strategy which aims at improving learners' KI in data structures (CS2) course. The results throw light on how QP activity using questioning prompts support the improvement of the cognitive processes of KI in learners.

Introduction

Knowledge Integration (KI) is defined as "the process by which learners sort out connections between new and existing ideas to reach more normative and coherent understanding of science" (Lee, Hofstetter, & Linn, 2008). The cognitive processes of KI involve connecting knowledge pieces coming from the plethora of knowledge-base, built using prior knowledge and new knowledge. Better KI means richer connections among knowledge components, coming from new knowledge and/or prior knowledge, which ultimately leads to more organized and deeper understanding of a topic. According to the KI instructional patterns, a KI environment should support four processes (Linn & Eylon, 2011): (1) eliciting ideas from prior knowledge; (2) focus on new ideas to help distinguish or link ideas; (3) distinguish ideas; and (4) sort out ideas. These processes can be supported at the learning environment level. A huge repertoire of work has been done to accomplish this for science education (Chiu & Linn, 2011). In our research, we examine if these processes can be supported directly at the cognitive level using the cognitive tool of question posing (QP). This research work extends previous research (Mishra & Iyer, 2015) that gave a proof of concept that QP involves the KI processes at the cognitive level, and identified different strategies by which learners integrate prior knowledge and the new knowledge to come up with questions that can help them to explore related knowledge, within CS2 domain. The strategies are known as exploratory question posing (EQP) strategies. In this paper, we present a QP-based learning strategy that aims at improving learners' KI performance in data structures. Our learning strategy is a computer-based adaptation of the guided cooperative questioning (King & Rosenshine, 1993) which used generic question prompts. Instead of using generic question prompts, our learning strategy uses the EQP strategies (Mishra & Iyer, 2015) as the domain-specific question prompts. We call our learning strategy as 'IKnowIT-pedagogy,' where 'IKnowIT' refers to "Inquiry-based Knowledge Integration Training."

IKnowIT-pedagogy

IKnowIT-pedagogy consists of six phases of activities as follows: **(1) Phase 1:** Learner reads introductory information about EQP and its importance. **(2) Phase 2:** Learner watches a video lecture on a topic and does QP. In our implementation, the video *("introduction to the tree data structure")* was approximately 15 minutes long, and learner gets total 45 minutes for watching the video and pose questions around its content. **(3) Phase 3:** Learner reads detailed information about the three EQP strategies (Mishra & Iyer, 2015). These three EQP strategies ('Apply,' 'Operate,' and 'Associate') are used as questioning prompts for data structures. The details are as follows. i) Apply (or Employ), where learner integrates the concepts from given knowledge with some goal 'application' or 'structural arrangement.' ii) Operate, where the QP involves integrating given knowledge with known goal state (or modifications) and seek operations/procedure to achieve the goal state. iii) Associate, where concepts from given and prior knowledge are integrated to seek insight into the given knowledge or prior knowledge. **(4) Phase 4:** Learner analyzes the questions generated in step 2 and categorizes them into the three EQP strategies. **(5) Phase 5:** Learner criticizes the questions and their categorizations generated by another learner (pre-stored). **(6) Phase 6:** Learner answers reflection questions to reflect on her/his experiences in the previous five phases.

Study methodology and results

Participants in the study were the 31 first-year engineering undergraduate learners, out of which 12 participated in the focused group interview (FGI). During the study, the learners undergone an IKnowIT session, followed by the FGI. The broad focus of the interview was to investigate the effects of each pedagogical features of IKnowIT on learners' improvement of KI processes. Later, the interview was transcribed and analyzed with the

theoretical lenses of exploratory question posing and knowledge integration framework (Linn & Eylon, 2011). Our process was based on the approach outlined by Charmaz (2006) that involves initial coding and focused coding. At the end of the analysis, the focused codes were abstracted into tentative theory (story) that is then checked against other parts of the data to test its explanatory power. The results include two stories coming out of the interview analysis. These stories explain certain mechanisms related to how exploratory QP and KI are linked with each other, and what are the effects of exposing learners to the three broad EQP prompts.

Story 1 – Linking QP and KI: Learners perceived that EQP is highly intertwined with knowledge integration. On the one hand, they perceived that more KI happens after they pose more questions - *"better question leads to better understanding... Questions drive the KI process, as questioning lead to getting more ideas."* Learners reported that QP required them to think more into the given knowledge, their relationship with what they already know, to focus on inconsistencies and gaps in their understanding, to focus on alternatives to what was given in the video lecture, and to elicit expectation mismatch concerning their prior knowledge. This was an important finding, as it shows that the effects of the learning activities clearly appear to support the first three out of the four cognitive processes associated with KI, as described by Linn and Eylon (2011): (i) Eliciting prior knowledge, (ii) Refocusing on given knowledge and (iii) distinguishing ideas. On the other hand, learners also perceived that better KI leads to better exploratory questions. They reported to have recalled their prior knowledge and connected them to the ideas given in the video lecture. These connections were in several dimensions such as comparing, contrasting, finding applications, finding methods of implementing ideas, etc. Learners perceived that integrating knowledge pieces is a precursor to the coming up with questions.

Story 2 – Role of EQP Prompts: Though the IKnowIT-pedagogy activities were primarily based on EQP and exposing learners to different EQP strategies (Mishra & Iyer, 2015), they perceived that the activities were more about understanding the topic in a better way than just being a QP session. We used the EQP strategies identified in the CS2 domain as questioning prompts. From the interview analysis, it was found that the utility of the EQP prompts was not just limited to assisting learners in posing better questions. Learners used the EQP prompts at several instances, viz.: (1) Before posing a question, or (2) After posing a question, or (3) Both before and after posing a question. Learners who used the strategies "before" posing question did so to either to give direction to their knowledge exploration or to make an explicit attempt to create a question that can demonstrate the structure of any EQP strategy. Whereas, the learners who used the strategies "after" posing the question did so with an intention to either validate if their question matches to the standard EQP strategies or to categorize their question and then determine the direction in which they should look for the answer. In the first case, learners reflected on the availability of relevant knowledge pieces and their possible integrations to suit the requirements of any strategy. In the latter case, learners reflected about the nature of their questions, i.e., which of the three EQP strategies a question matches with. Learners reported several other utilities of the EQP strategies such as: (i) it helped them in validating their questions *("makes us to know which is the best way to ask question.")*, (ii) improved clarity of questions *("knowing categories avoids the confusions due to overlapping multiple doubts, it gives direction"*). In this way, the EQP strategies also seem to help the fourth KI process of sorting out ideas by providing clear objective to the sorting process.

In conclusion, Story 1 shows the role of EQP activity in the IKnowIT-pedagogy. It shows that integrating knowledge pieces is needed for coming up with better questions. On the other hand, it also shows that posing better questions helps in refining and strengthening prior connections and provides objectives to further knowledge explorations and therefore leads to further KI. Story 2 throws light on the roles of EQP strategies in the IKnowIT-pedagogy. In the conference, we would present the IKnowIT-pedagogy and associated evaluations in detail.

References

Liu, O. L., Lee, H. S., Hofstetter, C., & Linn, M. C. (2008). Assessing knowledge integration in science: Construct, measures, and evidence. Educational Assessment, 13(1), 33-55.

Chiu, J. L., & Linn, M. C. (2011). Knowledge integration and WISE engineering. Journal of Pre-College Engineering Education Research (J-PEER), 1(1), 2.

Charmaz, K. (2014). Constructing grounded theory. Sage Publications Ltd, 1 edition, Jan. 2006.

King, A., & Rosenshine, B. (1993). Effects of guided cooperative questioning on children's knowledge construction. The Journal of Experimental Education, 61(2), 127-148.

Linn, M. C., & Eylon, B. S. (2011). Science learning and instruction: Taking advantage of technology to promote knowledge integration. Routledge.

Mishra, S., & Iyer, S. (2015, June). Question-Posing strategies used by students for exploring Data Structures. In Proceedings of the 2015 ACM Conference on Innovation and Technology in Computer Science Education (pp. 171-176). ACM.

Co-Designing Orchestration Support for Social Plane Transitions With Teachers: Balancing Automation and Teacher Autonomy

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Abstract: In classrooms, it can be difficult to implement adaptive activities that span social planes (e.g., whole class, group, individual) due to the demands on teacher attention. To make these activities more feasible in classrooms, orchestration tools, which support the classroom management, can be integrated. We present findings from co-design sessions conducted with seven teachers with the aim to understand how teacher autonomy and system automation can best be balanced to support adaptive transitions between activities in the classroom.

Introduction

In K-12 classrooms, students often work across multiple social planes (e.g., whole class, group, individual). Within the classroom, the transitions between these social planes are points of high orchestration load for the teacher (Dillenbourg & Jermann, 2010). Currently, many classrooms require that students transition between social planes at the same time to make the orchestration load on teachers manageable. However, this limits the ability for students to work at their own pace and allow students to work collaboratively or individually when it would be most impactful for them. To have more fluid, but theoretically effective, transitions (i.e., not all students are transitioning synchronously) between social planes, greater orchestration support for social transitions is needed so the orchestration load is manageable for the teachers. Although a general understanding of classroom orchestration features has been explored (Dillenbourg & Jermann, 2010; Prieto et al., 2011), these features often have the teachers still responsible for all of the decisions and actions, which provides teachers with autonomy but does not necessarily lower the orchestration load enough for an activity to be feasible in the classroom. There is limited investigation into how classroom orchestration can be automated, reducing orchestration load, while teachers maintain their autonomy, especially around fluid social plane transitions. To account for the dynamics of the classroom, it is important to work with teachers throughout the design process (DiSalvo & DiSalvo, 2014; Windschitl & Sahl, 2002). In this poster, we present results from our co-design process for developing design recommendations for balancing automatic orchestration support and teacher autonomy for social transitions.

Methods

A total of seven teachers participated (six females, one male) in the co-design sessions. The teachers ranged from teaching 2nd grade to 7th grade and came from five different schools. We conducted three 2-hour co-design sessions, two with two teachers, one with three teachers, along with a researcher who led the sessions. Each session was semi-structured discussing specific scenarios involving social transitions within the classroom. The scenarios highlighted the different types of transitions that could occur between social planes, such as "Consider the scenario where students are working individually but a few students are making the same mistakes continuously. Pairing some of the students would help them to learn the material more productively." The scenarios also focused on transitions that occur from changes in group aspects (e.g., absences, tardiness, change in groups due to expertise). Through the design discussions, we intended to elicit past experiences and pivotal moments that the teachers had within their classroom, where they wanted to spend their time, and where they were willing to allow automation from the system. We captured each of the 2-hour co-design sessions with video. To analyze the results, we reviewed the videos to reveal salient themes and needs expressed during the co-design sessions. During the review of the videos, we took notes on the conversations as they related to the teacher needs around social transitions for a total of 147 items. Using these items, we went through an iterative process using affinity diagramming to find themes around social plane transitions by grouping and regrouping notes to reveal teachers' underlying needs and current impediments in the classroom.

Results and design recommendations

On the surface, the themes that emerged from the co-design sessions are common themes to orchestration: namely, the importance of planning and classroom monitoring and flexibility. However, more nuanced patterns emerged

when analyzing the data in terms of the relationship between the system and the teacher that indicated important areas in which system automation and teacher autonomy could be balanced. Across all three sessions, the main theme that all seven teachers discussed was that "so much of being a good teacher at this time is just their management"; however, they are willing to allow the system more control if it means they can spend more time working with students as "the reality of it is, we get so much more done, so much faster one-to-one while everyone else is going that if [the system] can move the chips around the room, keep the flow going." Additionally, the teachers were willing to relinquish control of the system when they thought the system could perform the task better, such as when putting students in varying groups that still meet the necessary criterion, adapting quickly to "the fine details that we miss, that we do not know that we miss", and monitor students as "there really isn't a way to monitor [the groups]." Although the teachers were willing to relinquish control in some aspects, they still wanted to plan the "structure" and "routine" of the class and wanted "an override button" in real-time so that they could maintain control as it is still their job as a teacher and it is "intimidating" to put all of the trust in the system.

From the salient themes of the co-design findings, we extracted five design recommendations for how to balance system automation and teacher autonomy around the design of fluid transitions. One, provide tools for adaptable planning of fluid transitions for teachers to plan the activity before class but with a way for the tool to suggest groups. Two, automate the planned real-time decisions so that teachers can spend less time managing and more time supporting students on content learning. In other words, support autonomy during planning and provide automation during the execution of the plan. Three, have the system directly communicate information to the students so that the teacher does not have to spend all of their time monitoring the management. Four, provide high-level class monitoring to the teacher, which is a current feature that current orchestration tools often include. Five, allow teachers the flexibility to override system decisions, whether these are preplanned decisions or ones made by the system in real-time, which allows teachers to maintain autonomy over their class.

Discussion

Although at the surface, the topics discussed in the co-design sessions echoed previous literature around orchestration, which has emphasized the need for planning, monitoring, and flexibility within orchestration support (Dillenbourg & Jermann, 2010; Prieto et al., 2011), our results add to this literature by proposing that teachers do not need complete control of the system at all times, specifically when relinquishing that control gives them more time to work with students or when they feel the system can do the task better than they can. For example, the teachers wanted to maintain control of the learning aspects of the classroom through the development of the lesson plan and supporting individual knowledge acquisition in the classroom. However, they were willing to allow the system control over the management of the monitoring and adaptation in the classroom so that they could focus on spending time with the students and because the system may be able to pick-up on things that they as teachers cannot and react faster. If something does occur, it is important to have a way for the teacher to intervene in real-time since there may be some classroom signals that the system cannot detect. By having more automation in the real-time management of the classroom orchestration, we can monitor and react faster to student actions as well as allow students to follow their own paths through the activity without having to create a bottleneck that depends upon the teachers time in the classroom.

References

Dillenbourg, P. & Jermann, P. (2010). Technology for classroom orchestration. In *New science of learning* (pp. 525-552). Springer New York.

DiSalvo, B., & DiSalvo, C. (2014). Designing for democracy in education: Participatory design and the learning sciences. In *Proceedings of the 11th International Conference of the Learning Sciences*.

Prieto, L. P., Dlab, M., Gutiérrez, I., Abdulwahed, M., & Balid, W. (2011). Orchestrating technology enhanced learning: a literature review and a conceptual framework. *International Journal of Technology Enhanced Learning*, *3*(6), 583-598.

Windschitl, M., & Sahl, K. (2002). Tracing teachers' use of technology in a laptop computer school: The interplay of teacher beliefs, social dynamics, and institutional culture. *American Educational Research Journal*, *39*(1), 165-205.

Acknowledgments

Exploring How Students Learn Estimation Using a Modelling-based Learning Environment

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Abstract: Estimation is an important class of problems that engineering undergraduates must learn to solve. However, teaching-learning of estimation is under emphasized in the current engineering curriculum and in learning sciences research. In this work, we report on the evaluation of the first cycle of a design-based research (DBR) project to design a technology-enhanced learning environment (TELE) for estimation. The TELE includes a progressive higher order modelling-based structuring of the estimation process, a problem system simulator and metacognitive scaffolds. From a lab study we identified the role of these pedagogical features for doing and learning estimation and changes needed to the design.

Introduction

Engineers routinely make estimates of physical quantities such as power before they begin designing or making (Linder, 1999). In order to estimate a quantity, say power, a solver needs to make a simplified model, i.e., an equation relating power to parameters that significantly impact its value in the given real-world system (Linder, 1999). This is challenging for students because they must apply conceptual knowledge to a real-world system, identify the parameters that will dominate power requirements, make assumptions, quantify inefficiences and make judgements regarding numerical values (Linder, 1999). Thus estimation is an ill-structured problem, very different from the well-structured problems which remain the emphasis of engineering curricula (Linder, 1999). Research has found a marked difference between the estimation performance of expert engineers and graduating engineering students (Linder, 1999). Thus, there is a need to explicitly train engineering students in estimation problem solving. While several researchers (Mahajan, 2014; Linder, 1999) have offered guidelines for learning estimation, these guidelines have not been empirically validated for their effectiveness for learning estimation. This is the motivation for our DBR project to design a TELE for estimation.

Design of the learning environment

The main goal of our TELE is to provide learners a structured approach to reduce the complexities of a real-world problem system and create an equation. It has been found that causal model progression (Sun, 2013), serves as a scaffold to learners in creating quantitative models (equations). So we employed a progressively higher order modelling-based structure (Resier, 2004) to scaffold learners estimation process and get them to build models using appropriate affordances and scaffolds at each stage (Sun, 2013), such as simulations for qualitative modelling (Lindgren & Schwartz, 2009). Research shows that learners must be scaffolded in order to articulate and reflect on their problem solving (Kim & Hannafin, 2011), and question prompts (Ge & Land, 2004) are one way to do so. So we incorporated several question prompts to trigger learners' metacognitive processes. Our TELE is called **M**odelling-based **Est**imation **L**earning **E**nvironment (MEttLE) and learners solve an estimation problem by doing five tasks in a non-prescribed sequence (Figure 1): three stages of modelling (functional, qualitative and quantitative), at the end of which they have a simplified equation connecting the quantity to be estimated to the parameters that significantly impact it. There are affordances (such as a problem system simulator) and prompts available for learners to create these simplified models. Then they choose values for parameters, calculate and evaluate the estimate. At each stage, learners are prompted to evaluate and revise their developing models and plan the rest of the estimation. Finally, they reflect on their estimation process. The details of the pedagogical features of MEttLE are described in another paper (Kothiyal & Murthy, 2017).
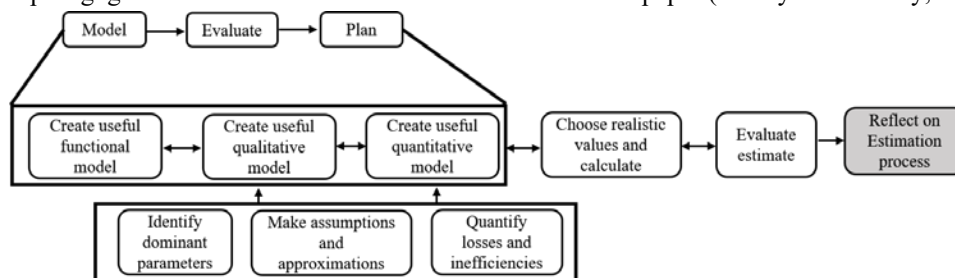
Figure 1. Workflow of MEttLE.

Methods

Broadly, we use DBR to design, evaluate and refine our TELE. Our research goal for the evaluation of the first cycle was to investigate how the pedagogical design of MEttLE supported learners doing of estimation. We performed a lab study and participants were six second year mechanical engineering students selected by convenience sampling. We collected qualitative, multimodal data and applied interaction analysis (Jordan & Henderson, 1995). We used their screen captures and video recordings to create detailed transcripts with annotations of the on and off screen actions done by learners during estimation, along with their explanations of their actions given during the interview. From this transcript, we identified the interaction patterns of learners in MEttLE and then the roles of various features in MEttLE on learners' estimation process.

Findings and discussion

The results showed that learners were able to apply the structured, progressively higher-order modelling-based process in MEttLE and use the modelling affordances and question prompts in order to create and refine models, and obtain estimates correct to the order-of-magnitude. Even though we had no post-test, learners reported during the post-interview that the three-phased modelling-based process was useful and applicable to other similar problems. Further we found that MEttLE supported a diverse set of productive actions which helped learners create models and solve the estimation problem. Finally, we found that the simulator served as a good tool for visualization and qualitative understanding of the problem system (Lindgren & Schwartz, 2009) which scaffolded learners when they lacked conceptual knowledge to build the qualitative models.

We found that the manner in which we structured the estimation process into a set of five tasks, each with two or three sub-tasks, each with a specific goal mentioned in the focus question, scaffolded learners in doing estimation and helped them abstract out the estimation process. As S3 reported, *"I didn't do it before, but you should know the concept what you are actually doing, you should know that before you actually solve the problem, and you should first analyse it qualitatively, like the relationships and all, that's actually one of the most important things to do and if we just look at it as a problem and just go through the quantitative part, that way I don't think it'll be as beneficial as it was today."* Learners followed the path of functional modelling, qualitative modelling, quantitative modelling, calculation and evaluation. If they made errors during modelling, they iterated between the sub-tasks and tasks until they obtained a reasonable estimate. This helped them recognized the utility of the progressively higher-order modelling-based process. Further, since there were five tasks only, all of them to be done in some order, this was a productive constraint that helped learners recognize the sequence that would be useful in solving the problem. This structure (Sun, 2013; Reiser, 2004), along with the reflection, gave learners an estimation process which they perceive to be useful to apply in future problems.

A significant gap that we observed in learners estimation after working in MEttLE was that they were unable to do estimation practices such as identifying dominant parameters, quantifying inefficiencies, making assumptions and reasoning about numerical values. While these practices take time to develop (Linder, 1999; Mahajan, 2014), learners' responses to the question prompts suggest that they need further scaffolds for these practices. Specifically, learners need to understand how to use conceptual knowledge in real-world conditions to make decisions. For this we will introduce guidance regarding expert practice at appropriate points in the pedagogy. This formative evaluation of MEttLE highlights the ways in which the pedagogical features lead to the doing and learning of estimation and what changes are needed to the design to further improve learning.

References

Ge, X., & Land, S. M. (2004). A Conceptual Framework for Scaffolding Ill-Structured Problem-Solving Processes Using Question Prompts and Peer Interactions. *Edu. Tech. Res. Devt., 52*(2), 5–22.

Kim, M. C., & Hannafin, M. J. (2011). Scaffolding problem solving in technology-enhanced learning environments (TELEs): Bridging research and theory with practice. *Comp. & Edu, 56*(2), 403-417.

Kothiyal, A., & Murthy, S. (2015). Examining Student Learning of Engineering Estimation from METTLE. In *Proceedings of the 25th Int. Conf. Comp. Edu. (ICCE 2017),* Christchurch, New Zealand.

Linder, B. M. (1999). Understanding Estimation and its Relation to Engineering Education. MIT.

Lindgren, R., & Schwartz, D. L. (2009). Spatial Learning and Computer Simulations in Science. *International Journal of Science Education, 31*(3), 419–438.

Mahajan, S. (2014). The art of insight in science and engineering: Mastering complexity. The MIT Press.

Reiser, B. J. (2004). Scaffolding Complex Learning: The Mechanisms of Structuring and Problematizing Student Work. *Journal of the Learning Sciences*, *13*(3), 273–304.

Sun, D., & Looi, C. K. (2013). Designing a Web-Based Science Learning Environment for Model-Based Collaborative Inquiry. *Journal of Science Education and Technology*, *22*(1), 73–89.

Leveraging MOOCs for Blended Learning: Capturing Effective 'Wrapping' Strategies With a Learning Design Pattern Language

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Abstract: There is an emerging trend to deploy MOOC resources in blended courses. This study aims to explore a systematic strategy for pedagogically productive exploitations of MOOC course designs in blended contexts. Adopting a design pattern language, this study documents and compares the learning designs of a Java course offered in both a fully online and a blended mode, so as to identify effective pedagogical patterns in transforming MOOCs to blended learning.

Introduction

The implications of massive open online course (MOOCs) have been widely expanded in the higher education landscape. Following the development of SPOCs (small private online courses), BOOCs (big open online courses) and DOCCs (distributed online collaborative courses), another new model is emerging, which uses MOOCs to support blended course design (Bruff, 2012; Bruff, Fisher, McEwen, & Smith, 2013; Caulfield, 2012a, 2012b; Fisher, 2012; Holotescu, Grosseck, Cretu, & Naaji, 2014). In this model, MOOCs, which have the functions of lecturing, testing and discussion, are regarded as 'super-textbooks', around which local instructors 'wrap' a set of in-class activities to customize their own courses. This approach promotes the exchange of learning design and materials in an online teaching community and opens up a new way to make use of MOOCs. However, building a blended course that incorporates an existing self-contained MOOC with the fixed content authored by another instructor can be challenging (Bruff et al., 2013; Caulfield, 2012a). The different targeted learners and manners of delivery, and the two instructors (in the video and the classroom) who may or may not hold the same view on the course content, could all be obstacles to a coherent coupling of online and offline components.

A small number of educational researchers and practitioners have been discussing and experimenting with effective strategies to build blended courses around MOOCs (Bruff, 2012; Bruff et al., 2013; Caulfield, 2012b; Fisher, 2012; Holotescu et al., 2014). These studies have identified various techniques that can usefully complement, extend and deepen the existing online components, such as creating small group discussions/activities, adding additional/challenging materials, clarifying concepts and questions shooting (ibid). Although these techniques are very effective practices in wrapping MOOCs, they are captured and presented as isolated ideas rather than as working parts of integrated approaches of teaching. The learning experience that a blended course creates for students is supposed to be fundamental and far-reaching (Garrison & Kanuka, 2004; Graham, 2006). When instructors develop a blended course, they cannot merely focus on instructional techniques by adding a group activity here and a different resource there. Instead, they should be cognizant of a spectrum of pedagogical approaches that organically synthesize across face-to-face and online components, through which the targeted learning outcomes can be effectively tackled. However, there has yet to be any systematic, well-documented and pedagogically-grounded strategies that teachers can draw upon when transforming MOOCs to a blended mode.

This study was set out to explore and develop a repertoire of pedagogically productive wrapping strategies that teachers can apply in developing blended courses from MOOCs. Adopting a learning design pattern language, this study documents and compares the learning designs of a Java course in both a fully online and a blended mode, in order to identify effective pedagogical patterns in transforming MOOCs to blended learning.

A learning design pattern language

We argue that systematic pedagogical deployment should focus on pedagogical patterns (Goodyear, 2005; Laurillard, 2012) as basic units in transforming MOOCs to blended mode. The learning design pattern language (Law, Li, Herrera, & Salas-Pilco, 2017) adopted in this study provides a research-based design language for clear representation of patterns in a systematic way. Specifically, the pattern language encompasses hierarchically nested structures that capture a course design at different levels of granularity: course, learning units and learning tasks (Figure 1). So instead of capturing fragmented techniques, the multilevel language allows us to document the dynamic process and the complete pedagogical approach in which the techniques are

embedded. This allows us to make visible the tacit knowledge of instructors' design thinking, and distil the effective design patterns that can play out in other contexts.
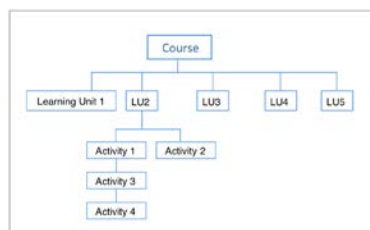
Figure 1. The hierarchically embedded 3-level structure of the learning design pattern language.

Research method and data collection

This study documents and compares the learning designs of the fully online and the blended modes of the Java course. Two research methods were adopted to obtain the required data. The first and primary method was observation. We have two team members auditing, in the role of students, both the fully online (archived) and the blended Java courses, and documenting the learning designs using the pattern language. In the meantime, we have conducted two rounds of interviews with the instructor to validate our documentation of the learning designs.

Findings

A series of design patterns have been captured from the two modes of the Java course. The findings show how the same learning outcome objectives were delivered differently in the two modes of the Java course. With the learning design pattern language, we are able to capture and present the instructor's MOOC-wrapping techniques in coherent pedagogical patterns. This allows us to see adequately how the different design components, online and offline, work together to generate transformative learning experience. In the poster session, we will present the full set of effective design patterns that we have identified in transforming MOOCs to blended contexts. They are envisioned to form a repertoire of strategies to support instructors' experimentations with leveraging MOOCs for blended learning.

References

Bruff, D., Fisher, D. H., McEwen, K. E., & Smith, B. E. (2013). Wrapping a MOOC: Student perceptions of an experiment in blended learning. *Journal of Online Learning and Teaching*, *9*(2), 187.

Caulfield, M. (2012, November 9). How Coursera Could Walk the Talk About MOOC-wrapping. Retrieved from https://hapgood.us/2012/11/09/how-coursera-could-walk-the-talk-about-mooc-wrapping/.

Fisher, D. (2012, November 7). Warming Up to MOOCs. Retrieved from https://news.vanderbilt.edu/2012/12/07/doug-fisher-warming-up-to-moocs/.

Garrison, D. R., & Kanuka, H. (2004). Blended learning: Uncovering its transformative potential in higher education. *The Internet and Higher Education*, *7*(2), 95–105.

Goodyear, P. (2005). Educational design and networked learning: Patterns, pattern languages and design practice. *Australasian Journal of Educational Technology*, *21*(1).

Graham, C. R. (2006). Blended learning systems: Definition, current trends, and future directions. In C. J. Bonk & C. R. Graham (Eds.), The handbook of blended learning (pp. 3–21). San Francisco, CA: Preiffer.

Holotescu, C., Grosseck, G., Cretu, V., & Naaji, A. (2014). Integrating MOOCs in blended courses. In *The International Scientific Conference eLearning and Software for Education*, 4, 243, National Defence University.

Law, N., Li, L., Herrera, L. F., & Salas-Pilco, S., Z. (2017). Bridging learning analytics to learning design through a pattern language based learning design studio. Paper presented in DesignLAK17 Workshop, Vancouver: LAK Conference.

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Leave Some Space to Think:
Can Less Guidance Bring More Product?

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Abstract: The purpose of the study was to develop an optimal form of support during the problem-solving phase in productive failure for the learners to benefit most from their failing experience. Learners' Representation and Solution Methods ("RSM") and cognitive load were analyzed accordingly. The results indicate that there are statistically significant differences in learners' RSM diversities based on the types of metacognitive prompt provided to each group, while the effect of the different types of metacognitive prompt on RSM structuredness and cognitive load are not significant.

Keywords: Productive failure, metacognitive prompt, representation and solution methods

Introduction

Productive failure is an instructional strategy that encourages learners to directly confront novel, complex problems through non-content-related support followed by instruction phase afterwards (Kapur, 2016). Through this delayed-instruction strategy, learners can be trained to think of their own solutions in a self-determined way while using and developing cognitive structures to solve novel problems. The complex problem is an instructional device to activate prior knowledge (either informal or intuitive), perceive knowledge gap, and generate RSM to the problems. The problem-solving process augments learners' data source and empowers the learners to transfer skills even if they fail to solve problems. The efficacy of the complex problem can be explained by *solution generation effect* which argues that the learners would perform better when they generate more RSMs (Kapur, 2012).

Much effort has been made for the learners to turn their failing experiences to be 'glorious'. Often, a learner may go through a failure from lacking domain knowledge, not from a condition in which they find it difficult even to start. To compensate for the lacking domain knowledge and to facilitate RSM generation, this study focused on providing metacognitive prompts during the problem-solving phase. The metacognition involves both knowledge and regulation of cognition and compensates for the lack of relevant domain-specific knowledge. Hence, in the absence of domain-specific and structural knowledge, the metacognition becomes critical for solving ill-structured problems (Wineburg, 1998) as they require both types of knowledge (Ge & Land, 2004). The experiment by Roll et al. (2012) showed that the learners outperformed in invention activity when they were provided with metacognitive prompts.

Meanwhile, the amount of support should also be considered because offering too much support may obstruct achieving productive failure, that is, to encourage learners to come up with their own solution. Guiding the whole process of problem-solving on evaluating and refining their solutions may improve RSM structuredness, but too much content in the worksheet (or material) would rather increase cognitive load. Concomitantly, drawing learners back repeatedly into situations that they had already skipped because they lacked the relevant knowledge can frustrate and exhaust them.

Therefore, it is necessary to devise an optimized prompt that contributes to an affordable failing experience. Such a prompt may allow a space to generate more RSMs by providing learners with less work than a fully-supporting prompt. Reviewing learners' RSMs during the problem-solving phase can be both time- and effort-consuming, and can ultimately become meaningless because the instruction phase provides a chance for learners to revise and compare their RSMs with a concrete lesson. Optimized prompt can, however, prevent cognitive overload from the difficulty and complexity of problems.

This study attempted to answer two research questions: (1) *In what ways do the different types of metacognitive prompt affect learners' RSMs in terms of diversity ("RSMD") and structuredness ("RSMS")?* (2) *In what ways do the different types of metacognitive prompt affect learners' cognitive load?*

Method

The research questions were tested in a quasi-experimental study on 106 undergraduate students who are majoring in mechatronics and enrolled in Intro to Mechatronics course in a university in Seoul, Korea. The participants were asked to solve two complex problems with peers and provided with prompts that offered no

support, optimized support, or full support. Results based on three measurements were collected throughout the session; RSMD (Cronbach's α = .82), RSMS (Cronbach's α = .86), and cognitive load (Cronbach's α = .87).

Results

The dependent variables for research question 1 were RSMD and RSMS. A MANCOVA test was conducted with different types of metacognitive prompt as the between-subjects factor, and the pretest score as the covariate. There was a significant multivariate effect of metacognitive prompt on participants' RMSD and RSMS scores ($F_{(2,102)}$ = 2.589, p = .038, η_p^2 = .048). However, one of the univariate effects of metacognitive prompt was not significant: RSMD ($F_{(2,102)}$ = 4.954, p = .009, η_p^2 = .089) and RSMS ($F_{(2,102)}$ = 1.583, p = .210, η_p^2 = .030). The result indicates that both the optimized support (mean difference = 1.077, p = .048) and no support group (mean difference = 1.333, p = .014) scored significantly higher on RSMD than the fully supported group. The difference between the RSMD scores of the optimized support group and no support group was not significant.

The dependent variable for research question 2 was the cognitive load. An ANCOVA test was conducted with different types of metacognitive prompt as the between-subjects factor, and the pretest score as the covariate. The difference among groups was not significant ($F_{(2,102)}$ = 2.045, p = .135, η_p^2 = .039).

Discussion

This study investigated the effect of different types of metacognitive prompt in association with the diversity and structuredness of learners' RSMs and cognitive loads. The MANCOVA test revealed that the optimized support and, surprisingly, the no support groups generated more RSMs than the full support group. The no support and optimized support groups could have benefitted from having their datasets regulated, leading to the *solution generation effect* (Kapur, 2012). This result is linked to the concept of productive failure, which is to problematize learners without giving guidance. Nonetheless, the findings propose that among different forms of support during the problem-solving phase, non-guided failures allow more opportunity to generate ideas or RSMs than the guided failures.

This study focused on the effects of changes in the problem-solving phase, thus, RSMS were measured to examine whether the fully supported group would generate more structured RSMs than the others. The results show that the differences among the groups' RSMS scores were not significant. This result can be explained by the nature of the metacognitive prompt that does not provide cognitive support. It is consistent with the findings of Kapur (2011), who found that having fewer failures during the problem-solving phase was not beneficial to learners' learning outcomes.

It was expected that the optimized support would reduce extraneous load hence have more room for the germane load. However, this study found that there was no statistically significant difference among the experimental groups' cognitive loads. This can be attributed to the fact that the learners did not consider the prompt to be a guidance nor they reported cognitive load based on the complexity of the problems instead of their own internal states. Measuring cognitive load after failed complex problem-solving experience may not make sense, as it would result in relatively high cognitive load. This study showed that reducing learners' cognitive loads through prompts is ineffective, therefore suggests future research to consider how to design productive failure environments that can reduce cognitive load and produce a productive failing experience.

References

Ge, X., & Land, S. M. (2004). A conceptual framework for scaffolding Ill-structured problem-solving processes using question prompts and peer interactions. *Educational Technology Research and Development*, *52*(2), 5-22.

Kapur, M. (2011). A further study of productive failure in mathematical problem solving: Unpacking the design components. *Instructional Science, 39*(4), 561–579.

Kapur, M. (2012). Productive failure in learning the concept of variance. *Instructional Science*, *40*(4), 651-672.

Kapur, M. (2016). Examining productive failure, productive success, unproductive failure, and unproductive success in learning. *Educational Psychologist*, *51*(2), 289-299.

Roll, I., Holmes, N. G., Day, J., & Bonn, D. (2012). Evaluating metacognitive scaffolding in guided invention activities. *Instructional science, 40*(4), 691-710.

Wineburg, S. (1998). Reading Abraham Lincoln: An expert study in the interpretation of historical texts. *Cognitive Science*, *22*(3), 319-346.

Student Engagement With Resources as Observable Signifiers of Success in Practice Based Learning

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Abstract. Practice-based learning activities with a focus on Science, Technology, Art, Math and Engineering (STEAM) are providing new opportunities for teaching these subjects. However, we lack widely accepted ways of assessing and monitoring these practices to inform educators and learners and enable the provision of effective support. Here, we report the results from a study with 15 teenage students taking part in a 2-day Hack. We present results from analysis of video data recording collaborative working between groups of students. The analysis of the video data is completed using the ERICAP analytical framework (Luckin *et al.*, 2017) based on ecology of resources and interactive, constructive, active and passive concepts. The results illustrate the differences between students' engagement with resources which might be utilized as signifiers of student success in similar learning environments.

Introduction

This paper reports the use of Learning Sciences constructs (Ecology of Resources and ICAP Framework) to support the potential analysis of collaborative problem-solving (CPS) in practice based learning (Cukurova *et al.*, 2016). We report an empirical study of teenagers who are using physical computing and design materials in to learn about STEAM subjects. Our goal in this study is to explore the ways students interact with the resources available to them to support their activities. The key question that drives the research we report here is: *How can we assess the effectiveness of a particular instance of students' group work to inform the future design of technology scaffolding for STEAM activities?*

Methodology

The participatory design-based study was conducted with 15 secondary school students aged 14-15 years. A range of data sources were collected during the hack event. In this paper, we only focus on the video data and in particular upon the interactions of individual learners within their CPS group. Two researchers coded the video of each group according to the ERICAP framework to identify the resources available and in use by the learners (see Luckin *et al.*, 2017 for the details of the framework). Resource use was recorded at 30 second intervals. To verify the validity of the video analysis we sought independent verification. An expert from another university who had not previously been involved in our study data collection or analysis provided this verification. We asked her to watch our video data of the 3 groups who took part in the Hack Event as illustrated in Tables 2 and 3 there was evidence that the group ERICAP framework overlaps with expert evaluation of students' CPS.

Results

Figure 1 illustrates a comparison between two learners from the coin sorter project group. It illustrates the chronology of the resources used by each learner over an hour period in the middle of the first day of the Hack event. The white areas indicate that a resource is not present, the striped areas indicate that a resource is present, but not in use, and the black areas indicate that a resource is being actively used by the learner in focus.
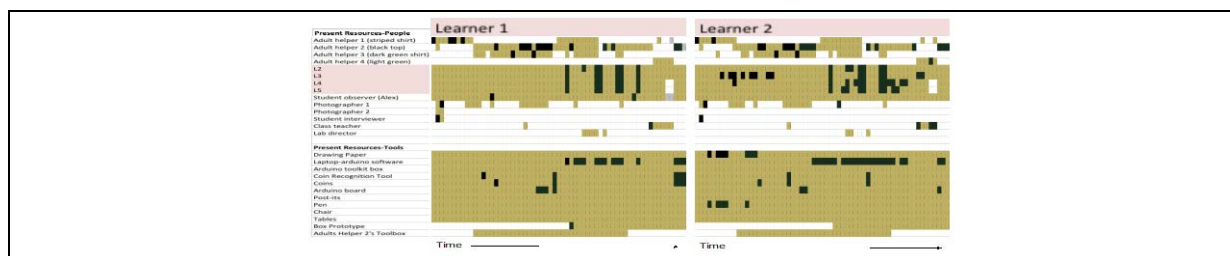
Figure 1. Comparison of resource use by individual students in a group.

Looking more closely at this data, in particular at the black areas in Figure 1, we can see the resources that were actively in use by each learner at the same time, indicating a relationship between these resources with respect to that learner. These periods of active engagement are markedly different between L1 and L2 who were

working as part of the same group: L1 starts their active engagement with multiple resources 15 minutes into the session and engages actively with multiple resources for a total of 30% of the session. By contrast, L2 started actively interacting with multiple resources, much earlier in the fifth minute, and L2 interacted in this way for 50% of the session. In order to probe learners' activity with resources in greater depth, we focus our attention on the interactions between learners and resources. The ERICAP analysis for L1 and L2 reveals that there is only 1 minute, which is less than 2% of the hour-long session in which L1 interacts at levels 4 or 5 (interactive and constructive engagement), both socially with other learners and physically with the tools required for the problem-solving activity. This suggests that L1 engages in little CPS activity in this particular hour-long session of the Hack Event. By contrast, L2, interacts at levels 4 or 5 both socially with other learners, and physically with the tools required for the problem-solving activity for 23 minutes (38%) of the session.

Table 1: The % of the session that each learner spent interacting with Constructive or Interactive engagement

	Robot Group	Coin Group	Glove Group
L1	62.5	65.83	95
L2	72.5	72.5	96.67
L3	45	56.67	91.67
L4	31.67	72.5	96.67
L5	43.33	70.83	88.33

Table 2 shows the variance across all learners in the observable evidence of CPS, which ranges from 31.67% of the session for L4 in the Robot group to 96.67% for L2 in the Glove group. To verify the validity of the ERICAP video analysis we sought independent verification. An expert from another university who had not previously been involved in our study data collection or analysis provided this verification. We asked her to watch our video data of the 3 groups who took part in the Hack Event as illustrated in Tables 2 and 3 and identify the times during the learners' interactions when in her judgement there was evidence that the group was engaged in CPS.

Table 2: Average % of the session when learners were Constructively or Interactively engaged with resource

Group Name	%
Robot Group	51
Coin Group	67.67
Glove Group	93.67

Table 3: The % of the session that an independent expert rated as consistent with CPS

Group Name	%
Robot Group	18
Coin Group	47
Glove Group	95

The ERICAP framework analysis ranks the groups in the same order as the independent expert. However, the data concerning the Robot group is at particular variance between the ERICAP analysis and the human expert. The possible explanation for this may lie in the fact the coders using the framework did not code the students' interactions with this ready-made robot as interactions with the prototype, the independent expert did accept students' interactions with this ready-made robot as interactions with a prototype. It is however important to recognize the significance of such a disagreement, because technology interventions for such evaluations of CPS would need to be able to cope with such differences.

Conclusions

The ERICAP framework has been informed by theories from the Learning Sciences and used for the analysis of data collected from practice-based learning activities involving groups of teenage learners solving problems collaboratively as parts of a Hack event. Our analysis enabled us to identify that whilst all groups of learners were provided with a similar set of resources, the resources that they chose to use in their collaborative problem-solving activity were quite different. There is often a motivation to provide similar types of resources to all learners taking part in these sorts of collaborative activities. Our findings suggest that these resources are not accessed in a consistent manner. We illustrated that there were particularly substantial differences between learners in the extent to which their engagement with resources can be categorized as interactive or constructive.

References

Luckin, R., Cukurova, M., Mavrikis, M., & Millan, E. (2017). Context and Collaborative Problem Solving (CPS). CSCL17. Philadelphia.

Cukurova, M., Avramides, K., Spikol, D., Luckin, R., & Mavrikis, M. (2016). An analysis framework for collaborative problem-solving in practice-based learning activities: A mixed-method approach. ACM.

How Learning Outcomes are Measured in Digital Learning Environments in Higher Education

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Abstract: We investigated how learning outcomes are typically measured in empirical studies of digital learning environments in higher education. A database search of articles published in peer-reviewed journals between January 2000 and May 2017 resulted in $n = 356$ articles whose abstracts we screened for different types of dependent variables. We identified seven categories of learning outcomes: Self-reports, observable behavior, learning skills, elaboration depth, personal initiative, digital activity, and social interaction. We discuss opportunities for future research on the basis of these categories.

Keywords: learning outcomes, digital learning environments, higher education, database search

Digital learning environments

Even though several factors have been identified as being relevant for successful learning in digital learning environments (e.g., Tham & Werner, 2005), it remains largely unclear how digital learning environments improve learning success (Al Zahrani & Laxman, 2016). At least in part, this lack of clarity may be due to the heterogeneous definitions of learning with digital media and the great variety of different measures of learning success. Based on this assumption, we aimed to conduct a detailed review of prototypical approaches that are used for operationalizing learning outcomes in existing research on digital learning environments. Moore, Dickson-Deane, and Galyen (2011) analyzed existing literature to identify how current research defines digital learning environments. Although the authors encountered a lack of consistency in the terminology, they found four core characteristics of digital learning environments: (1) the provision of learning materials independent of time and space, (2) the broad access to learning materials, and (3) the support of educational opportunities (4) even for non-traditional learners. These characteristics are also highly relevant in higher education, resulting in increasing importance of digital learning environments for higher education contexts (e.g., Bientzle, Griewatz, Kimmerle, Küppers, Cress, & Lammerding-Koeppel, 2015). Currently, it is evident that the approaches to measuring learning outcomes in digital learning environments are quite manifold, making it very difficult to recognize potential success factors of digital learning. We therefore set out to identify how previous empirical research studies have measured learning outcomes in digital learning environments in higher education.

Methods

The aim of our study was to describe how previous research has measured learning outcomes in the context of digital media in higher education. We followed the procedure proposed by Cooper (2016) and identified four relevant thematic threads for our search in peer-reviewed journals: (1) digital learning environment, (2) instructional design, (3) higher education, and (4) performance criteria. The first thread of thought ensured that we would maintain a neutral perspective by finding as many studies as possible which dealt with operationalization of digital learning environments independently of theoretical traditions. The second thematic thread focused on the instructional perspective, since we were interested in cognitive processes and properties of digital learning environments that might support learning and instruction. The two remaining threads restricted our search to higher education and learning outcomes in that context. Learning outcomes of students are often referred to as academic performance, so that the fourth thread aimed to identify performance criteria. We searched the database *Web of Science* and limited our results to English language articles of empirical studies published in peer-reviewed journals with a publication date from January 2000 to May 2017. We further limited the results to the top three *Web of Science* research areas (*Education & Educational Research*, *Computer Science*, and *Psychology*) and the 25 most frequently represented journals. This procedure resulted in $n = 1492$ records. We ranked these journals with respect to their impact factor and included only journals with an impact factor equal to or larger than 0.8. The journal that was the most frequently represented was *Computers & Education*. Our next step was to conduct an abstract screen for the resulting $n = 758$ articles. We excluded qualitative studies that did not have precise operationalizations of learning outcomes as dependent variables.

Similarly, we excluded samples without students and studies without teacher instructions. We included data from the abstract screening of the remaining articles ($n = 356$). The features which were relevant to describing learning outcomes were the particular dependent variables of the respective studies.

Results

These data indicated seven categories with respect to digital learning environments. (1) *Self-reports* refer to accounts by learners of their own attitude, satisfaction, or motivation. To evaluate learning outcomes, it is important to know how individual learners assess their learning outcomes based on their experiences and perceptions. (2) *Observable behavior* is the learners' goal-orientated behavior, observed with the goal of evaluating learning outcomes in a more activity-oriented way, such as the evaluation of learners' intention to learn, choice of lectures, and persistence. (3) *Learning skills* refer to metacognition (e.g., time management, reflection, or self-regulation), writing, reading or listening skills, as well as awareness of group processes, workspaces or persons, and even usage of technologies, software or tools. This list of skills is not exhaustive but represents variables of skills in higher education. (4) *Elaboration depth* refers to the amount of mental effort invested, understanding, and comprehension, and cognitive load. This category represents cognitive information processing. (5) *Personal initiative* as a core property of interacting with digital media represents the commitment necessary for learning and learners' impact on social interaction (e.g., participation, attendance, access, and amount of contributions to a discussion). (6) *Digital activity* represents active and adapted use of digital tools (e.g., searching and sourcing). (7) *Social interaction* refers to the influence of the involved learning community on learners' outcomes, for example by providing feedback, and through co-operation or collaboration in group specific tasks (Jeong, Cress, Moskaliuk, & Kimmerle, 2017).

Discussion

Previous research has shown that a broad variety of variables are involved in learning with digital media in higher education. The results of our analysis indicate that the definition of learning outcomes in existing research is correspondingly multifaceted and versatile. Even within the limited context of students in higher education, the terminology for learning outcomes in empirical studies is multifarious and diverse. The data gathered for this research synthesis are preliminary results from screening abstracts. Some abstracts did not provide sufficient information about sample, design, variables, or effects. It would therefore be important to carry out a full-text screening of the empirical studies. This, in turn, could provide detailed descriptions of context, designs of the studies, methods, and statistical analyses to provide a reliable evaluation of learning outcomes with digital media in higher education. We have made a first step by describing measurements of learning outcomes, but no overall conclusion concerning the relationship of these learning outcomes with particular features of digital learning environments could be made and would definitely be required for future research. The process of identifying independent variables that are associated with these learning outcomes would also be a future significant step. Gathering and structuring these data would empower practitioners and scientists to be able to rely on the huge amount of results already in existence.

References

Al Zahrani, H., & Laxman, K. (2016). A critical meta-analysis of mobile learning research in higher education. *Journal of Technology Studies, 42*, 2-17. doi:10.21061/jots.v41i2.a.1

Bientzle, M., Griewatz, J., Kimmerle, J., Küppers, J., Cress, U., & Lammerding-Koeppel, M. (2015). Impact of scientific versus emotional wording of patient questions on doctor-patient communication in an internet forum: A randomized controlled experiment with medical students. *Journal of Medical Internet Research, 17*, e268. doi:10.2196/jmir.4597

Cooper, H. (2016). *Research synthesis and meta-analysis: A step-by-step approach*. Thousand Oaks, California: Sage Publications.

Jeong, H., Cress, U., Moskaliuk, J., & Kimmerle, J. (2017). Joint interactions in large online knowledge communities: The A3C framework. *International Journal of Computer-Supported Collaborative Learning, 12*, 133-151. doi:10.1007/s11412-017-9256-8

Moore, J. L., Dickson-Deane, C., & Galyen, K. (2011). E-learning, online learning, and distance learning environments: Are they the same? *The Internet and Higher Education, 14*, 129-135. doi: 10.1016/j.iheduc.2010.10.001

Tham, C. M., & Werner, J. M. (2005). Designing and evaluating e-learning in higher education: A review and recommendations. *Journal of Leadership & Organizational Studies, 11*, 15-25. doi:10.1177/107179190501100203

Rethinking TPACK in the Digital Age:
Non-Linear Relationships Between Learning by Design, Teachers' Technology-Related Knowledge and Technology Integration in the Classroom

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Abstract: Teachers are increasingly required to integrate educational technology in the classroom, therefore to acquire and practically apply technology-related knowledge. This knowledge was described by the TPACK (Technological, Pedagogical and Content Knowledge) framework, and it is assumed to be best acquired by teachers' participation in Learning by Design (LbD) practice. However, little is known about the relationships between LbD, TPACK and technology integration (TI) in the classroom. A survey involving $N = 101$ US American secondary school mathematics teachers was conducted in a northeastern state to address this research gap and, surprisingly, it revealed non-linear relationships. These suggest that, while TPACK partially mediates the LbD-TI relationship as expected, technological knowledge can have a saturation effect on TI, and both LbD and TPACK can, under certain circumstances, decrease TI. Consequences for further research and teacher professional development practice are discussed.

Introduction

Little is currently known about which knowledge and competences may enable teachers to integrate technology in the classroom in a meaningful and effective way, and how teachers can acquire the needed knowledge. One of the few approaches on teachers' technology competences is the Technological, Pedagogical and Content Knowledge (TPACK) framework established by Mishra and Koehler (2006), who further propose the Learning by Design (LbD) approach (Kolodner et al., 2003) carried out in teachers' communities of practice as a means to acquire the necessary TPACK. However, little is known about the relationships between LbD, TPACK, and technology integration (TI) in the classroom. After a brief overview on TPACK and LbD, the paper presents a study addressing this research gap. The findings imply consequences for further research and for teacher professional development, as discussed in the final part.

Research questions and methodology

Aiming to address the research gap identified above, the following research questions were examined. RQ1: To what extent does teacher participation in Learning by Design predict their TPACK? RQ2: To what extent does teacher TPACK predict technology integration? RQ3: To what extent does TPACK mediate the relationship between participation in Learning by Design and technology integration?

A quantitative, correlative field study was employed using cross-sectional questionnaire survey data. The examined population ($N = 101$) was located in a northeastern US American school district with a total of 2862 teachers, from which 127 were teachers of mathematics. The TPACK and LbD variables were measured using the adapted TPACK questionnaire by Zelkowski et al. (2013); additional items were formulated ad-hoc for TPACK and TI. Besides IBM SPSS Statistics 24, data were analyzed using WarpPLS 6.

Findings

In response to **RQ1** (Figure 1 a, b), two nearly linear and positive relationships were found, LbD–TK ($\beta = .42$, $p < .01$, $R^2 = .18$) and LbD–TPACK2 ($\beta = .38$, $p < .01$, $R^2 = .14$). The relationships LbD–TPK ($\beta = -.26$, $p < .01$, $R^2 = .07$), LbD–TCK ($\beta = -.21$, $p < .01$, $R^2 = .04$) and LbD–TPACK ($\beta = .26$, $p < .01$, $R^2 = .07$) were significant in the sense that a curve describing the relationship could be fitted to the data, however the relationship explained a small amount of variance in the dependent variable ($R^2 < .10$). Therefore, these relationships were disregarded. In response to **RQ2**, four strongly curvilinear relationships were found (Figure 1 c, d, e, f): TK-TI ($\beta = .23$, $p < .01$, $R^2 = .18$), TPK-TI ($\beta = .28$, $p < .01$, $R^2 = .20$), TCK-TI ($\beta = .19$, $p < .01$, $R^2 = .16$), and TPACK2-TI ($\beta = -.24$, $p < .01$, $R^2 = .18$). The relationships TPACK–TI and TPACK1–TI were not significant

($p > .05$). The mediation analyses responding to **RQ3** indicated both direct and mediated, significant relationships between LbD and TI, with R^2 between .16 and .20. The relationship LbD–TI was U-shaped, with minimum points corresponding to z values of LbD between .25 and .45, as shown in Figure 1 g, h. The mediation by TPK and TCK was disregarded due to the small amount of mediator variance involved ($R^2 < .10$).
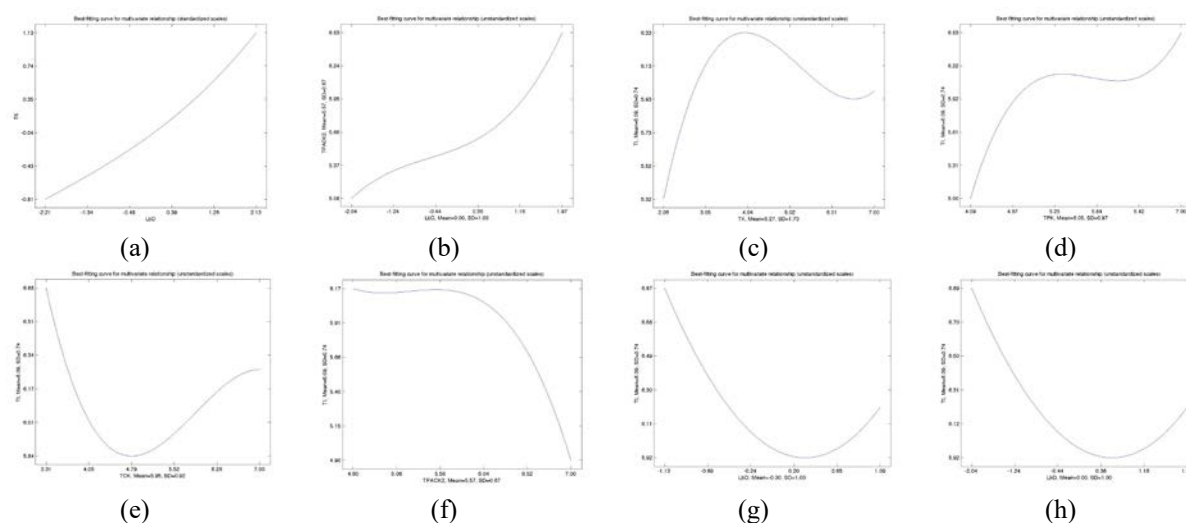
Figure 1. Relationships corresponding to RQ1: (a) LbD–TK, (b) LbD–TPACK2; RQ2: (c) TK–TI, (d) TPK–TI, (e) TCK–TI, (f) TPACK2–TI; RQ3: (g) LbD-TK-TI, and (h) LbD-TPACK2-TI.

Discussion

In general, LbD predicted TI, as suggested by Mishra and Koehler (2004), however according to a U-shaped relationship. This relationship was partially mediated by TK and TPACK2 (specific, applicative technology-related knowledge). More in detail, LbD predicted TK and TPACK2 displaying a nearly linear relationship; and TK, TPK, TCK, and TPACK2 were significant, curvilinear predictors of TI. Interestingly, TPACK1 (general technology-related knowledge) did not predict TI. The surprising results mainly consisted of the curvilinear shaped relationships found between the variables. This suggests that, in the teaching practice, TI may be initially, or partially, based on spontaneous action, rather than on well-founded knowledge. Further unexpected results were the non-linear relationships TK–TI and TPACK2–TI. The relationship TK–TI (Figure 1c) suggests a saturation effect, in the sense that an increase in teachers' knowledge of educational technology may be useful for technology integration only up to a certain limit, after which additional technology applications are hardly possible. Similar findings were reported by Valtonen et al. (2017).

The validity and applicability of the presented findings are limited by several methodological aspects. The findings are based on self-report data, whereas several authors (e.g., Valtonen et al., 2017) criticize the construct validity of the TPACK instrument. The presented results support this point of critique and emphasize the need for a more thorough construct validation, and for the complementary use of more objective data. Furthermore, some authors regard non-linear relationships as a euphemism for non-significant relationships. However, in this study we have made a distinction between both. Lastly, only mathematics teachers were examined, and the study does not include an insight in teachers' specific LbD activities.

References

Kolodner, J. L., Camp, P. J., Crismond, D., Fasse, B., Gray, J., Holbrook, J., Puntambekar, S., & Ryan, M. (2003) Problem-based learning meets case-based reasoning in the middle-school science classroom: Putting Learning by Design™ into practice. *Journal of the Learning Sciences, 12*(4), 495-547.

Mishra, P., & Koehler, M. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *The Teachers College Record, 108*(6), 1017–1054.

Valtonen, T., Sointu, E., Kukkonen, J., Kontkanen, S., Lambert, M. C., & Mäkitalo-Siegl, K. (2017). TPACK updated to measure pre-service teachers' twenty-first century skills. *Australasian Journal of Educational Technology, 33*(3). Retrieved from https://www.learntechlib.org/p/180264

Zelkowski, J., Gleason, J., Cox, D., & Bismarck, S. (2013). Developing and validating a reliable TPACK instrument for secondary mathematics preservice teachers. *Journal of Research on Technology in Education, 46*(2), 173–206.

The Difference That Counts: Guiding Knowledge Exchange by Visualizing Levels of Co-Learners' Knowledge

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Abstract: Many studies have shown that the complementarity of co-learners' knowledge has a positive effect on knowledge exchange in collaborative learning. It has also been proven that visualizing given levels of knowledge guide co-learners' questions and answers during the exchange. However, the question remains unanswered as to what extent visualized relative and absolute levels of knowledge have an influence on behavior. To find an answer to this question, which could also be used for optimizing complementarity-based group formations, we have systematically varied learners' knowledge levels relative to learning partners' levels (continuous distance) and absolute levels of knowledge (three levels) in 33 visualizations to investigate associated question and explanation intentions. The results confirm a strong influence of distances on intentions, moderated by absolute knowledge levels. In addition, we report from which distance learners decide to ask questions or provide explanations.

Theoretical background

Knowledge exchange is a core activity of collaborative learning, which can be triggered in learning groups by distributing learners' characteristics in specific ways (Dillenbourg & Jermann, 2007). Common approaches to group formation target to group learners with complementary knowledge by either forming groups of learners with given characteristics, or by providing teammates with complementary information, both aiming at promoting a mutual exchange of knowledge that enables learners to solve tasks for which their own knowledge is not sufficient (Dillenbourg & Jermann, 2007). Either way, providing co-learners additionally with the information, on which the group formation is based on, might further improve knowledge exchange. Cognitive group awareness tools visualize such knowledge-related information in order to improve the awareness of learning partners' knowledge and to suggest specific behaviors (Bodemer, Janssen, & Schnaubert, in press). Research in this area has revealed that group awareness improves co-learners adaptation of communication in terms of applying better strategies when asking questions on a learning topic and of providing more elaborated explanations to less knowledgeable learning partners (Dehler Zufferey, Bodemer, Buder, & Hesse, 2011; Erkens, Bodemer, & Hoppe, 2016). It can be assumed that these effects depend on the levels of knowledge relative to a learning partner and the absolute levels of knowledge. Since this has not yet been investigated, the present study aims to identify guidance principles that can be triggered by visualizing knowledge-related information and to use them for the improvement of group formation. For this reason, we investigate the research question of what influence the visualization of relative and absolute knowledge levels has on the exchange of knowledge. We assume that the intention to ask increases with an increasingly negative distance between own and partner knowledge (H1a) moderated by the level of knowledge (H1b) and the intention to explain increases with an increasingly positive distance (H2a) moderated by the level of knowledge (H2b). In addition, we investigate exploratively thresholds of knowledge distance from which learners start asking questions or giving explanations on a learning topic.

Method

We investigated the effect of visualized levels of knowledge in an online study with 126 participants (46 men; 80 women; age: $M = 27.63$, $SD = 11.88$). To test our hypotheses, we have varied the continuous predictor *relative level of knowledge* (distance values between the visualized bar of the participant and the bar of a learning partner ranging from -5 to +5) and the categorical moderator *absolute level of knowledge* (no knowledge, little knowledge, medium knowledge) in 33 systematically created visualizations (see Figure 1). For the purpose of capturing the dependent variables, we asked the participants to report for each of the visualizations their intention to ask a question and to give an explanation on a six-point scale (from (1) 'strongly disagree' to (6) 'strongly agree'). In addition, we have calculated thresholds for each participant based on binary logistic regressions. Resulting values x_1 ($x_1 = -\beta_0 / \beta_1$) describe the knowledge distance at the turning point of the logistic function meaning the visualized distance from which learners start asking or explaining.

Results

In order to answer our first research question, we investigated the impact of visualized levels of knowledge on knowledge exchange. For this purpose, we have used a moderation analysis with the distance values as predictor,
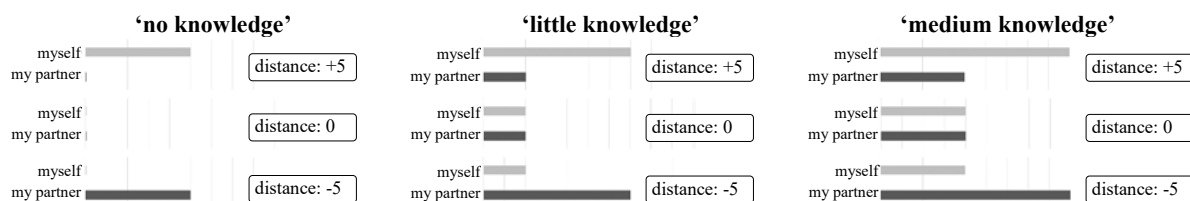
Figure 1. Extract of visualizations used. The 9 examples show the visualizations of the highest (+5), lowest (-5) and not given (0) distance between co-learners for all absolute levels of knowledge (no, little, medium).

absolute level of knowledge as moderator and the intention to ask or to explain as dependent variable. We dummy coded the absolute level of knowledge and used Helmert contrasts. Regarding hypothesis 1, results indicated that the intention to ask increases with decreasing distance, especially when the absolute level is 'no knowledge'. The interaction explained a significant increase in variance regarding the intention to ask, $\Delta R^2 = .06$, $F(2, 27) = 6.57$, $p < .01$. Regarding hypothesis 2, results indicated that the intention to explain decreases with decreasing distance, especially when the absolute level is 'no knowledge'. The interaction explained a significant increase in variance in the intention to explain, $\Delta R^2 = .05$, $F(2, 27) = 5.64$, $p < .01$. To answer our second research question, we have calculated thresholds at which learners begin to ask or to explain. We identified three groups: (1) learners with an intention to ask questions or give explanations, depending on the given knowledge distance, (2) learners who would always ask and explain, and (3) learners who would never ask or explain. As far as group (1) is concerned, we found that most of the learners (23 out of 79) were already starting to ask questions from a distance of 1 (indicating that learners know a little bit more) and 29 out of 80 learners would start giving explanations from a distance of -1 (indicating that they know a little bit less).

Discussion

The results indicate that the visualized knowledge differences of co-learners who have a similarly high overall knowledge on a topic should be as large as possible for each sub-area of the topic. Furthermore, the absolute level of knowledge seems to be relevant for knowledge exchange. While the high intention to ask questions is similar across absolute levels of knowledge when the visualization shows that a learning partner knows more than a learner, the intention to ask is especially low when the visualization shows a more knowledgeable learner in combination with a learning partner with no knowledge. Similarly, learners demonstrate a high intention to explain beyond the absolute levels of knowledge, if they are made aware that they know more than the learning partner does. Furthermore, they offer the learning partner little explanation, especially if the visualization shows a more knowledgeable learning partner in combination with no learner's knowledge. Taken together, this suggests that we should take into account for group formation that one co-learner should alternately have no knowledge. Regarding the question of a necessary minimum distance between co-learners, we have found that learners often start asking questions, although the visualization shows that they know a little more than their partner (with increasing intention, the more a learning partner knows compared to a learner). Further, they start giving explanations, although the visualization shows that they know something less than their partner (with increasing intention, the less a learning partner knows compared to a learner). Thus, there seem to be minimum differences from which learners start showing a specific behavior, but they lie outside our expected range, and a minimum at first glance does not seem to be a relevant for grouping. However, this could be different under real conditions, so levels of knowledge and thresholds should be further explored in the field based on these first promising results.

References

Bodemer, D., Janssen, J., & Schnaubert, L. (in press). Group awareness tools for computer-supported collaborative learning. In F. Fischer, C. E. Hmelo-Silver, S. R. Goldman, & P. Reimann (Eds.). *International handbook of the learning sciences.* NY, USA: Routledge / Taylor & Francis.

Dehler Zufferey, J. D., Bodemer, D., Buder, J., & Hesse, F. W. (2011). Partner knowledge awareness in knowledge communication: Learning by adapting to the partner. *The Journal of Experimental Education*, *79*(1), 102–125. doi: 10.1080/00220970903292991

Dillenbourg, P., & Jermann, P. (2007). Designing integrative scripts. In F. Fischer, I. Kollar, H. Mandl, & J. M. Haake (Eds.), *Scripting computer-supported collaborative learning* (pp. 275–301). NY, USA: Springer.

Erkens, M., Bodemer, D., & Hoppe, H. U. (2016). Improving collaborative learning in the classroom: text mining based grouping and representing. *International Journal of Computer-Supported Collaborative Learning*, *11*(4), 387–415. doi: 10.1007/s11412-016-9243-5

"Sorry if I'm Leaving You in the Dust": Toward Understanding the Importance of Student Goals in Collaborative Problem Solving

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Abstract: This study reports on a study of the influence of students' *goal*—speed versus mastery—as they solve a computer science problem collaboratively. We conducted a study with 254 university students enrolled in introductory computer science, pairing based on the goal they reported for that day. Results with a comparison condition show that matching by goal may not benefit student learning unless other factors are also considered. However, for students who hold a mastery goal, pairing with another student who shares that goal may significantly improve the learning experience. These results advance our understanding of how we might adapt collaborative learning practices based on students' goals.

Introduction

Collaborative learning has long been shown to promote effective learning through exposing students with various perspectives on problem solutions, and fostering critical thinking through interaction (Lin, 2015). For computer science learning in particular, the collaborative paradigm of *pair programming* is a widely used collaboration strategy, and has shown significant advantages over solo (individual) programming approaches including an increase code quality, and student confidence. In pair programming, two learners collaborate on the same code and take turns in typing at the computer (the *driver*) and examining the code, helping to plan and catch errors (the *navigator*). Challenges observed within collaborative learning across many domains—such as conflicts between partners (Weinberger et al., 2010) or inequity arising within the discussion (Engle, Langer-Osuna, & McKinney de Royston, 2014)—have also been documented in pair programming. In particularly, when students hold different goals for an activity, such as whether to finish quickly or whether to spend as much time as needed to master the material, inequitable dynamics can emerge (Lewis & Shah, 2015). Agreeing upon a shared *goal* is an important component to the success of collaborative learning (Barron, 2003).

This paper presents a study of the impact of pairing students based on their goals during collaborative computer science learning that investigate the following question: *What is the impact of pairing students based on their goal (speed vs. mastery) for a collaborative computer science assignment?* The results shed light on how we may more effectively scaffold collaborative learning, particularly for students who hold a *mastery* goal for that activity.

Methods

We conducted a two-condition exploratory study to investigate the effects of pairing students based on their goal—speed versus mastery—for a particular learning activity. The study was conducted with students who were actively enrolled in a Programming Fundamentals computer science course at a large public university in the southeastern United States. Out of the 278 consenting students, 254 students were present on the day that the research study was conducted. After students completed the lab assignment and a posttest and post-survey, they were free to leave. The course required all students to attend labs and complete the lab assignments even if they did not consent to participate this research study. The basis of the weekly lab was a learning task that reinforced concepts covered in the lecture over the preceding week. The programming task for this lab week was to implement a fictional game called "Hexbowling" in the Java programming language. Students across all 18 labs completed the same learning task. Each of the lab classes was randomly assigned into one of two conditions. Nine labs were assigned to the *Goal-Matched* condition, in which students were matched based on whether they reported a mastery goal or a speed goal. In this condition, because student goal would be made public to other students through matching, students were shown a short video emphasizing that many factors and constraints influence a person's goal on a given day and one goal is not considered "better" than the other. Then students indicated their goals for that day on a small index card and were paired by goal by their teaching assistant. In the comparison condition (the *Randomly-Matched* condition), students completed the same index card but were randomly paired and were not made aware of each other's preference. After completing the task, students completed a posttest consisting of seven multiple choice questions on the concepts from the lab. Students also completed a post-survey reporting on their learning experience, including one item that asked students to rate whether they would like to work with the same partner again, with choices of Yes, Maybe, and No.

Findings

First, we performed a top-level analysis comparing the two different conditions, *Goal-Matched* and *Randomly-Matched*, based on posttest score. Students in the *Goal-Matched* condition had a lower mean posttest score of 3.87 (n=112, *sdev*=1.52) than students in the *Randomly-Matched* condition had a posttest score of 4.41 (n=142, *sdev*=1.33). This difference is significant (t(252)=2.96, p=0.003, Cohen's d=0.38). With this result in hand, we looked more deeply at the students in each condition based on goal preference (Speed versus Mastery). We conducted a two-factor ANOVA to examine this possible interaction with respect to the outcome of posttest score. The main effect of Condition shows that students in the *Randomly-Matched* condition performed significantly better than students in the *Goal-Matched* condition (F(1, 250)=11.89, p=0.001, *partial eta*=0.045). The main effect of Goal reveals that students with the Speed goal achieved significantly higher posttest scores than students with the Mastery goal (F(1, 250)=4.73, p=0.03, *partial eta*=.019). The two-factor interaction term of Condition*Goal was not significant (F(1, 250)=2.33, p=0.19, *partial eta*=0.009).

After examining the posttest scores, we compared students' satisfaction level as measured by a post-survey item asking whether they would want to work with the same partner again. Once again using Condition and Goal as factors, we conducted a two-way ANOVA for satisfaction, which showed no main effect of Condition (F(1,250)=0.863, p=0.35, *partial eta* = .003) and no main effect of Goal (F(1,250)=1.886, p=1.171, partial eta = 0.007). However, the model revealed a two-way interaction of Condition and Goal (F(1,250)=8.368, p=0.004, *partial eta* = 0.032). Students with the Mastery goal indicated significantly greater satisfaction in the *Goal-Matched* condition than in the *Randomly-Matched* condition.

Overwhelmingly, students report willingness to work with the same partner again. This bias toward positivity is common among peers, and it means that a response of "No" is particularly noteworthy. Students with a Mastery goal gave more negative ratings in the *Randomly-Matched* condition (15.28% negative) than the *Goal-Matched* condition (4.35% negative).

Conclusion

Collaborative learning is increasingly essential for today's complex problem solving. However, the success of collaborative learning depends on many factors. The goal of the study reported here has been to examine whether matching students by their goal—speed versus mastery—for a particular learning activity was beneficial to their learning and satisfaction. The results show that simply matching students based on goal regardless of other factors may not be a beneficial approach. Overall, students in the Goal-Matched condition achieved lower on a posttest and did not see any difference in satisfaction with their partner compared to students in the *Randomly Matched* condition. However, when we look specifically at students who held the goal of mastering the material during that activity, the results tell a different story. These students did not show lower posttest scores in the Goal-Matched condition, and they reported significantly higher satisfaction with their partner when they were matched based on goal than when they were matched randomly. Since we know that satisfaction in each learning episode can accumulate to have a broader impact, this consideration is a substantial one. Future work should consider this question even more deeply. As we advance our understanding of factors that foster successful collaboration, we can develop adaptive techniques that empower students to reach their learning goals more effectively.

References

Barron, B. (2003). When Smart Groups Fail. *Journal of the Learning Sciences*, *12*(3), 307–359.

Engle, R. A., Langer-Osuna, J. M., & McKinney de Royston, M. (2014). Toward a model of influence in persuasive discussions: Negotiating quality, authority, privilege, and access within a student-led argument. Journal of the Learning Sciences, 23(2), 245-268.

Lewis, C. M., & Shah, N. (2015). How Equity and Inequity Can Emerge in Pair Programming. In *Proceedings of the eleventh annual International Conference on International Computing Education Research - ICER '15* (pp. 41–50). New York, New York, USA: ACM Press.

Lin, L. (2015). Exploring Collaborative Learning: Theoretical and Conceptual Perspectives. In *Investigating Chinese HE EFL Classrooms* (pp. 11–28). Berlin, Heidelberg: Springer Berlin Heidelberg.

Weinberger, A., Stegmann, K., & Fischer, F. (2010). Learning to argue online: Scripted groups surpass individuals (unscripted groups do not). *Computers in Human Behavior*, *26*(4), 506–515.

Acknowledgements

Biohacking Food: A Case Study of Science Inquiry and Design Reflections About a Synthetic Biology High School Workshop

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Abstract: In synthetic biology scientists genetically modify—or biohack—cells in order to repurpose their function or products. While synthetic biology is gaining societal relevance, few opportunities exist for K-12 students to have actual biodesign or biohacking experiences. We developed and implemented a workshop in which high school students genetically modified and repurposed yeast to produce and deliver vitamin A. Analyzing workshop observations and interviews of focus groups, we addressed the following research questions: (1) How did biodesign activities reflect science practices as characterized in national science standards? and (2) What did students have to say about their experiences with bio-design activities? We also discuss what we learned about facilitating and improving biodesign in K-12 classrooms.

Introduction

The last decade has seen growth in synthetic biology, where organisms are genetically modified for growth into real-world applications (e.g., Cheng & Lu, 2012). This technology has made it possible to develop numerous products like: : Vanillin™, a synthetic alternative to vanilla grown using yeast by Evolva and Biosteel™, a fully biodegradable high-performance fiber used in Adidas sneakers. Given that synthetic biology has moved out of research labs and into our day-to-day lives, there is an urgent need to introduce the field and its associated issues into K-12 education (NRC 201). Most existing research in K-12 life science education has concentrated on students' understanding of and attitudes toward biotechnology (Dawson, 2007). However, hands-on experiences with synthetic biology are lacking in these K-12 settings, even though they are widely available in community biolabs and universities laboratories (Loparev et al., 2016). In this study, we designed and implemented a synthetic biology-based workshop called BioCakes. We identified which science practices (as described in Next Generation Science Standards, or NGSS, 2012) were realized (or not) in order to explore synthetic biology's potential for learning in contemporary science curriculum frameworks and also investigated students reflections on their experiences. The goal of our research is to develop a better understanding of how design in biology may contribute to science inquiry (and vice versa).

Context and methods

Our BioCakes workshop took place at a science center in a northeastern U.S. city, with nine students from a partnering high school (6 White, 2 Asian, 1 Black; 5 Females, 3 Males, and 1 They). The workshop spanned seven two-hour sessions and activities were divided into three phases: fabrication, application, and imagination. The fabrication and application phase involved wet lab procedures needed to genetically modify yeast cells to produce vitamin A and bake an enriched cake. Teams of 2-3 students used a prototype of the biomakerlab, a low cost and portable wetlab machine (Kafai et al., 2017). The imagination phase involved developing an hypothetical application of synthetic biology in a real-world context and required research on existing methods for delivering a medicine, vaccine or vitamin. Students were then asked to create a 2-4 minute video 'pitch' of their idea.

We examined video data from two case study groups and two debriefing focus groups. We developed codes based on the existing NGSS framework applied by two coders in order to establish 100% consensus. Codes were applied only in instances when science practice behaviors were unprompted. In the focus groups, we asked students about their perspectives and experiences of synthetic biology,struggles during the workshop, and processes they used to develop their final pitches. We analyzed transcriptions of student responses for instances when there was consensus around particular ideas (i.e., perspectives about participating in this BioCakes workshop).

Findings

We identified four of eight NGSS practices at work during through the workshop including: (1) asking questions and defining problems (41%); (2) analyzing and interpreting data (18%) and (3) engaging in arguments from evidence (18%); and (4) obtaining, evaluating and communicating information (23%). Here, we describe one example of engaging in argument from evidence practice because, by nature, it requires engagement with the other three practices. When developing their video pitches, students Mel engaged in a discussion about whether a

synthetic-biology based vaccine could be delivered through skin pores using a facial mask. Another participant, Daniel, critiqued Mel's idea using his prior scientific knowledge as he asserted:

> Daniel: The reason that a shot works so well is that it's injecting right into your bloodstream.
>
> Mel: You're literally trying to replace a vaccination with a vaccination.
>
> Daniel: No no, I'm not trying to. I'm just saying that's why the vaccination works. The problem with the pores, it's a good idea, but the problem with the pores is that the pores don't lead into the bloodstream. So it would be harder...for that vaccination to get around the body as quickly.

By comparing a facial mask to a shot, students demonstrated how they could evaluate competing design solutions based on existing knowledge and limitations (NRC, 2012). Iteration of design ideas therefore emerged as students constructed explanations for rationales when developing their imaginary synthetic biology-based delivery systems.

Focus group responses provided insights into student experiences. They described their efforts coming up with iterations of their imaginative designs. Jesse explained his reaction to being assigned the vitamin deficiency as the issue to address with an imagined genetically-modified organism (GMO): "I thought that the [assignment] would limit the possibilities for us but [we] came up with a lot of ideas I feel." In fact, members of Jesse's group went through four iterations before finally deciding on using a yogurt to deliver vaccines, which was completely different than their original focus (i.e., vitamins delivered by lozenges). While the procedural hands-on portion of the activity did not yield opportunity to iterate upon ideas, students' responses illustrated how the imagination activity not only supported personal expression but also iteration and revision—hallmarks of making and inquiry-driven learning.

Discussion

Our project took a first stab at illustrating what biodesign activities could look like in a class-like K-12 STEM setting and how students engaged with various science practices in the process. While students do engage with some of the science and engineering practices articulated in the NGSS science standards when participating in biodesign, they were also many other practices that we did not see in our analysis of workshop interactions. The success of the imagination activity was an unexpected outcome, since this was where we observed many science practices. Future research should consider how biodesign activities could enhance student design competencies, which have been shown to be an instrumental part of learning and making.

References

Cheng A. A. & Lu, T. K. (2012). Synthetic Biology: An Emerging Engineering Discipline. *Annual Review of Biomedical Engineering, 16*(14), 158-178.

Dawson, V. (2007). An Exploration of High School (12–17 Year Old) Students' Understandings of, and Attitudes Towards Biotechnology Processes. *Research in Science Education, 37*(1), 59-73.

Kafai, Y., Telhan, O., Hogan, K., Lui, D., Anderson, E., Walker, J. T., & Hanna, S. (2017, June). Growing Designs with biomakerlab in High School Classrooms. In Proceedings of the 2017 Conference on Interaction Design and Children (pp. 503-508). New York, NY: ACM.

Loparev, A., Westendorf, L., Flemings, M., Cho, J., Littrell, R., Scholze, A., & Shaer, O. (2017). BacPack: Exploring the Role of Tangibles in a Museum Exhibit for Bio-Design. In Proceedings of the Eleventh International Conference on Tangible, Embedded, and Embodied Interaction TEI'17 (pp. 111-120). Yokohama, Japan.

National Research Council. (2012). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas.* Washington, DC: The National Academies Press.

Palmer, M., Kuldell, N., & Sittenfeld, D. (2016, May). Building with Biology. *O'Reilly BioCoder, 41.* Retrieved from: https://www.oreilly.com/ideas/building-with-biology

Acknowledgments

How Groups Regulate Their Learning: The Influence of Achievement Goals on Self-, Co- And Shared Regulation Strategies

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Abstract: Study groups need to regulate learning on three levels: the self-, the co- and the socially shared level. We investigated how students' achievement goals are associated with regulation processes within groups. $N = 277$ students were asked to imagine being part of a group with low prior knowledge and low study motivation and to name regulation strategies they would apply. Results indicated that mastery and performance-approach goals played a positive role in predicting regulatory effort.

Keywords: collaborative learning, self-regulated learning, achievement goals, socially shared regulation

Introduction

At university, students often deliberately choose to study in groups, especially when it comes to exam preparation. When they do so, problems like differences in personal priorities, styles of working and communication often arise (Järvenoja, Volet, & Järvelä, 2013). Thus, failure of collaborative learning can at least partially be attributed to a group's inability to regulate its learning process. Järvelä and Hadwin (2013) suggest that to make collaborative learning a successful endeavour, learners need to engage in regulation processes at three social levels: self, co, and socially shared. First, learners can self-regulate for the sake of their own learning success and apply strategies to regulate their own learning (such as monitoring their own understanding; self-level). Second, they can guide other group members or be supported by them (co-level). Third, they can jointly develop an understanding of the topic and solve learning problems through mutual engagement, e.g. by jointly discussing ways to approach or solve the task (shared-level). Quite some research has taken up this differentiation over the past few years (Panadero & Järvelä, 2015). Yet, little is known about whether and how learners' individual achievement motivation influences regulatory processes within groups.

As a major aspect of achievement motivation, achievement goals determine how a person is motivated in academic contexts. An important distinction is the differentiation between mastery and performance goals which are further divided into approach and avoidance performance goals: Students exhibiting a mastery goal are oriented towards developing and improving skills, competence or knowledge. Learners with performance-approach goals strive to demonstrate their superior competence to others, whereas learners with performance-avoidance goals strive to avoid performance situations in order to hide their (actual or assumed) incompetence (Elliot & Harackiewicz, 1996). Prior research has demonstrated that the activation of different achievement goals correlates with a number of processes learners engage in during studying (e.g., Cellar et al., 2011). Mastery goals consistently correlate well with different indicators of self-regulation over a large number of studies, while performance-avoidance goals exhibited consistently negative connections with self-regulation and positive correlations with maladaptive regulation strategies. Performance-approach goals, however, often have no or mixed connections with self-regulation.

Research question and hypotheses

Our research question was: How do different achievement goals relate to students' engagement in regulation strategies at the three social levels proposed by Järvelä and Hadwin (2013)? We set up the following hypotheses:

(1) Mastery goals have a positive relationship with regulation engagement on all three regulation levels.

(2) Performance-approach goals stand in a relationship with regulation engagement at all three levels.

(3) Performance-avoidance goals are negatively related to regulatory effort at all three levels.

Method

N = 277 undergraduates (*M* = 21.5 years old, *SD* = 2.6) read a case vignette that described that their study group (which is preparing for an exam) is exhibiting both knowledge and motivation problems towards dealing with the subject matter. The vignette was followed by three open-answer questions on what the participants would do (sample question: "Do you personally do anything in this situation to ensure a high quality of your own learning?"). Each of the three questions focused on one of the three levels of regulation: self ("your own learning"), co ("learning of individual others") and socially shared ("learning of the group as a whole"). Trained coders categorized the reported strategies (Cohen's κ = .70) which then were counted as dependent variable. To measure academic achievement goals, the Scales for the Assessment of Learning and Performance Motivation (SELLMO; (Spinath, Stiensmeier-Pelster, Schöne, & Dickhäuser, 2012) were used ($\alpha \geq .84$).

Results

We used structural equation modelling to test our hypotheses (see Fig. 1). (1) Mastery goals positively predicted regulation on all three levels as hypothesized. (2) Performance-approach goals predicted regulation on two of three levels (self- and shared-level) as expected, whereas (3) performance-avoidance goals did not predict regulation at all, contrary to our expectations.
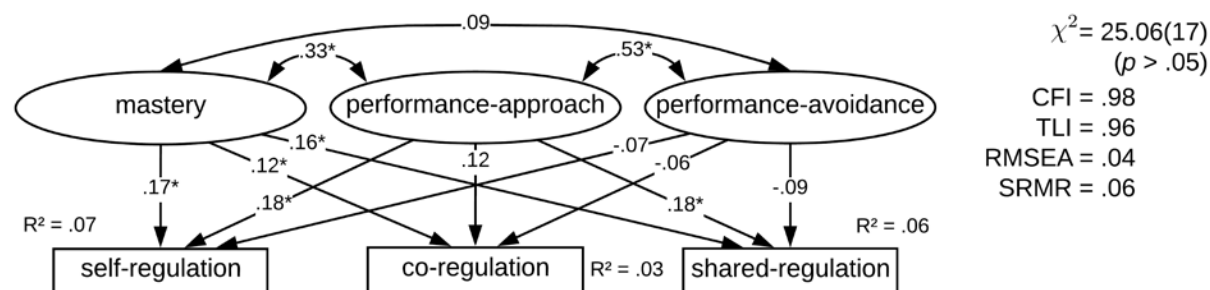
Figure 1. Achievement goals predicting regulation on self-, co- and socially shared level.

Discussion

As supposed, achievement goals were associated with students' reports of regulation activities while collaboratively preparing for an exam. Learners with mastery goals seem to be especially interested in the regulation of challenges that appear in their study groups which mirrors the pattern established by literature for individual regulation (e.g., Cellar et al., 2011). Performance-approach goals also predicted regulation on most regulatory levels positively. We suppose that a study group is a context very suitable to demonstrate ability. Thus, the effect on regulation might be more positive in study groups than the literature on individual regulation (e.g., Cellar et al., 2011) predicted. The missing (negative) effect of performance-avoidance goals could be explained as follows: Maybe, group members do not arouse fear of a deficit in competence being revealed because they are well-known and of equal status. Yet, these findings might be, at least in part, due to the specific context of (a) studying for an upcoming exam and (b) of the presence of low motivation to learn and low prior knowledge. Even though the study certainly has limitations (e.g., the lack of data from real group processes), our results emphasize the importance of achievement goals for regulation processes within groups.

References

Cellar, D. F., Stuhlmacher, A. F., Young, S. K., Fisher, D. M., Adair, C. K., Haynes, S., … Riester, D. (2011). Trait Goal Orientation, Self-Regulation, and Performance: A Meta-Analysis. *Journal of Business and Psychology*, *26*(4), 467–483. https://doi.org/10.1007/s10869-010-9201-6

Elliot, A. J., & Harackiewicz, J. M. (1996). Approach and avoidance achievement goals and intrinsic motivation: A mediational analysis. *Journal of Personality and Social Psychology*, *70*(3), 461–475.

Järvelä, S., & Hadwin, A. F. (2013). New Frontiers: Regulating Learning in CSCL. *Educational Psychologist*, *48*(1), 25–39. https://doi.org/10.1080/00461520.2012.748006

Järvenoja, H., Volet, S., & Järvelä, S. (2013). Regulation of emotions in socially challenging learning situations: an instrument to measure the adaptive and social nature of the regulation process. *Educational Psychology*, *33*(1), 31–58. https://doi.org/10.1080/01443410.2012.742334

Panadero, E., & Järvelä, S. (2015). Socially Shared Regulation of Learning: A Review. *European Psychologist*, *20*(3), 190–203. https://doi.org/10.1027/1016-9040/a000226

"Things Are Made to Fail": Constructive Failures in a Middle School Robotics Curriculum

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Abstract: Framing failure as constructive can help students engage in design practices. This case study examines the role of failure in a middle school human-centered robotics curriculum. *Constructive failures* are scaffolded failures that build a base for solving engineering design problems. This research explores constructive failure as an asset for learning through iterative design and considers the role of the facilitator in providing space for and supporting constructive failure experiences.

Keywords: STEM learning, human-centered robotics, problem-based learning

Twenty-first century collaborative problem-solving skills, which include negotiating ideas, organizing the problem-solving process, and maintaining communication, are essential in the everyday work of engineering (Dym et al., 2005). Here, we explore how framing failure as constructive within an engineering design unit supported the development of these skills. This work builds on conceptualizations of productive failure and productive success (Kapur, 2016), providing examples of one instructor's framing and scaffolding of failure to further theorize about the role of failure experiences in problem-based learning.

Constructive failures are those in which students experienced frustration and uncertainty, received support as they worked through this frustration, and were able to move forward in a collaborative design process. These supports enabled productive success, the achievement of viable solutions to complex problems (Kapur, 2016). Constructive failure is a scaffolded dimension of productive success, supporting student efforts by framing iterative trial and error as necessary. Supporting failures *throughout* a learning experience can help students by encouraging them to articulate their challenges and providing opportunities for learning in problem-based activity (Blumenfeld et al., 1991).

This research presents a problem-based human-centered robotics (HCR) unit as a context to spark learners' interest in STEM by connecting to the social aspect of engineering design (Hamner et al., 2008). HCR centers on the design of robots that serve human needs (Schaal, 2007). This work explores how students solving an HCR problem engaged in collaborative design through the positioning and negotiation of failure experiences as they worked collaboratively to design a robot that served a need in their local environment. The curriculum engages students in engineering design cycles that involve asking questions, brainstorming solutions, collecting information, developing and testing solutions, and improving designs (Resnick, 2007). In earlier iterations of this unit, learners struggled to harness their frustration and move forward (Gomoll et al., 2016). The unit was iteratively refined to provide opportunities to navigate inevitable failures with facilitator support. We consider failures during the problem-solving process as a positive norm for learning through design (Kolodner et al., 2003).

This case study examines how framing failure supported students' work imagining, designing, and building robots to be used in their classroom. We conjecture that by re-positioning failure as a norm, students were able to publicly test their designs and learn from their mistakes—leveraging failure as constructive.

Methods

Participants included sixteen students (ages 12-14) taking an Applied Science class in a rural U.S. public middle school. The HCR unit took place over approximately 25 class sessions with 35-50 minute sessions daily. All written artifacts were collected, each group was audio recorded, and video footage capturing the full class and several student groups was collected each day.

To understand the role of failure, we focused on two groups that navigated failures that went beyond social dynamics and progressed furthest with their designs despite early frustration. Group 1 was composed of one eighth grade female, one eighth grade male, and two seventh grade males. Group 2 was composed of two eighth grade males, one eighth grade female, and one seventh grade female. The activity of both groups was traced using Jordan and Henderson's (1995) guidelines for interaction analysis. Across collaborative data analysis sessions, definitions of failure were refined, and themes related to the role of failure were highlighted.

Results and discussion

Across four episodes, we show how the instructor introduced and scaffolded failure as a constructive learning opportunity. Her consistent framing of failure as a norm helped students to feel supported as they failed early and often, leveraging failure as constructive in the learning process. In studying the groups' failures and how they moved forward, we better understand how failure within a PBL cycle and design experience can provide an authentic context to help learners orient to failure as a norm in collaborative engineering design. Throughout these episodes, iterative failure contributed to groups' successes as is typical in engineering design.

In our first episode, we highlight the instructor's use of metacognitive modeling early in the unit to demonstrate how students could talk themselves through inevitable challenges. Within this episode, the instructor legitimized emotional reactions to failure and presented failure as a norm in the design process. This framing helped students to become aware of and manage failure in situ. Our second episode highlights early frustration experienced by a student group as they engaged in an embodied programming experience. Here, students struggled to agree on a set of directions and did not reach a consensus. The instructor recognized this challenge and asked students why they were frustrated—validating their emotional response and helping them to move forward. At this point, the instructor noted that in the process of design, it is not expected that students can (or should) get things right the first time. This support helped the group to own and articulate future instances of constructive failure. In episode three, this same group discussed their prototype. One student stated: "It's a prototype, things are made to fail." This response appropriated the teacher's guidance on the role of failure in design. The student who made this statement used failure constructively to move his group forward and to carry out initial phases of user testing. Finally, episode four centers on a second group engaged in troubleshooting as they tested code they had written for their robot. Recognizing that the robot's wheels weren't calibrated correctly, the group used trial and error to see what programmed instruction would result in the 90-degree angle they needed to move their robot to a specific location. As the group bounced between numbers, they displayed their ability to negotiate disagreements and come to a consensus. This group demonstrated agency as they leveraged a failure experience. They did not ask for help immediately, and they embraced an iterative design cycle.

Throughout these episodes, failure functioned as a formative assessment by allowing students to test their design ideas and receive feedback—ultimately leading to productive success. For many students, particularly those who have been trained to avoid failure, early failure without support may trigger disengagement. As 21st century STEM careers require practitioners to solve problems collaboratively, manage uncertainty, and engage in design thinking, we argue that curricula and facilitation that explicitly incorporate failure experiences will better prepare students for future STEM engagement and careers. This work is a starting point for future research that explores the cultivation of collaborative problem solving and design thinking skills through formative experiences of failure.

References

Blumenfeld, P. C., Soloway, E., Marx, R. W., Krajcik, J. S., Guzdial, M., & Palincsar, A. (1991). Motivating project-based learning: Sustaining the doing, supporting the learning. *Educational Psychologist*, *26*(3-4), 369-398.

Dym, C. L., Agogino, A. M., Eris, O., Frey, D. D., & Leifer, L. J. (2005). Engineering design thinking, teaching, and learning. *Journal of Engineering Education*, *94*(1), 103-120.

Gomoll, A., Hmelo-Silver, C. E., S, Šabanović, S., & Francisco, M. (2016). Dragons, ladybugs, and softballs: Girls' STEM engagement with human-centered robotics. *Journal of Science Education and Technology, 25*(6), 899-914.

Hamner, E., Lauwers, T., Bernstein, D., Nourbakhsh, I. R., & DiSalvo, C. F. (2008, March). Robot Diaries: Broadening Participation in the Computer Science Pipeline through Social Technical Exploration. In *AAAI spring symposium: using AI to motivate greater participation in computer science* (pp. 38-43).

Jordan, B., & Henderson, A. (1995). Interaction analysis: Foundations and practice. *Journal of the Learning Sciences*, *4*(1), 39–103.

Kapur, M. (2016). Examining productive failure, productive success, unproductive failure, and unproductive success in learning. *Educational Psychologist*, *51*(2), 289–299.

Kolodner, J. L., Camp, P. J., Crismond, D., Fasse, B., Gray, J., Holbrook, J., ... & Ryan, M. (2003). Problem-based learning meets case-based reasoning in the middle-school science classroom: Putting learning by design (tm) into practice. *The Journal of the Learning Sciences*, *12*(4), 495-547.

Resnick, M. (2007, June). All I really need to know (about creative thinking) I learned (by studying how children learn) in kindergarten. In *Proceedings of the 6th ACM SIGCHI conference on Creativity & cognition* (pp. 1-6). ACM.

Schaal, S. (2007). The new robotics—towards human-centered machines. *HFSP journal*, *1*(2), 115-126.

Using a Video-Based Approach to Develop Pre-Service Science Teachers' Understanding of How to Teach the Nature of Science

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Abstract: This study examined if and how the dialogic discourse triggered by viewing multiple authentic classroom video footage arranged in themes enhanced pre-service science teachers' (PSTs') PSTs' understanding of the explicit-reflective approach. The findings suggest that the PSTs made use of several sense-making strategies to interpret the various classroom enactments of the explicit-reflective approach captured in the video clips. This in turn led to new ideas and understandings of how the explicit-reflective approach could be best implemented in actual classrooms.

Introduction

Enhancing students' conceptions of the nature of science (NOS), their cognitive understandings of the enterprise of science and the nature of scientific knowledge, has been regarded as essential to their scientific literacy. Arguably, efforts to promote contemporary views of NOS among learners are largely unproductive unless teachers' understanding of how to provide quality NOS instruction is first enhanced. Despite this, fewer studies have described how to effectively enhance PSTs' understanding of the specific pedagogy for teaching. Among the small but growing number of studies, few have used authentic classroom videos to enhance PST learning. Hence, few details have been available in the literature on how videos can be used to enhance PSTs' understanding of NOS-specific pedagogy in teacher education activities. This study aims to fill this gap by exploring the use of a video-based approach to improve PSTs' understanding of the instructional approach most germane to effective NOS instruction, that is, the explicit-reflective approach (Akerson, Abd-El-Khalick & Lederman, 2000). We engaged the PSTs in dialogic discussions of multiple authentic classroom video clips arranged in a series by themes (e.g., concluding a lesson on NOS). Our research question is: In what ways does dialogic discussion triggered by exposure to multiple authentic classroom video clips provide opportunities for PSTs to discuss different ways of using the explicit-reflective approach in NOS instruction?

Methods

Context of the study

Ten science PSTs seeking certification to teach high school science voluntarily participated. They attended two three-hour teaching sessions on teaching NOS conducted by the teacher-researcher (the first author).

Pedagogical design

Watching multiple authentic classroom videos in a series: The PSTs watched authentic classroom video footage selected and edited from the video archive of a prior local professional development. Short video clips (<5 minutes) were organised for presentation by sorting them into themes (e.g., introducing students to NOS, concluding a lesson on NOS). These short video clips were presented successively with a brief pause in between.

Dialogic discourse: After watching a series of teaching videos, open-ended prompts (i.e., (1) What did you notice in the videos?) were used to elicit the PSTs' opinions of them. The students' views and collective consensus were made visible on a large whiteboard.

Methods

Multiple data sources include (1) videos of the two lessons (three hours each) and (2) exit reflections of the PSTs. We identified the turns in which the PSTs commented on more than one video in the lesson transcripts. Codes were developed to characterize the strategies the PSTs used to make sense of the video clips using the constant comparison method. The transcripts were then searched for instances in which the PSTs discussed different ways of implementing the explicit-reflective approach and codes was developed to characterize their understanding through inductive analysis of the transcripts and the exit reflections.

Findings and discussion

Below is one illustrative example of the video-mediated dialogic discussion.

1	Teacher:	Anything you noticed? And you want to share with us? (Wait 3s) Yes, Kathy.
2	Kathy:	I think Teacher A [*Video A*], Ms Chow [who used] only 1 sentence [to describe the goal of the lesson] is too simple. It is too abstract for students to get a quick concept of what science is. But for, I think evolution, Mr Tam [i.e., *Video B*], he tries to compare the two sentences to tell what science is and it is more practical. …
3	Teacher:	It seems that you don't agree with Fred's idea. Fred mentioned that it is good to simplify the key term, but then you think, probably, it is not that desirable to simplify too much … What is the purpose of investigating or exploring the two cases [in *Video B*]?
4	Tom:	He pointed out there're two aspects of NOS. He wanted them [the students] to know which is theory, the nature of theory and law. And then the other case was how we can generate scientific knowledge without doing experiments.
5	Teacher:	Yes, Carrie.
6	Carrie:	I like *Video B* [i.e., Mr Tam's video] and *[Video] E* because what the point is talking about with NOS is related to the content of the lesson. But, for *[Videos] A*, *C* and *D*, it seems like the lesson is just on NOS, but because NOS is supposed to be taught for every topic, so I don't agree that they should just start the lesson like, this is a lesson about NOS
7	Teacher:	Any more that you want to share with us? Any more that you noticed?
8	Tom:	Ms Tam [in *Video E*] was, I think, the only one who started with an example and then ask students to infer the NOS from the example of the food pyramid. So… so that it's kind of opposite to what Mr Tam [in *Video B*] did, which is to list out the aspects of NOS. But then, in *[Video] E*, Ms Tam asked… so the students arrived at the conclusion themselves.

In Turn 1, one of the PSTs, Kay, compared and contrasted two videos within the series of videos and identified two different ways of introducing the lesson goals in an NOS-focused lesson. The teacher-researcher co-ordinated the discussion by contrasting the ideas without imposing any judgement (Turn 6). He then prompted the PSTs to consider the rationales underpinning the teacher's actions in *Video B* (Turn 3). This question led the PSTs to realize the connection between the lesson's activities (i.e., examining historical cases related to evolution) and targeted aspects of NOS (i.e., scientific theory and laws, empirical NOS) as evident in Tom's utterance (Turn 4). This discussion of integrating the teaching of science content with aspects of NOS further motivated Carrie to *spontaneously* express a new idea (Turn 6). Carrie *categorized* the five videos into two different groups (i.e., situated NOS instruction and VS non-situated NOS instruction). After highlighting the differences between the two groups of videos by Carrie (Turn 6), Tom further expressed his views on one of the groups. The strategies used to interpret the videos included identifying *Video E* as an "*odd man*" (Turn 8) evidenced by Tom saying that the teacher in *Video E* "*was the only one*" adopting a certain approach to teaching. He then went on to *contrast* this video with *Video B* from the video group previously identified by Carrie. From there, he brought up a new idea, that there were at least two different approaches (i.e., inductive and deductive) to embedding NOS into science content teaching. This opened up further discussion on how best to conduct an NOS lesson in which the teacher overtly makes the aspects of NOS visible to the learners.

Conclusion and implications

The data suggest that exposing PSTs to thematically-arranged video footage can potentially deepen their examinations and interpretations of the explicit-reflective approach. We also illuminated several sense-making strategies the PSTs used to interpret videos viewed in a thematic manner (e.g., comparing videos, categorising videos, odd man), thereby contributing to the literature on the use of video in teacher education.

References

Akerson, V. L., Abd-El-Khalick, F., & Lederman, N. G. (2000). Influence of a reflective explicit activity-based approach on elementary teachers' conceptions of nature of science. *Journal of Research in Science Teaching*, *37*(4), 295-317.

Videocase Complexity and Preservice Teacher Noticing: Examining the Effects of Cognitive Load

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Abstract: Despite the growing research base on preservice teacher noticing of children's mathematical thinking with video, few studies consider the complex nature of the video representations. Borrowing from cognitive load theory, we coded the complexity of the salient teaching and learning events captured in video and analyzed the relationship between video complexity and PST noticing. Results indicate that videos with higher intrinsic load increase opportunities for noticing, and videos with higher extraneous load negatively affect noticing.

Over the past decade, the use of video to support teacher learning has grown considerably in the field of teacher education (Brophy, 2008). Researchers utilized the construct of *teacher noticing* to understand what and how teachers learn from video (cf. Sherin, Jacobs, & Philipp, 2011). Research on preservice teachers' (PST) noticing in video has demonstrated positive impacts on PSTs' ability to attend to and interpret children's mathematical thinking (CMT). As learning from representations of teaching is dependent on the nature of the representations, we shift the focus of research on PST noticing from what PSTs notice in video to how video representation complexity impacts PST noticing. We focus on the following research question: (1) How does complexity of a video representation impact PSTs' attending to and interpreting of CMT?

Framing

Following Jacobs and her colleagues, we operationalize PST noticing as attending to and interpreting CMT. Our prior research suggested that the use of videocases to support PSTs' ability to notice CMT, in particular, seemed ineffective, particularly as not all video representations are created equal, which has considerable implications for PST noticing in video. Incorporating video clips that are more or less complex in terms of the nature of the teaching and learning events portrayed is particularly important for novices who often struggle to pay attention to CMT in video (Jacobs et al., 2010). Video is a type of representation of complex teaching and learning practices, which highlights the salient events and at the same time masks other events related to the represented events. We define this simultaneous highlighting and masking as video *complexity*.

Borrowing from cognitive load theory, we developed a rubric for analyzing the complexity of the salient teaching and learning events captured in video clips. Cognitive load theory distinguishes between three types of load: intrinsic load, extraneous load, and germane load (Sweller, 2003). Drawing on cognitive load research (Sweller, 2003) and teacher noticing research (Jacobs et al., 2010), we coded *complexity* under two dimensions. The intrinsic load dimension included Depth of Enacted Task, Clarity of Student Thinking, Teacher Participation, Sequential Moments of CMT, Simultaneous Moments of CMT, and Types of CMT. The extraneous load dimension Non-CMT Moments and Visual-Verbal Noise.

Analysis

Two coders followed a 2-stage coding scheme. The first stage assessed whether a PST's response described what the children were doing or saying about mathematics. The second stage of coding explored the degree of evidence (i.e., none, limited, robust) for attending to and interpreting CMT in the PST's response. Two coders were assigned to each videocase, and there was greater than 90% reliability in both rounds of coding. Then, using the video complexity rubric, two coders scored each videocase as low or high on the load-noticing categories and reconciled discrepancies. Seven total videos were scored, ultimately reaching 100% agreement. Data for this analysis comes from 233 PSTs over two semesters of required math courses from an elementary teacher education program at an urban university in a large, Midwestern city in the United States. PSTs were assigned to view videocases for homework during a semester. The data presented unique constraints for the analysis, and so we utilized generalized estimating equations (GEE) for the analysis as it allows for repeated measures analysis (Zeger & Liang, 1986), a working, autoregressive correlation matrix that adjusts for within-observation correlations (Fitzmaurice, Laird, & Rotnitzky, 1993), and an ordinal outcome variable with missing data (Kenward, Lesaffre, & Molenberghs, 1994).

Results and discussion

SPSS was used for the analysis with level of noticing as the outcome variable and cognitive load criteria as the independent factors. Scaffold level and videocase ID were used as within-subject variables. Two redundant covariate, Sequential Moments and Visual-Verbal Noise, and two non-significant variables, Clarity of Student Thinking and Types of Moments, were removed for the second model with results in Table 4. Four cognitive load criteria from our rubric significantly predict the population of PSTs level of attending: Depth of Enacted Task, Teacher Participation, Simultaneous Moments of CMT, and Non-Moments of CMT.

Table 4: Parameter estimates, standard errors (SE), Wald statistics (χ^2,degrees of freedom), corresponding significance probabilities (p), and log odds ratio from the analyses

Parameter	Model 1					Model 2				
	Est.	SE	Chi Square (df)	p	Exp(B)	Est.	SE	Chi Square (df)	p	Exp(B)
Depth of Enacted Task	0.268	0.171	2.463 (1)	0.117	1.307	0.322	0.122	6.977 (1)	0.008	1.308
Clarity of Student Thinking	0.060	0.153	0.155 (1)	0.694	1.062					
Teacher Participation	0.600	0.168	12.715 (1)	0.000	1.821	0.614	0.106	33.254 (1)	0.000	1.847
Sequential Moments of CMT	-	-	-	-	-					
Simultaneous Moments of CMT	0.147	0.104	1.997 (1)	0.158	1.158	0.156	0.073	4.496 (1)	0.034	1.168
Types of CMT in Videocase	-0.078	0.101	0.608 (1)	0.435	0.925					
Non-CMT Moments	-0.518	0.121	18.317 (1)	0.000	0.596	-0.527	0.080	43.339 (1)	0.000	0.591
Visual-Verbal Noise	-	-	-	-	-					

Depth of enacted task, significantly impacts PSTs' level of attending ($\beta_1 = .322$, $\chi^2 = 6.977$, $df = 1$, $p = .008$). This outcome suggests a videocase with a high depth of enacted task resulted in a higher percentage of PST responses that attended to CMT *and* discussed the strategy being implemented by the child(ren). In other words, a PST can attend to CMT with some degree of recognition of strategies if more opportunities are presented to the PST. The intrinsic cognitive load criteria, teacher participation, significantly impacts PSTs' level of attending ($\beta_3 = .614$, $\chi^2 = 33.254$, df = 1, p = .000). This outcome suggests the presence of a teacher in a videocase who asks questions to elicit CMT lowers the level of attending by the population of PSTs. In other words, PSTs seem to attend to CMT and attend with more interpretation when a teacher is not asking children questions to elicit thinking. The intrinsic cognitive load criteria, simultaneous moments of CMT, significantly impacts PSTs' level of attending ($\beta_5 = .156$, $\chi^2 = 4.496$, $df = 1$, $p = .034$). This outcome suggests, aligning with the findings of the depth of enacted task dimension, the population of PSTs can attend to CMT at a higher level if more opportunities for attending to CMT are present, even when simultaneously presented in a videocase. The intrinsic cognitive load criteria, non-moments of CMT, significantly impacts PSTs' level of attending ($\beta_7 = -.527$, $\chi^2 = 43.339$, $df = 1$, $p = .000$). This finding suggests non-moments of CMT in videocases present additional, extraneous cognitive load on the population of PSTs and reduces the level of attending to CMT by the population of PSTs.

In addition, two of our hypothetical cognitive load criteria, clarity of student thinking and type of CMT, did not significantly impact the population of PSTs' noticing of CMT as hypothesized. While no conclusions can be drawn, this suggests further research is necessary, particularly on the relevance of clarity of student thinking due to its prevalence in noticing research. In sum, as research on PST noticing continues to evolve, researchers should consider the nature of the video representations used in their work, and the relationship between what PSTs are attending to and how they are interpreting the captured events.

References

Brophy, J. (2008). *Using video in teacher education*. New York, NY: Emerald Group Publishing.
Fitzmaurice, G. M., Laird, N. M., & Rotnitzky, A. G. (1993). Regression models for discrete longitudinal responses. *Statistical Science*, 8(3), 284-309.
Jacobs, V. R., Lamb, L. L. C., & Philipp, R. A. (2010). Professional noticing of children's mathematical thinking. *Journal for Research in Mathematics Education, 41*(2), 169-202.
Kenward, M. G., Lesaffre, E., & Molenberghs, G. (1994). An Application of maximum likelihood and generalized estimating equations to the analysis of ordinal data from a longitudinal study with cases missing at random. *Biometrics*, *50(4)*, 945-953.
Sweller, J. (2003). Evolution of human cognitive architecture. In B. H. Hoss (Ed.), *The psychology of learning and motivation: Advances in research and theory* (pp. 216-266). San Diego, CA: Academic Press.
Zeger, S. L., & Liang, K. (1986). Longitudinal data analysis for discrete and continuous outcomes. *Biometrics*, 42(1), 121-130.

Effects of Expertise on Teachers' Technology-Supported Teaching Scripts

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Abstract: Technology can promote learning if teachers know how to effectively integrate it in the classroom. This might depend on teachers' expertise. Therefore, we investigated how teachers at four different expertise levels plan their technology-supported lessons. Results indicate only small expertise effects. The potentials of technology are neither fully used by teachers at lower nor by teachers at higher levels of expertise.

Keywords: technology-supported teaching, scripts, learning activities, technology, expertise.

Problem statement

To promote learning in schools, a lot of potentials are attributed to digital technology. However, in order to exploit these potentials in the classroom, it is necessary to clarify what good technology-supported teaching actually means. Results from research that focuses on how novice and expert teachers differ in their teaching indicate that lesson plans of more proficient teachers provide more actual learning opportunities for their students than those of less proficient teachers (e.g., Borko, Livingston & Shavelson, 1990). Even though these findings give insights in expert teachers' planning processes, this research has mainly focused on teaching in general. Yet, little is known about the extent to which these considerations also hold true for the ways teachers intend to use digital technology in the classroom.

Technology-supported teaching scripts

To conceptualize teachers' planning processes with respect to where, when and how to embed specific kinds of technologies in the classroom, we suggest taking on a script perspective. A script is a cognitive structure that guides an individual in understanding and acting in a certain class of situations. According to Fischer, Kollar, Stegmann and Wecker (2013), scripts consist of different hierarchically structured components including Play, Scenes and Scriptlets. At the top level, the *Play* component represents knowledge about the type of situation (e.g., "technology-supported teaching in the classroom" play). Once a teacher selects this play, s/he will automatically derive expectations regarding the *Scenes* or phases of this play (e.g., first an input phase, followed by an exercise phase) as well as the kinds of activities that are to be shown in a phase. Knowledge about these activities is stored in *Scriptlets* (e.g., students watch a video). Based on these components, we assume that it is possible to differentiate more effective technology-supported teaching scripts from less effective ones with regard to their effects on student learning.

In this paper, we are particularly concerned with the activities that teachers try to promote by using digital technology (Scriptlet component). Chi and Wylie (2014) differentiate between passive (e.g. watching a video), active (e.g. pausing/forwarding a video), constructive (e.g. drawing a digital concept map) and interactive activities (e.g. writing a joint review in a collaborative text editor). They hypothesize that on average, learning gains increase from an engagement in passive over active and constructive to interactive activities.

A subsequent question is whether certain types of technology may provide more affordances to stimulate constructive and interactive learning activities than others. We suggest to heuristically differentiate between four types of technology (see Müller, Blömeke & Eichler, 2006): *Information technology* (e.g. digital presentations) is believed to mainly afford an engagement in passive activities. *Self-assessment technology* (e.g. online-quizzes) can be considered to mainly afford active and constructive activities. *Editing technology* (e.g. text editors) might particularly afford an engagement in active or constructive activities. Finally, *collaboration technology* re (e.g. etherpads) should afford an engagement in interactive activities. Results of previous meta-analyses on the effects of technologies on student achievement seem to go well along with these considerations (e.g., Castillo-Manzano, Castro-Nuño, Lopéz-Valpuesta, Sanz-Diaz & Yñiguez, 2016; Wecker, 2013).

Research questions

We asked two research questions: To what extent do teachers at different expertise levels differ with respect to (1) the *types of learning activities* they intend to promote with digital technology, and (2) the *types of technology* they intend to use in the classroom? Based on Borko et al. (1990), we assumed that teachers on

higher expertise levels would target more high-level learning activities (esp. constructive and interactive) and make more use of technologies that would easily afford an engagement in these activities (esp. self-assessment, editing, and collaboration technology) than teachers at lower expertise levels.

Method

N=110 pre-service teacher freshmen ("Novices"; $M_{semester}$=1.51, SD=0.88), N=94 advanced pre-service teachers ("Advanced Beginners"; $M_{semester}$=5.77, SD=1.73), N=25 pre-service teachers enrolled in a supplement on technology-supported teaching ("Competent in Theory"; $M_{semester}$=8.27, SD=3.49) and N=41 technology-experienced in-service teachers ("Competent in Practice"; $Median_{teaching\ experience}$=11-15) participated. They were asked to describe an ideal technology-supported lesson and requested to select from a list (1) the kind of learning activities and (2) types of technology which they had aimed at. For (1) learning activities, a self-developed list of 21 items was used to measure the intended activity intensity with regard to participants' mentioned technologies. For (2) types of technology, participants had to pick from a list of technology types (information, self-assessment, editing, collaboration) which ones they had intended to use in the classroom.

Results

With regard to (1) learning activities, we found a significant, but small effect of expertise (F(12,690.83)=2.46, p=.00, η^2=.04). Pair-wise post-hoc comparisons showed that novices aimed significantly more at passive learning activities than the Competent in Practice group (p=.01), and the Competent in Theory group aimed significantly more at interactive learning activities than Novices (p=.01) and Advanced Beginners (p=.03). Active and constructive learning activities were mentioned to a similar degree by the different expertise groups (all p>.05). With regard to (2) the types of technology, Advanced Beginners mentioned self-assessment technology significantly less often than all other expertise groups (χ^2(3, N=270)=17.8, p=.00). No significant differences were found for the other types of technology (all p>.05).

Discussion

Results indicate expertise effects with regard to passive and interactive learning activities which basically is in line with findings on teacher experts' lesson plans, even though effects are small. With regard to types of technology, teachers at higher expertise levels hardly seem to use technologies in their lesson plans that might more easily afford an engagement in higher-level activities. Differences between groups could only be observed for self-assessment technology. This might be due to a cohort effect: Advanced pre-service teachers might have not made own experiences with that rather new type of technology in comparison to the other groups. Overall, our results indicate a need to facilitate teachers' technology-supported teaching scripts, for example by scaffolding their noticing and knowledge-based reasoning processes (e.g. Seidel, Blomberg & Renkl, 2013). In conclusion, a script-based investigation of pre- and in-service teachers' planning of technology-supported lessons seems to be helpful to reveal that the potentials of technology are often not considered, neither by pre- nor by even experienced in-service teachers.

References

Borko, H., Livingston, C., & Shavelson, R. J. (1990). Teachers' thinking about instruction. *Remedial and Special Education*, *11*(6), 40-49.

Castillo-Manzano, J. I., Castro-Nuño, M., López-Valpuesta, L., Sanz-Díaz, M. T., & Yñiguez, R. (2016). Measuring the effect of ARS on academic performance: A global meta-analysis. *Computers & Education*, *96*, 109-121.

Chi, M. T., & Wylie, R. (2014). The ICAP framework: Linking cognitive engagement to active learning outcomes. *Educational Psychologist*, *49*(4), 219-243.

Fischer, F., Kollar, I., Stegmann, K., & Wecker, C. (2013). Toward a script theory of guidance in computer-supported collaborative learning. *Educational Psychologist*, *48*(1), 56-66.

Müller, C., Blömeke, S., & Eichler, E. (2006). Unterricht mit digitalen Medien – zwischen Innovation und Tradition? Eine empirische Studie zum Lehrerhandeln im Medienzusammenhang. *Zeitschrift für Erziehungswissenschaft, 9*(4), 632-650.

Seidel, T., Blomberg, G., & Renkl, A. (2013). Instructional strategies for using video in teacher education. *Teaching and Teacher Education*, *34*, 56-65.

Wecker, C. (2013, August). *Does PowerPoint foster learning? A meta-analysis*. Paper presented at the on 15th Biennial Conference for Learning and Instruction der European Association for Research on Learning and Instruction (EARLI). Munich, Germany.

Space for All: Learner Self-Construct While Learning in the Digital Age

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Abstract: While there are numerous benefits to teaching coding in schools, current practices seem too focused on the vocational aspects of computer science, with computer programming as the only route to a successful future. The danger is that this approach excludes some students who may not be drawn to coding, leaving them to think that our technological society has no place for them or their unique talents, skills, and passions. In this paper, we present our work with third and fourth graders to use an instructional design framework to involve children in a design and development project that includes coding but also other non-coding activities. We argue that the instructional design process can be a way of engaging children in our technological society in meaningful ways while still making a place for a wide variety of skills and interests.

Introduction

Numerous scholars have written on the importance of having realistic expectations towards innovations, especially when it comes to the impact on education. For example, Cuban (1986, 2009) has written on innovations that were supposed to revolutionize education but have not delivered. Mayer (2005) emphasized the need to be learner-centered and focused on helping people learn rather than simply giving access to the newest tools. In our contribution to the *rethinking learning in the digital age* dialogue, we argue for a critical examination of a new innovation, teaching coding in school, particularly in the early grades.

The focus on coding in schools is based on the premise "that by learning to think like a computer scientist, students can solve everyday problems, design systems that we all use in daily life, and progress and innovate in other disciplines" (Kafai & Burke, 2014, p. 4). Our concern is that currently, teaching coding in schools overemphasizes the vocational aspects of computer science, with computer programming as the only route to success in the digital economy. We believe that programming is not the only option in a digital age. Contrary to Rushkoff's (2010) dire warning to "program or be programmed" (pg. 8), we believe that this instrumental view excludes some students who may not be drawn to coding, leaving them to think that our technological society has no place for them or their unique talents, skills, and passions. We present our work with third and fourth graders that used an instructional design framework to involve children in a design and development project, which includes coding but also non-coding activities. We argue that the instructional design process can be a way of engaging children in our technological society in meaningful ways while still making a place for a wide variety of skills and interests.

Conceptual lens

Our study is guided by the concept of *possible selves* (Markus and Nurius, 1986) which is anchored in "the dynamic properties of self-concept" (p. 954). While self-concept has been described in various ways, what underlies most definitions is that an individual's perception of the self "is continually reinforced by evaluative inferences and that it reflects both cognitive and affective responses" (Bong & Clark, 1999, p. 140). Possible selves are particularly concerned with the image individuals hold regarding what or who they would like to become. As Markus and Nurius (1986) put it, "Possible selves represent individuals' ideas of what they might become, what they would like to become, and what they are afraid of becoming, and thus provide a conceptual link between cognition and motivation (p 954).

What we are arguing in our work is that if a student develops a possible self as someone whose career has no place in our technology-driven society, this may have harmful impact on goals they set for themselves. For this reason, we feel there is a need to introduce the teaching of coding, particularly in the early grades, within a context that acknowledges and values a broad range of skills and interests.

Method

Our study began as a request from a teacher looking for more innovative ways to use the technology at her school. Over the course of three weeks, we engaged in design activities with students at a private school in the

Midwest United States. Students in the third and fourth grades (ages 8 to 10) worked in teams to design a mobile application that met a need identified by the children themselves.
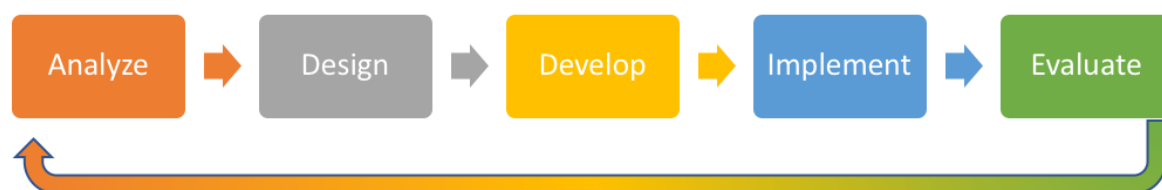
Figure 1. The ADDIE Framework.

Our study used the ADDIE framework (Branch, 2009) (figure 1) to guide the process and provide opportunities for children to apply a diverse set of skills toward accomplishing a common goal. The designed activities consisted of the following five stages: (1) students formed teams, analyzed their potential audience, and identified needs for their potential app; (2) teams designed and documented a detailed plan for the mobile app; (3) teams developed a working prototype of their mobile app using the MIT APP Inventor (http://appinventor.mit.edu/explore/) platform; (4) teams implemented the app by sharing it with their classmates for usability testing; (5) the intention at this stage was to have students evaluate the app and reflect on what they would like to change to improve it.

Data for this study was gathered through surveys, observations, video recordings and collection of artifacts. A brief pre and post survey was given to students to obtain their self-perceptions of their abilities to work with computers as well as the types of jobs they envisioned themselves having in the future.

Findings and discussion

Using the ADDIE framework, all students were able to contribute to the design of a mobile application using a range of skills such as coding, drawing, writing, or communicating orally. Preliminary analysis suggests that students ended the project feeling confident in their skills but still holding misconceptions that "working with computers" equaled computer programming. As we continue to analyze the data further we are also planning to enact a second version of this study at a different school, where we expect the demographic and socioeconomic status will be different.

Teaching programming in schools has many benefits. Luminaries such as Pappert (1980) long argued for the transference of skills from programming to literacies and math. Our research aim was not to minimize the importance of coding but rather to argue against the seemingly emerging perspective that the only way that students of the future can succeed and have a fulfilling life is if they are coders. Contextualizing a coding project within a broader design project provides young students with a chance to envision possible selves that include their diverse talents and interests and are valued in the digital age.

References

Bong, M., & Clark, R. E. (1999). Comparison between self-concept and self-efficacy in academic motivation research. *Educational psychologist*, *34*(3), 139-153.

Branch, R. M. (2009). *Instructional design: The ADDIE approach* (Vol. 722). Springer Science & Business Media.

Cuban, L. (1986). *Teachers and machines: The classroom use of technology since 1920*. Teachers College Press.

Cuban, L. (2009). *Oversold and underused*. Harvard University Press.

Kafai, Y. B., & Burke, Q. (2014). *Connected code: Why children need to learn programming*. MIT Press.

Markus, H., & Nurius, P. (1986). Possible selves. *American psychologist*, *41*(9), 954.

Mayer, R. E. (Ed.). (2005). *The Cambridge handbook of multimedia learning*. Cambridge university press.

Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas*. Basic Books, Inc., 1980.

Rushkoff, D. (2010). *Program or be programmed: Ten commands for a digital age*. Or Books.

Stevenson, J., & Clegg, S. (2011). Possible selves: Students orientating themselves towards the future through extracurricular activity. *British Educational Research Journal*, *37*(2), 231-246.

Supporting SEL in Progressive Design Contexts

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Abstract: The current study examines the use of CA approach to support SEL and identify micro-level instructional strategies. Using interaction analysis, we identify eight strategies used by an expert facilitator that have implications for designing situated professional development programs for training novice facilitators to become more effective at fostering SEL competencies.

Keywords: Social and emotional learning, Progressive Education, Cognitive Apprenticeship

In the recent years the field of Education has brought holistic education to the forefront by emphasizing issues surrounding socio-emotional learning (SEL). SEL is the process of regulating one's thoughts, feelings, and behaviors for making responsible decisions, maintaining empathetic learning environment, and collaborating with others by becoming aware of one's own and other's behavior (CASEL, 2012; Weissberg, Durlak, Domitrovich & Gullotta, 2015). Despite SEL's success in enhancing children's mental well-being and academic performance (Elias & Moceri, 2012), developing productive SEL environments is challenging. The challenges emerge from a lack of support for teachers to develop socio-emotional skills among the students, and SEL's reliance on traditional behavioristic instructional paradigms in developing the curriculum. To address these challenges, systemic level changes, along with a movement towards more progressive socio-cultural instructional paradigms are needed (Elias & Moceri, 2012). The strategic choices that teachers make to enact the curriculum are fundamental in implementing SEL curriculums, yet rarely studied by researchers. Hence, we propose the use of a Cognitive Apprenticeship (CA) model of instruction (Collins, Brown & Newman, 1988) for promoting SEL among children. We examine (RQ) What strategies a teacher uses to operationalize CA methods in the teaching of SEL. By unpacking how SEL principles align with CA model, we analyze the difficulties in applying the CA methods in SEL environments and recommend professional development strategies to adopt progressive forms of instruction.

The study was conducted during Fall 2015 and Spring 2016 semesters, in a weekly afterschool design club at an elementary charter school in the Northern US. Two facilitators led four groups of sixteen 3rd to 6th grade students, who worked on fictional design projects using different kinds of technologies. One of the facilitator was an expert with 15 years of experience working with children developing socio-emotional skills and the other facilitator was a 2nd year graduate student with limited experience in the field. The afterschool club was a program that emphasized developing children's design skills in collaborative learning environment. Video recordings of classroom sessions were reviewed for identifying lessons taught by the expert facilitator (expertise in CA methods), addressing aspects of SEL. Eight episodes of varying lengths (approximately 14 incidents and 80 minutes of teacher talk) were preliminarily selected for further analysis. An episode was an uninterrupted whole class discussion and incidents were split within episodes based on the topic of discussion. Using Interaction Analysis methods (Jordan & Henderson, 1995), the episodes were analyzed for understanding teacher's instructional moves and open-coded for specific strategies used by the teacher. Once the first level codes were generated and reviewed collaboratively they were refined, compared and reorganized around the teaching methods designed by the Cognitive Apprenticeship model (Collins, Brown & Newman, 1988).

SEL encompasses competencies pertaining to cognition and emotion. Eight strategies emerged from the data that connected to or extended CA methods within SEL environments. As shown in Fig. 1, these strategies were embedded within the larger context of situated, reflective practices and further categorized as Emotion-focused or Cognition-focused strategies. The Emotion-focused strategies mostly pertained to SEL competencies of self-management and self-awareness: regulating and recognizing emotions, sense-making, positive mind-set etc. The Cognition-focused strategies mostly pertained to SEL competencies of responsible decision-making, relationship skills and social awareness: making constructive choices, problem-solving, empathy, effective communication etc. Although similar evidences were gathered for all the strategies, in this section we will only discuss the Emotion-focused strategies. In one of the episodes from L4 (Fall 2015), the expert facilitator used Emotion-focused strategies to appreciate a team's effort at regulating their emotions and managing conflicts; and encouraged other students to do so. She *Replayed an experience* from previous class in order to help students develop a deeper understanding of desired design processes. She discussed this incidence during the whole-class reflection session by saying "So, last time, they (group 2) were trying to design a garden just like many of you were, but they had some differences with

regards with types of things they wanted. Leo really wanted to design a car, and the other team members push Leo to try and explain and provide some reasons for why he should try & build a car. Now, Leo tried to provide some rationale, and they tried to think about it very, you know, very hard, but, was this an easy conversation for you guys to have?" She then *reframed* some of the difficult conversations as evidence of '*hard work*' and *acknowledges* their frustration by saying "that happens because it's really difficult for any group to try to make a joint decision. This is really, really, common, but that level of frustration and difficulty shows that you are actually doing something right". The facilitator used a variety of other strategies not explicitly stated in the CA framework. These strategies focus on helping students regulate their emotions. By reframing, the facilitator reduced the amount of negativity associated with a difficult process and acknowledged emotions using articulation. Unlike CA model, the facilitator helped the students think aloud about their thinking processes and encouraged the class to talk about how it makes them feel so as to normalize and contextualize these feelings.

Our findings show that SEL can be integrated by using CA model of instruction; however, the model needs to be extended for supporting the emotional aspects through practices grounded in theories of emotional scaffolding and regulation (Rosiek, 2003). The strategies used by the teacher for developing
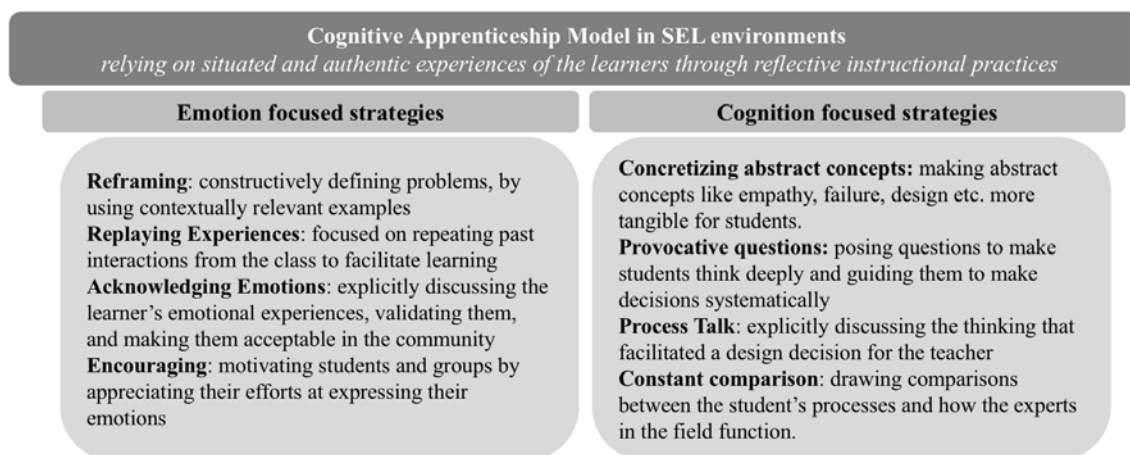
Figure 1. Definitions of Emotion-focused and Cognition-focused strategies

these competencies have to be equally diverse and well-integrated. The teacher's allegiance with the student's classroom experiences and letting their needs drive the curriculum is fundamental. As such, helping teachers to develop the necessary professional skills to learn how to support SEL with progressive models of instruction like CA may require us to rethink our approach to professional development. However, more research is needed on unpacking expert progressive practices to support the types of complex socio-emotional and domain-specific learning required by an increasingly collaborative, socio-technical society.

References

Collaborative for Academic, Social and Emotional Learning (CASEL). (2012). 2013 CASEL guide: Effective social and emotional learning programs-preschool and elementary school edition. Chicago.

Collins, A., Brown, J. S., & Newman, S. E. (1988). Cognitive apprenticeship: Teaching the craft of reading, writing and mathematics. *Thinking: The Journal of Philosophy for Children*, *8*(1), 2-10.

Elias, M. J., & Moceri, D. C. (2012). Developing social and emotional aspects of learning: the American experience. *Research Papers in Education*, *27*(4), 423-434.

Jordan, B., & Henderson, A. (1995). Interaction analysis: Foundations and practice. *The Journal of the Learning Sciences*, *4*(1), 39-103.

Rosiek, J. (2003). Emotional scaffolding: An exploration of the teacher knowledge at the intersection of student emotion and the subject matter. *Journal of Teacher Education*, *54*(5), 399-412.

"If You Add Too Much Science, It Gets Boring." Exploring Students' Conceptual Change Through Their Game Design Iterations

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Abstract: Game design offers many opportunities for facilitating and understanding learning. We facilitated a 5-day game design workshop for eleven grade 7 students to design educational board games about virology. Through analyses of field notes, audio recording, and design artifacts, we illustrate conceptual change of virology through two student teams' game design iterations. Findings show how the design process facilitates conceptual change, and how games can be used as assessments of student thinking.

Background and objectives

Games are dynamic systems, and models of their designer's understanding of that system. When students design games to teach domain content, their games become sites for assessing their understanding (Ackerman, 2001). However, some argue that the educational value of design is in the process, and not in the product (Dancz et al., 2017). Indeed, student designers can learn content even when their designs are not effective at teaching it to their peers (Harel & Papert, 1990). Game design engages valuable skills of inquiry, problem-solving, reflection, explanation, critique, refinement, and collaborative knowledge construction. In particular, designing games for learning requires integrating knowledge of games, of relevant domain content, and of how people learn (Khaled & Vasalou, 2014). We argue that the iterative process of game design embeds opportunities for designers to test and get feedback on their current understanding, and to identify and correct misconceptions. Doing so can ultimately lead to better game designs as well as to better learning outcomes for designers and their players.

Based on two student teams creating games to teach players about the measles virus, we ask: (1) How do students approach the challenge of designing games for learning? and (2) What do students' game design iterations reveal about their science understanding? Findings from this study have implications for using game design as an activity to support and assess science learning.

Methods and data analysis

We created a 5-day long elective game design workshop for eleven grade 7 students from a diverse public school in the eastern United States. The workshop occurred during the final week of the academic year, and was part of an effort to explore the opportunities of transmedia game design for shaping students' scientific and design dispositions. Five graduate student facilitators and two accompanying teachers guided three student teams in designing games to teach players about measles, based on the comic book *Carnival of Contagion* (Hall, West & Diamond, 2017, worldofviruses.unl.edu/carnival-of-contagion). This comic tells of a dream shared by a group of unvaccinated youth as fall ill with measles. We asked students to create games to teach players the science covered in the comic, including the transmission and symptoms of measles and the importance of herd immunity. Here, we focus on contrasting episodes from two of the three student groups—*The Musketeers* (3 boys), and *The Weirdos* (4 girls)—to illustrate the ways that game designs can be evidence of learning.

We collected field notes, research reflections, and audio recordings of all activities, including within-team and student-facilitator discussions; students' final game design artifacts; and documentation of their iterations. We then conducted a thematic analysis of the data (Vaismoradi, Turunen, Bondas, 2013), and met regularly to discuss, define, and refine emergent themes.

Findings

Students' understanding of vaccines and of viral transmission was reflected in their design iterations. Creating the alignment between player actions (e.g., jumping, collecting objects) with learning actions (e.g., solving problems), which characterizes effective games for learning (Plass et al., 2011), was a chance to grapple with science concepts. In general, students easily identified misalignments within existing games. As one male student noted about a poorly designed digital mathematics game, "you just shoot things… adding (numbers) doesn't have anything to do with shooting (those things)." Comparing this to a better designed math game, he noted that the player's action "actually has something to do with (…) actually solving (math problems)."

However, students struggled to varying extents to embody this alignment in their own games. For example, when encouraged to incorporate more science into their path-based board game, The Weirdos added

"fun fact cards" about measles, from which players selected on landing on marked squares. While the team learned content by making the cards, these were purely informational, and did to advance gameplay. Their cards represented an *extrinsic* integration (Kafai et al., 1998), wherein learning goals were not a component of the mechanics, but exist alongside them. Their superficial treatment of the science through this simple game design decision may have been a missed opportunity for the Weirdos to engage more deeply with the science.

In contrast, the Musketeers began with a misconception about vaccines that ultimately changed through their attempts to align learning with player actions. Initially, they proposed a game concept in which players "vaccinate the sick" to "cure" them or to "remove symptoms," an idea that reflects their misunderstanding that vaccines are curative rather than preventive. By their third iteration, this misconception had transformed. Adam (pseudonym) of the Musketeers described a game concept in which players "get chances to get different vaccines to prevent different diseases….some prevent one, some prevent three or four." However, the team struggled to integrate the preventive (vs. curative) nature of vaccines into an engaging game mechanic that would have the desired impact on players (damage to health) without the players' characters dying and causing the game to end prematurely. Through playtesting with facilitators, the Musketeers eventually formulated a solution in which each player controlled a party of characters who would not become infected all at once.

The Musketeers' solution and approach to incorporating the making and use of vaccines into their game mechanics reflects an intrinsic level of integration (Kafai et al., 1998), and their nuanced understanding of the alignment between player and learner actions. Their decision also showed the team's ability to incorporate accurate science into engaging game mechanics without needing to sacrifice one for the other, and effectively balancing fun and education in their design. As Adam noted, "The whole point is, we just want our gameboard to be fun, but like science. (…) If you add too much science, it gets boring."

Conclusions and implications

Designing games for learning requires integrating various skills and knowledge that students have yet to master. Our findings suggest that the process of designing such games offers a unique context for observing how students think about science concepts, and about a design practice. However, students' games may not reflect the extent of their understanding. Thus, continued research might expand on our sample size and seek ways to distinguish students' science understanding from their game design abilities, and the impact of designing games on science understanding. Future research might identify individual, social and contextual influences on the interactions between science understanding and design decisions.

References

Ackermann, E. (2001). Piaget's constructivism, Papert's constructionism: What's the difference. *Future of learning group publication*, 5(3), 438.

Dancz, C. L., Parrish, K., Bilec, M. M., & Landis, A. E. (2017). Assessment of Students' Mastery of Construction Management and Engineering Concepts through Board Game Design. *Journal of Professional Issues in Engineering Education and Practice*, 143(4), 04017009.

Hall, B., West, J. & Diamond, J. (2017). *Carnival of Contagion*. Lincoln, NB: University of Nebraska Press.

Harel, I., & Papert, S. (1990). Software design as a learning environment. *Interactive learning environments*, *1*(1), 1-32.

Kafai, Y. B., Franke, M. L., Ching, C. C., & Shih, J. C. (1998). Game design as an interactive learning environment for fostering students' and teachers' mathematical inquiry. *International Journal of Computers for Mathematical Learning*, 3(2), 149-184.

Khaled, R., & Vasalou, A. (2014). Bridging serious games and participatory design. *International Journal of Child-Computer Interaction*, *2*(2), 93-100.

Plass, J. L., Homer, B. D., Kinzer, C. K., Frye, J., & Perlin, K. (2011). Learning mechanics and assessment mechanics for games for learning. *G4LI White Paper, 1*, 2011.

Vaismoradi, M., Turunen, H., & Bondas, T. (2013). Content analysis and thematic analysis: Implications for conducting a qualitative descriptive study. *Nursing & health sciences*, 15(3), 398-405.

Acknowledgments

Individualized Assessment and Automated Feedback
in Undergraduate Computer Science Education

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Abstract: This study examines modalities of generating and providing automated formative feedback to Computer Science undergraduate students' and their experiences with the system and the received feedback. A software for automated feedback has been developed and used in this study in order to both support the students learning process, and to test how a set of elaborated assessment criteria can contribute to the students better understanding of their own knowledge and learning. The findings show that providing the students with explicit feedback in addition to regular summative evaluation (grades and point sum) stimulated their understanding and awareness of their knowledge level and exam performance. Besides, it triggered ideas and reflections related to their future learning steps and approaches, which follows the principles of feedforward.

Introduction

This contribution presents case studies of the development and use of a software program and criteria for providing automatic feedback in a Computer Sciences undergraduate program. Feedback is viewed as a pedagogical strategy in teaching-learning environments that has potential to facilitate the students' learning in a meaningful manner (Jansson, 2006). Greenhow's (2015) argues for the inclusion of a formative component when developing digital environments for providing feedback. The increase in student population and the ever-evolving knowledge to be conveyed makes the task of providing feedback and assessment that has a formative value becomes quite difficult. Usually, the automatic feedback in a digital assessment system is given by a short indication of whether the answer is wrong or right. A number of studies examined the effectiveness of providing formative feedback for summative computer-aided assessment, by giving individualized feedback derived from each of the five results sections of the assessment was provided to each student (Lewis & Sewell, 2007), or how an automated short-answer marking system can be effectively used to improve teaching and learning at university level (Siddiki et al., 2010). In the latter, the system did not allow features that can provide detailed statistical analysis of students' performances for both lecturers and students so that each may adjust or modify their teaching or learning approach for the course.

Our study addresses these issues and aims to provide a better understanding of how a software program developed for providing automatic formative feedback in a Computer Sciences undergraduate course was implemented, how the automated feedback contributed to improved learning and how the students experienced both the use of the system and receiving feedback in this manner. Whether students engage productively with feedback, whether it enhances their learning and performance, and whether automated feedback can have meaningful role in these processes are questions that require empirical examination. For the feedback process to be productive, learners need to make meaning of the relevant criteria and standards, how their performance compares against them and what they can do to improve against those standards. This is achieved collaboratively between students, teachers, tools, course activities. From a socio-material perspective, the tools can facilitate conveying the feedback, that is, they mediate the process. In this case, the automated feedback software becomes an entity and a meaning-making resource intertwined in the interaction between students, teachers, and standards for learning and assessment, which has potential to lead to a better understanding of own process and performance.

Methods

The studies presented in this paper were conducted in the context of Computer Sciences program at a large university in Norway. Dataset from two courses are included in this paper. In each course, lectures, labs weekly assignments and course compulsory assignment were part of the course design. Feedback was provided on the submitted assignments. The software program (Mirmotahari, 2016) was initially developed to facilitate exam assessment, but it gradually displayed great potential for being used to give formative feedback. The program was designed with several stakeholders and users in mind, namely (i) exam evaluators; (ii) students,; and (iii) the teachers. The program can provide both the arguments for the grade as well as an individual formative feedback. If the evaluator or the teacher chooses to provide students with both arguments for their grade and an

individual formative feedback, the first part of the feedback will consist of the arguments for each assignment and grade. The second part will be an individual formative feedback based on feedforward principles. The main component of the assessment program is the generation of the criteria, their weight in measurement and the textual phrases linked together. A taxonomic model (inspired roughly by Bloom's taxonomy) was used to develop a set of criteria that focused on the students' learning understanding of abstract knowledge and the way to employ this in solving computing problems. The back-end of the program is constantly monitoring and analyzing the evaluator's choice and overruns. The results of these analysis lead to individual feedback to each student. The feedback consists of three main parts; (i) academic feedback and discipline-based justification of grade, (ii) personal feedforward and finally (iii) a profiling for the learning outcome. The length of the feedback is entirely dependent on the amount of choices the evaluator has made and the accumulated sum of the weights of the criteria throughout the whole assignment. The accumulated sum for each criterion is normalized to the classes and based on predefined thresholds groups the results. All the students' hand-in assignments were scanned and automatically uploaded into this assessment program. After each iteration, the students were asked to answer an online questionnaire. The average response rate has been 77%. Different questionnaires have been used to collect
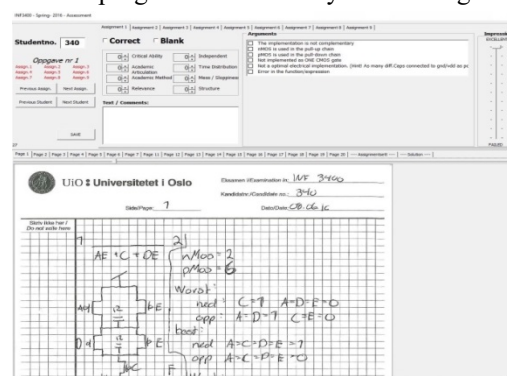
Figure 1. Software program interface.

in answer regarding one or more of these topics: questions about the assignment; perception of the feedback received; evaluation of the technical aspects of the assessment program (computer program, usability, and time usage); development in relation to the professional domain; their experience of being a peer reviewer; learning outcome for the students as a participants and a peer-reviewers. The results from the questionnaires were also discussed in the qualitative interviews. Since the questionnaire was anonymous, there was no opportunity to connect the questionnaires with the interviews. We have conducted qualitative interviews with 15% of the enrolled students.

Findings and relevance

The findings indicate positives experiences and students benefiting from the feedback. In line with arguments made by Greenhow (2015) and Siddiki et al. (2010), the findings show that providing the students with explicit feedback in addition to regular summative evaluation (grades and point sum) stimulated their understanding and awareness of their knowledge level and performance. The program supports providing feedback specifically aimed at the students' professional skills, triggering focused alternatives for future learnings steps and reflections related to their future learning steps and approaches. The study also provides insights into how automated feedback generated through the use of criteria can be organized by means of a dedicated software program. At the level of practice, the method employed provides an innovative available for the teacher and the sensor to provide the students feedback. The developed system involves teacher's work to define in writing what given values of criteria mean and the different feedback will make it easier to calibrate the evaluators across the subject. That way, not only the students benefit from this approach, but also the teachers/evaluators gain better understanding of what is required of the students for the various assignments and future learning. Follow-up studies are recommended in order to examine the quality of feedback not only based on the students perceptions, which have a subjective nature, but also based on quality criteria distilled from specialist literature.

References

Greenhow, M (2015). Effective computer-aided assessment of mathematics; principles, practice and results. *Teaching Mathematics and its Applications: An International Journal of the IMA,* 34(3), 117 - 137.

Lewis, D. J. A. &. Sewell, R. D. E (2007). Providing Formative Feedback From a Summative Computer-aided Assessment. *American Journal of Pharmaceutical Education*, 71(2), https://doi.org/10.5688/aj710233

Mirmotahari, O. & Berg, Y. (2016). *Individuell «automagisk» tilbakemelding på skriftlig eksamen.* Nordic Journal of STEM Education, Vol. 1, No. 1, 287-293.

Siddiqi, R., Harrison, C.J., Siddiqi, R., Improving Teaching and Learning through Automated Short-Answer Marking, IEEE Transactions on Learning Technologies, Vol. 3, No. 3, pp 237-249.

Skyscraper Games: Designing Professional Development for Middle School Teachers to Promote Computational Thinking Using Custom Tools

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Abstract: We are piloting professional development (PD) for six middle-school teachers from a Philadelphia, Pennsylvania, USA. Our goal is to involve students from underrepresented STEM populations in programming through an annual game design competition that allows students to display their game on a large skyscraper in the city through the Skyscraper Games project. The initial PD group includes educators from public schools, charter schools, and afterschool programs. We are using a design-based approach to (1) create a sustainable, ongoing professional development program for educators of middle-school students; (2) develop a library of curricular materials for Skyscraper Games; and (3) enhance and upgrade our website and online programming tool. The goals of these activities are (1) to better understand how the interaction of professional development, curricular materials, and our online tool affect computational thinking for young people and (2) to use these results to iteratively improve our professional development, curriculum, and web-based tools for use by both middle-school students and their teachers in formal and informal settings.

Major issues

Background

On a chilly night in April 2014, Philadelphia residents looked up to see the 29-story Cira Centre briefly transform into the World's Largest Video Game. The players were miles apart, maneuvering the familiar rainbow blocks of Tetris as they cascaded down the 120,000-sq. ft. surface. The spectacle was the culmination of years of careful work and planning by Dr. Frank Lee, director of the Entrepreneurial Game Studio (EGS) at Drexel University's ExCITe Center. For Lee, this was more than just a public art installation. It was the first step in creating a new, exciting platform to engage young people in computer programming. Since that day, EGS has hosted onsite workshops for 82 middle schoolers from diverse backgrounds, with more than half of them identifying as female or gender-nonconforming. Now, the team is working with a small group of STEM educators to encourage middle school students from all backgrounds to participate in an annual game design and development competition, with the opportunity to display their final game on the skyscraper itself.

Current research

We are designing a professional development (PD) training sequence for middle school teachers to help them integrate the Python computer programming language and computational thinking skills into their existing curricula. To do this, they are using our custom web-based Skyscraper Games editor to create games and display them on a virtual skyscraper. This paper focuses on the following research question: *In what ways can a design-based approach to professional development assist middle school STEM teachers with integrating computational thinking skills in their classrooms?*

This pilot study, which is still under way for the 2017 – 2018 school year, includes the design of three different but connected components: (1) the professional development program itself, (2) the accompanying curricular materials, and (3) the online programming tool and associated website. We have adopted a design-based research (DBR) approach. Some key features of DBR are mixed-methods, an intervention, iterative repetitions and refinements, and a recognition of its situated nature (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003; Gresalfi & Barab, 2011).

For this PD intervention, we are collecting quantitative data that include teacher pre- and post-surveys concerning technology beliefs and classroom integration (Brinkerhoff, Ku, Glazewski, & Brush, 2001), a research-team created Game Design and Creative Code Computational Thinking Assessment for the students, and student computer attitude pre- and post-surveys (Loyd & Gressard, 1984). Qualitative data include audio/video of PD sessions, researcher observation notes and memos, and interviews. Each month, beginning in November 2017 and ending in June 2018, we are meeting with the teachers for a professional development session. The first

session was five hours, and each monthly session after that will be two hours. There are six participants for this pilot study: three males and three females. Four were middle school teachers in formal educational settings; of those four, two taught at urban public schools (mathematics, technology) and two taught at urban charter or private schools (technology, media literacy). The private school is a girls-only school. The other two educators worked with non-school community-based computer programming organizations.

Theoretical approaches

Brinkerhoff (2006) studied a long-term professional development academy for integrating technology into schools in New Mexico. The study identified barriers to effective PD, with the three most relevant to this project being (1) resources, (2) institutional and administrative support, (3) training and experience. The findings also suggested several key components for creating a successful PD program. Those most relevant for our study are (1) extended contact hours for instruction and practice, (2) provision of materials to teachers, and (3) holding participants accountable for integrating their ideas into practice.

Conclusions and implications

We will add more results as we collect and analyze additional data, but the early implications are that the Brinkerhoff guidelines for PD are relevant.

The following barriers have been evident in our preliminary data analysis. (1) Resources: time and equipment are the primary concerns for the teachers. (2) Institutional support has proven to be an issue for some teachers; in one case, the teacher tried unsuccessfully for nearly four months to get the Skyscraper Games website unblocked before the research team was able to help. (3) Of the six teachers, two do not have formal training in computer science. This has been an issue for one of these teachers, who requires additional support in learning programming generally, beyond the specific requirements of the Skyscraper Games tool.

Briefly, this is how we have addressed the elements for successful PD. (1) Extended contact hours: meeting for several hours each month has provided an opportunity to discuss pedagogical approaches, review and request curricular materials, and use the website and coding tool in order to generate a list of action items for improving those. (2) Provision of materials to teachers has been important, both to help them understand the tool and how they might use it, and also to demonstrate that they are being supported by the research team. (3) While we cannot require teachers to actually use the tool in their classrooms, we worked with them to create a timeline for the year that culminates in a student showcase at the end of May 2018. This has helped to motivate them, particularly since the student teams that complete a game will have the opportunity to play their games on the Cira Centre itself later in the summer/early fall of 2018.

This study will provide important information for researchers who are interested in designing effective PD opportunities for computational thinking using custom technological tools, particularly at the middle school level where CS is generally not a required course.

References

Brinkerhoff, J. (2006). Effects of a long-duration, professional development academy on technology skills, computer self-efficacy, and technology integration beliefs and practices. *Journal of Research on Technology in Education, 39*(1), 22-43.

Brinkerhoff, J., Ku, H., Glazewski, K., & Brush, T. (2001). *Development, results and validation of technology integration surveys for preservice and practicing teachers*. Paper presented at the Association for Educational Communications and Technology, Atlanta, GA.

Cobb, P., Confrey, J., diSessa, A., Lehrer, R., & Schauble, L. (2003). Design experiments in educational research. *Educational Researcher, 32*(1), 9-13.

Gresalfi, M., & Barab, S. (2011). Learning for a reason: Supporting forms of engagement by designing tasks and orchestrating environments. *Theory Into Practice, 50*(4), 300-310. doi:10.1080/00405841.2011.607391

Loyd, B. H., & Gressard, C. (1984). The reliability and validity of an instrument for the assessment of computer attitudes. *Educational and Psychological Measurement, 45*(4), 903-908.

Acknowledgments

Opening the Door to Algebra: The Role of Fraction Knowledge in Algebra Learning

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Abstract: We examine 6th, 7th, and 8th grade classes in order to determine how fraction knowledge improves naturally during business as usual instruction and whether naturally occurring improvements in fraction knowledge are related to improvements in algebra readiness/achievement outcomes.

Significance

Recent research has confirmed speculation of scholars and practitioners alike: Students' knowledge about fractions is predictive of their Algebra readiness (Booth & Newton, 2012), and performance and learning in algebra (Booth, Newton, & Twiss-Garrity, 2013). However, the mechanisms underlying the relation between fraction knowledge and improved algebra performance and learning are yet unclear, especially as the benefits of fraction knowledge appear even when students solve problems that do not involve fractions. In the present study, we examine naturally-occurring changes over the course of a school year in different types of fraction knowledge (magnitude knowledge, comparison, and arithmetic) and investigate whether and how those changes are predictive of changes to different types of algebra knowledge. This project fills a critical gap in the present knowledge on how fraction knowledge is related to Algebra performance and learning, including which types of fraction knowledge are critical for improving algebra learning and the mechanisms underlying these effects.

Theoretical background

Several mechanisms have been proposed to explain *why* fraction knowledge impacts algebra performance and learning. The most straightforward hypothesis is that lack of conceptual understanding of fractions "…limits students' ability to solve problems with fractions and to learn and apply computational procedures involving fractions (p. 6)" (Siegler et al., 2010). This would necessarily lead to difficulty solving problems in algebra, as they frequently require manipulation of fractions and other rational number representations. However, recent evidence demonstrated that the correlations between fraction knowledge and equation-solving skill were not limited to equations that contained fractions (Booth & Newton, 2012). This suggests that, while proficiency with fraction computation may certainly be one mechanism behind the connection between fractions and algebra learning, it may not be the only one.

Some scholars argue that, in addition to facility with computation, students need a deep understanding of the number system, including the place of fractions in that system, in order to succeed in algebra (Empson & Levi, 2011; Wu, 2001). Central to such a deep understanding of numbers is knowledge about magnitude (Siegler, Thompson, & Schneider, 2011). In particular, students' understanding that the magnitude of fractions is determined by a relationship between two numbers (a notion that is unfortunately difficult to grasp (Siegler & Pyke, 2012) is crucial for development of strong concepts of fraction equivalence and proportionality. Such proportional reasoning is thought to play an important role in algebra learning. For example, Empson & Levi (2011) suggest that understanding that "all fractional representations of 1/3 will fit into the equation, $x/y = 1/3$, which is equivalent to the equation $y = 3x$" (p.134) will help students to comprehend algebraic equations. Further, Wu (2001) suggests that rules and ideas learned when dealing with fractions are often applicable to algebraic topics, thus making that foundation knowledge about the rational number system crucial for algebra.

Here, we examine both student knowledge of fraction computation and knowledge of fraction magnitudes to determine whether changes in either or both are predictive of changes in algebra readiness or learning.

Method

Participants in this study are students in intact 6th, 7th, and 8th grade mathematics classrooms (N=45 classrooms) in diverse school districts. All students in participating classrooms are undergoing business as usual instruction at their grade level during the term. They completed fraction and algebra measures at the beginning of the year, and will complete those measures again at the end of the year, as well as a measure of grade-level mathematics competence. Demographic information is supplied by the school district.

Two fraction knowledge measures are used. *Fraction magnitude knowledge* is assessed using a number line estimation task (e.g., Siegler & Opfer, 2003). Students are presented with blank number lines with 0 marked at the left endpoint and 1 marked at the right endpoint. A fraction with a magnitude between 0 and 1 is printed on top of each line and students are asked to place a mark on the number line where they believe the indicated fraction belongs. *Fraction computation knowledge* is measured using items representative of the types of problems found in fraction arithmetic lessons (i.e., ½ + ¼; ⅔ x ⅝; 6÷ ⅓). Addition, subtraction, multiplication, and division with fractions are included.

Three algebra knowledge measures are used. *Equation Encoding* is assessed using a reconstruction task (e.g., McNeil & Alibali, 2004) in which students are presented with an equation or expression briefly and then asked to reconstruct the problem from memory immediately after it disappears from view; students complete this task for a series of equations with different structural formats and different placements of key problem features. *Feature knowledge* is assessed using previously established items designed to address students' understanding of concepts that have been identified in previous research as crucial for success in Algebra (e.g., the meaning of the equals sign, the significance of negatives in terms, identification of like terms, etc (Booth & Newton, 2012). Finally, *problem-solving* is assessed using items that measure students' ability to effectively carry out procedures to solve problems. These items are representative of the types of problems found in Algebra I textbooks and taught in Algebra I courses (i.e., $6x - 8 = 12$; $7x + 4 = 10x - 5$; $4 = 2/3x$).

General mathematics competence will be assessed using grade-specific mathematics ability tests comprised of items from that grade's mathematics textbooks aligned with that grade's CCSS-M content standards.

Anticipated results

We will assess how fraction knowledge related to improvements in various facets of algebra readiness and performance through a series of multiple regression analyses, regressing each end of year algebra score (# conceptual encoding errors, % correct on feature knowledge, and % correct on problem-solving) on students' start of year fraction and algebra measures, improvement on each of the fraction measures over the course of the school year, students' end of year math ability score, and relevant demographic variables (e.g., gender, ethnicity, SES). This will allow us to determine how initial fraction knowledge and improvements that result from traditional instruction are predictive of improvements in students' algebra readiness or performance.

References

Booth, J. L., & Newton, K. J. (2012). Fractions: Could they really be the gatekeeper's doorman? *Contemporary Educational Psychology, 37*, 247-253

Booth, J.L., Newton, K.J., Twiss-Garrity, L. (2014). The impact of fraction magnitude knowledge on algebra performance and learning. *Journal of Experimental Child Psychology,118,* 110-118.

Empson, S. B., & Levi L. (2011). *Extending children's mathematics: Fractions and decimals.* Portsmouth, NH: Heinemann.

McNeil, N. M. & Alibali, M. W. (2004). You'll see what you mean: Students encode equations based on their knowledge of arithmetic. *Cognitive Science, 28*, 451-466.

Siegler, R., Carpenter, T., Fennell, F., Geary, D., Lewis, J., Okamoto, Y., et al. (2010). *Developing effective fractions instruction: A practice guide* (NCEE #2010-009). Washington, DC: National Center for Education Evaluation and Regional Assistance, Institute of Education Sciences, U.S. Department of Education.

Siegler, R. S., & Opfer, J. E. (2003). The development of numerical estimation: evidence for multiple representations of numerical quantity. *Psychological Science, 14*, 237-243.

Siegler, R. S., & Pyke, A. A. (2012). Developmental and individual differences in understanding of fractions. *Developmental Psychology, 49*(10), 1994-2004.

Siegler, R. S., Thompson, C. A., Schneider, M. (2011). An integrated theory of whole number and fractions development. *Cognitive Psychology, 62*, 273-296.

Wu, H. (2001). How to prepare students for algebra. *American Educator*, 25(2), 10-17.

Acknowledgments

How to Enjoy Writing Papers: Supporting Literature-Based Inquiry Learning to Reduce Procrastination and Foster Ownership and Positive Emotions

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Abstract: Literature-based inquiry learning is a common form of instruction in the Humanities and Social Sciences but usually lacks the necessary support. In this paper, the effects of an online environment to support the literature-based inquiry process with scaffolds and prompted learning diaries are compared to unguided learning processes. We find a significant decrease in procrastination and a significant increase in perceived psychological ownership and positive emotions. In-depths interviews give insights into the learning process and epistemic emotions during the process when the supportive environment is used. Further data collection is currently in progress and will add to these findings.

Introduction and theoretical background

A specific problem of literature-based inquiry learning is *procrastination* as research on academic writing has shown (Klingsieck & Golombek, 2016) resulting in lack of time to plan the process, apply effective strategies to accomplish relevant tasks, and reflect about the process – the three central components for successful self-regulated learning (Zimmerman, 2001). Unsuccessful self-regulation processes, in turn, lead to unpleasant emotions and aversive attitudes towards literature-based inquiry. Aversive attitudes towards a learning task have been shown to be major causes of further procrastination behavior (Steel, 2007). A sense of *psychological ownership*, i.e. the feeling that the written text is 'mine' or an 'extended part of me', has been found to be linked to perceived control, increased self-efficacy, and motivation (Pierce, Kostova, & Dirks, 2003), thus being conducive to pleasant emotions. Additionally, during learning processes, many different epistemic emotions of rather pleasant or unpleasant nature can occur that influence information processing and learning behavior.

In order to enable learners to efficiently self-regulate during literature-based inquiry learning and gain a sense of psychological ownership that can lead to pleasant epistemic emotions, guidance, structure, and information in moments of insecurity are necessary. A virtual environment can provide such support by making the activities of a literature-based inquiry process visible and by supporting the externalization of learners' internal inquiry processes. In STEM areas, positive effects of *scaffolds* that provide an externalized schema of the steps of the inquiry-learning process and guide the learners through this process have extensively been found (e.g. de Jong, 2006). Additionally, learning diaries that include cognitive and metacognitive prompts have shown to be a good means of support for long-term learning processes such as the literature-based inquiry process, which usually takes several weeks of self-regulated work. (Berthold, Nückles & Renkl, 2007). These assumptions lead to the following research questions:

RQ 1: To what extent does a virtual environment that combines scaffolds and prompted learning diaries foster beneficial *learning processes* (reflection and decreased procrastination) during literature-based inquiry?

RQ 2: To what extent does a virtual environment that combines scaffolds and prompted learning diaries foster *learning outcomes* (positive emotions towards literature-based inquiry and psychological ownership for a term-paper) during literature-based inquiry?

Methods

We used a design-based research approach that included data collection in the form of an experimental field study on different cohorts of students in a German Educational Science B.A. program as well as in-depths observation of the learning process of three individual students. The three cohorts consisted of a *baseline group* (N = 27), which did not receive specific support. We followed three of them while they tested the first version of the support instrument. The *experimental group of cycle 1* (N = 16) received access to the first version of the support instrument as part of an introductory course in Educational Science and scientific writing. The *experimental group of cycle 2* (data collection is still in progress) receives access to an improved version of the support instrument.

As a support instrument for the inquiry process of a literature-based term-paper, we designed the "Online-Research Log" which is set up in a moodle course as a work-flow-management-system. It visualizes the main necessary steps in a literature-based inquiry process by structuring each step according to three core elements: (a)

Setting concrete and terminated goals for the step, (b) conducting the whole step and uploading the result, (c) reflecting about the process, focusing especially on what has been learnt, problems that have been solved, and achieved goals. The support instrument was improved between cycle 1 and 2 regarding its overall outline (one step was broken down into two smaller steps), in the information available (an introduction video was added), and in the reflection prompts (a rating scale for current epistemic emotions was added).

All three groups were asked to fill in online-questionnaires, the experimental groups received a pre- and a post-test before they started and after they finished the inquiry process. The questionnaires include instruments to measure procrastination behavior during each step of the inquiry process, psychological ownership towards the term-paper, and state emotions towards future literature-based inquiry. Differences between the groups were analyzed using t-tests and Man-Whitney-U-tests. Additionally, we will analyze the reflection data. For the in-depths observation of the three individuals in the baseline group, who tested the first version of the support instrument, we conducted a series of interviews over a period of two months.

Findings

When comparing the reported procrastination behavior during the seven steps of the inquiry process between the baseline group and the experimental group in cycle 1 (RQ 1), we found that the experimental group in cycle 1 reported significantly reduced procrastination behavior for most of the steps. During the in-depths observations, participants pointed out that the identifying and understanding appropriate literature was especially challenging for them. Furthermore, the in-depths analyses revealed that participants had problems in setting appropriate goals as well as reflecting efficiently. Looking at the outcomes of the literature-based inquiry process (RQ 2), we see a significant improvement in psychological ownership towards the term-paper and in positive emotions towards future literature-based inquiry for the experimental group in cycle 1 compared to the baseline group. In-depths analyses show a huge fluctuation of epistemic emotions during the process but for all participants a rapid decrease of fear when working with the Online-Research Log. The support instrument was improved accordingly, and we expect to reduce procrastination behavior in cycle 2.

Conclusion and further plans for research

The preliminary results indicate that it seems possible to support learners during literature-based inquiry not only in cognitive aspects – which was the focus of previous research – but also in emotional and motivational aspects. Providing structure and guiding learners' reflections in an online environment seem to be a way to support complex inquiry processes that can otherwise hardly be supported sufficiently in a regular educational context. Furthermore, setting the focus on emotional aspects of inquiry learning could be important to better understand why learners are able and willing (or not) to use efficient learning strategies and show relevant learning activities related to tasks with which they have previous experiences.

However, the sample in this study is currently quite small and additional data is needed to validate these findings. Additionally, further analyses will show how learners' emotions change on a long-term basis, as well as on a short-term basis within the literature-based inquiry process when additional data of cycle 2 is available. Data about how aspects students reflect will give further insights into the learning and self-regulation process.

References

Berthold, K., Nückles, M. & Renkl, A. (2007). Do learning protocols support learning strategies and outcomes? The role of cognitive and metacognitive prompts. *Learning & Instruction, 17*(5), 564-577.

De Jong, T. (2006). Scaffolds for scientific discovery learning. *Handling complexity in learning environments: Theory and research*, 107-128.

Klingsieck, K. B. & Golombek, C. (2016). Prokrastination beim Schreiben von Texten im Studium. In A. Hirsch-Weber & S. Scherer (Hrsg.), *Wissenschaftliches Schreiben in Natur- und Technikwissenschaften* (S. 195-205). Wiesbaden: Springer.

Pierce, J. L., Kostova, T., & Dirks, K. T. (2003). The state of psychological ownership: integrating and xtending a century of research. *Review of General Psychology, 7*, 84–107.

Steel, P. (2007). The nature of procrastination: a meta-analytic and theoretical review of quintessential self-regulatory failure. *Psychological Bulletin, 133*(1), 65-94.

Zimmerman, B. J. (2001). Theories of Self-Regulated Learning and Academic Achievement: An Overview and Analysis. In B. J. Zimmerman & D. H. Schunk (eds.), *Self-regulated learning and academic achievement. Theoretical perspectives* (pp. 1-37). Mahwah, NJ: Erlbaum.

Identifying Methods to Induce Productive Confusion for Improving Performance in Physics

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Abstract: A gap currently exists in the literature regarding how to most effectively harness the power of confusion in learning. In order to address this gap, the present study sought to explore which methods of confusion induction are most beneficial for deep learning. Results revealed that Breakdown Scenarios were the most effective confusion induction technique compared to a lecture-based format. Additionally, significant interactions were discovered between Breakdown Scenarios and certain individual difference measures.

Introduction

The current study sought to demonstrate the most effective ways to induce the impasses that lead to productive confusion which in turn result in significant learning gains. The reason that we focused on confusion is because research has suggested that confusion is both prevalent in and important to learning (Craig et al., 2004; D'Mello & Graesser, 2011; D'Mello, Lehman, Pekrun & Graesser, 2014). According to these theories, confusion is triggered when learners are confronted with information that is inconsistent with existing knowledge and learners are unsure about how to proceed. These events that trigger impasses place learners in a state of cognitive disequilibrium, which is ostensibly associated with heightened physiological arousal and more intense thought as learners attempt to resolve impasses.

Procedures

Following the informed consent, participants completed the following tests: Achievement Goal Questionnaire and the Attributional Complexity Scale. After the completion of the tests of individual differences, participants completed the pretest (counterbalanced with the posttest). Because the study was a laboratory-based randomized experimental trial, participants were randomly assignment to one of **four levels** of our independent variable (i.e., induction of desirable confusion): **1) Breakdown Scenarios 2) Deep Questions 3) Intra-testing, and 4) Control** to determine impact on students' learning. In all sessions, participants watched pre-recorded "tutoring/content delivery". Physics was the content domain used in all conditions. The physics content scripts were developed by a physics professor at the university where the research was conducted. In the Breakdown Scenario condition, participants were presented a scenario that does not work as expected. The participants were then asked to explain the rationale (i.e., the physics principle) for why the scenario was not working. In the Deep Questions condition, participants were given questions that could only be answered by having a conceptual understanding of the material being covered. The questions were classified as deep according to an existing question taxonomy (Graesser & Person, 1994). The Intra-testing condition required students to complete a mathematically based physics problem. The control condition was an information delivery of the content.

Results

Initial data analysis revealed the largest differences between the Breakdown Scenarios condition and the Control condition. Because of this, Deep Questions and Intra-testing were removed from subsequent analyses. Results revealed that participants in the Breakdown Scenarios ($M = 2.55$) learned significantly more from pretest to posttest compared to participants in the Control condition $(M = .83)$, $t\,(55) = 2.316$, $p = .024$, $d = .63$. Additionally, a significant pairwise comparison was discovered between Condition and Attributional Complexity. More specifically, participants with high Attributional Complexity in the Breakdown condition ($M = 3.00$) had significantly higher pretest to posttest change scores compared to those with high attributional complexity in the Control condition ($M = .941$), $p = .03$. Results revealed multiple significant pairwise comparisons between Condition and Goal Orientation. Participants in the Breakdown Scenario with Performance Approach Goal Orientation ($M = 4.60$) learned significant more than participants in the Control with Performance Approach Goal Orientation ($M = .917$), $p = .019$.
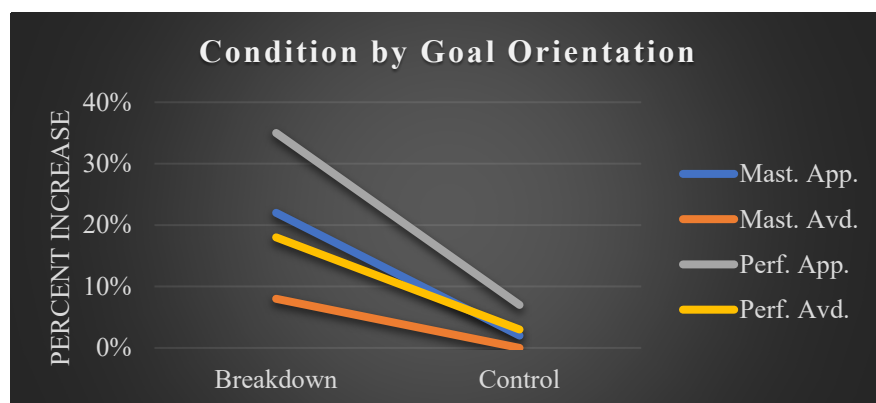
Figure 1. Learning gains for condition by goal orientation interaction.
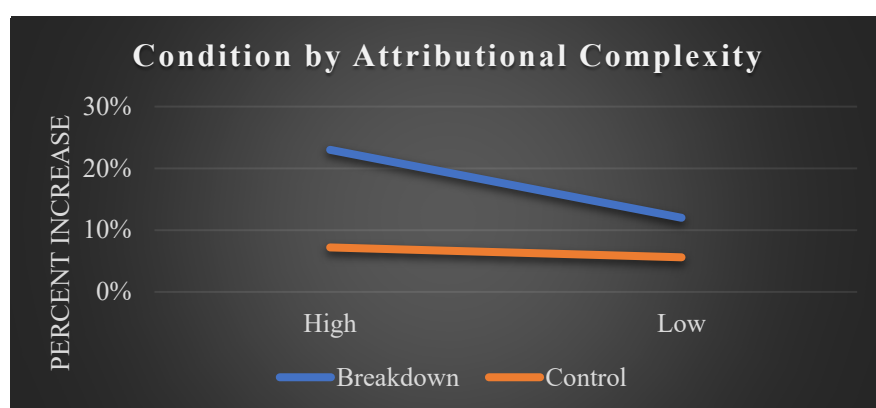
Figure 2. Learning gains for the condition by attributional complexity interaction.

Scholarly significance

Adding to the body of research on emotions and learning, results suggest that *Breakdown Scenarios* were the most effective method to induce an impasse which in turn led to the highest learning gains compared to lecture based information delivery. It is the opinion of the authors that the reason for the lack of significant learning taking place in the remaining conditions was due to the presence of frustration or hopeless confusion rather than a state of productive confusion. Frustration occurs when an individual experiences repeated failures and is stuck. Persistent (or hopeless) confusion occurs when conflict resolution fails and an individual is unable to restore equilibrium. The learners in the *Breakdown Scenarios* were most likely to engage in conflict resolution given the nature of the different interventions. This conflict resolution required the learners in the *Breakdown Scenarios* to stop, think, effortfully deliberate, problem solve, and revise their existing mental models which in turn led to a deeper understanding and retention of the physics content being delivered. Educators need to think about confusion in learning as an elastic slingshot. It has the potential to propel some learners into higher altitudes of understanding. However, pull too tight and the elastic breaks resulting in negligible or negative learning gains.

References

Craig, S. D., Graesser, A. C., Sullins, J. & Gholson, B. (2004). Affect and learning: An exploratory look into the role of affect in learning. *Journal of Educational Media, 29*, 241-250.

D'Mello, S. K., & Graesser, A. C. (2011). The half-life of cognitive-affective states during complex learning. *Cognition and Emotion*, 25(7), 1299-1308.

D'Mello, S. K., Lehman, B. A., Pekrun, R., & Graesser, A. C. (2014). Confusion can be beneficial for learning, *Learning & Instruction*, 29(1), 153-170.

Graesser, A. C., & Person, N.K. (1994). Question asking during tutoring. *American Educational Research Journal, 31*, 104-137.

Examining Sixth Graders' Science Identity Development in a Multimodal Composing Environment

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Abstract: This study explored sixth graders' science identity development in an integrated STEAM course. Data sources include online surveys, semi-structured group interviews, and students' multimodal artifacts. The results showed that (1) Multimodal composing practices extended students' understanding of scientific knowledge and practices; (2) Taking the role of scientist made students actively think about what scientists would do in their professions; (3) Some students developed hybrid roles to resolve science identity conflicts and transitions.

Keywords: science identity, role-taking, multimodality, scientific knowledge and practice

Introduction

As students may identify themselves as constructors, consumers, or critics of science knowledge, one challenge in science education is to help students develop appropriate science identities (National Research Council, 2017). Although much work has been devoted to investigating and supporting students' science identity development over time (Barron et al., 2010; Carlone, 2017; Van Horne & Bell, 2017), little is known about their perceptions of their own science identity development. Moreover, a growing body of research on digital multimodal composing has shown promise for facilitating the development of disciplinary identities (Smith, 2017). However, most of the studies focused on the cultivation of literate identities and there is a lack of research in exploring the effect of multimodal composing on disciplinary identity development beyond literacy.

Taking on these challenges, we developed an integrated STEAM course that aimed to facilitate students' disciplinary identity development. Two design features were utilized in the course to realize this goal. First, role-taking was used as an explicit means to facilitate students' disciplinary identity development. Second, the course was driven by multimodal composing, through which students' disciplinary identity development could be expressed in multiple ways. The study investigated the following research question: *How did playing the role of scientist while multimodal composing contribute to science identity development?*

Theoretical framework

We employ a sociocultural perspective that people embody a collection of roles in different organizations and communities (McCall & Simmons, 1966; Stryker & Burke, 2000). From this perspective, a science identity is enacted when a person demonstrates normative science knowledge and practices (Carlone & Johnson, 2007), shows positive attitude towards science and science related careers (Archer et al. 2010), and gains recognition as a legitimate participant by self and others in various communities related to science (Lave & Wenger, 1991).

We also draw a social semiotic approach to multimodality (Jewitt, 2010; Kress, 2010). A multimodality framework posits that individuals make meaning with multiple modes and identities are developed through multimodal composing processes and products (Halverson, 2010).

Methods

The STEAM course was offered as an elective for 6th graders in a public, magnet school in a large southeastern city in the United States. A total of 32 students enrolled in the course. The course was driven by a final project to create a multimodal science fiction and students worked in small groups of three to five on their projects. Besides working on their projects, major course activities included technological training, science lessons, guest lectures and lab visits led by faculty members from the university, and multimodal reflections (Smith & Dalton, 2016). The students used iKOS (ikos.miami.edu) to create knowledge entries and chapters for their multimodal science fictions.

When working on their final project, each student selected one of the following roles with the requirement that each group had to have at least one writer and one scientist: writer (developing the narrative), scientist (integrating science), and designer (creating multimodal representations). Despite the differentiated roles, team members were asked to collaborate with each other on their tasks.

Data analysis involved recursively coding online surveys, semi-structured group interviews, student artifacts, and multimodal reflections to compare cases and generate crosscutting themes related to science identity development.

Findings

Nine students (Female: 4; Male: 5) selected the role of scientist and they are the focus of this study. Through our analysis, three themes related to science identity development emerged.

First, the students extended views on how to represent science knowledge through multimodal composing. All of the nine students created multimodal artifacts that integrated a variety of text, images, comics, animations, videos, and charts to represent science knowledge. Through creating multimodal artifacts in the course, eight out of the nine students developed new and broader perceptions of representations of science knowledge and six out of the nine students identified being a scientist as a future career. Thus, leveraging interests in using multiple modes as resources to access, learn, investigate, engage, communicate and represent science had the power to forge science identities.

Second, the students developed extended views of scientific practices (e.g., online researching and collaboration) and enjoyed their role as a scientist. Through taking the role of scientist, seven out of the nine students reconceptualized what science is and what scientists can do. Taking the role of scientists did not guarantee that students would pursue a future career in science, but it made students actively thought about what scientists would do, instead of purely focus on scientific knowledge.

Lastly, the students were consistent in reporting that they eventually ended up with hybrid roles. Regardless of role preferences or level of interests in science, all students changed from scientists to hybrid roles, which consisted of a combination of the role of scientists with other roles. The hybrid roles enabled students to learn science concepts and represent science ideas from the perspectives of different roles. The discrepancy between their preferred professional identity and roles in the team rendered visible issues of identity conflict and transition.

Discussion and implication

In this study, we examined students' science identity development through role-taking and multimodal composing. Our findings indicate that multimodal composing creates an alternative space for students to express and author science identities. This finding highlights the importance of allowing multiple points of entry for students to practice science and express their understanding. We also found that students actively investigated and reflected on what scientists would do as a profession while taking the role of scientists. The finding points to the potential of embedding students in the role of scientists that can foster students' interest in science and motivation to pursue science as a career. In addition, students ended up with hybrid roles in this program. This phenomenon calls attention on helping students make connections between a science identity and other more preferred identities.

This work contributes to the research on science identity development by exploring the ways that playing the role of scientist and multimodal composing provided unique opportunities for sixth graders to engage in science, to develop identities in science, and to see and understand science differently. Also, it contributes to designing learning environments in facilitating the youth to develop disciplinary identities.

Selected references

Carlone, H. B., & Johnson, A. (2007). Understanding the science experiences of successful women of color: Science identity as an analytic lens. *Journal of research in science teaching, 44*(8), 1187-1218.

Kress, G. (2010). *Multimodality: A social semiotic approach to contemporary communication*. New York: Routledge.

Lave, J., & Wenger, E. (1991*). Situated learning: Legitimate peripheral participation.* Cambridge university press.

McCall, G. J., & Simmons, J. L. (1966). *Identities and interactions*. New York: The Free Press.

Smith, B. E. (2017). Composing across modes: A comparative analysis of adolescents' multimodal composing processes. *Learning, Media and Technology, 42*(3), 259-278.

Stryker, S., & Burke, P. J. (2000). The past, present, and future of an identity theory. *Social psychology quarterly*, 284-297.

Van Horne, K., & Bell, P. (2017). Youth disciplinary identification during participation in contemporary project-based science investigations in school. *Journal of the Learning Sciences, 26*(3), 437-476.

'I Think It's Kind of Made Everybody a Little Closer:' A Virtual Platform Extending Parent Learning as Community of Practice

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Abstract: Analysis of interviews with parents in a program for families with young children revealed evidence of Community of Practice domain knowledge and shared practice. Membership (inclusive of children and staff), relationship values, learning processes and context features were community elements experienced, and when using an online social platform. Online spaces for parents that complement offline community, continue a focus on their children, and that are 'socially secure' may foster engagement that extends learning.

Keywords: Parenting, Community of Practice, Social Learning, Online Communities

Parent learning as community

Sociocultural perspectives on parenting recognize how domain knowledge is constructed through observation and mentorship of others, and through wider interactions with social settings, actors and systems (e.g., Marienau & Segal, 2007; Rogoff, 2003). Parenthood is also a life role that changes the conception of oneself (Azar, 2003). Shifts in identity that occur are also influenced by interactions in the parent's social context. The Community of Practice (CoP) framework (Wenger, 1998) is suitable to apply to parent social learning, particularly when parents intentionally gather in practice groups (Campbell & Palm, 2018). Theoretically, relationships of mutual engagement as a community that bind parents together into a meaningful social entity would be constructive to improving the quality of practice (Laluvein, 2008). And complementary online platforms that foster continued community engagement for parents would contribute to learning and relational benefits (Nieuwboer, Fukkink, & Hermanns, 2013). One such group on which to test the CoP perspective is Early Childhood Family Education (ECFE). Throughout Minnesota, school districts offer parents and young children (Birth to 5years) 2 hour weekly sessions in which they learn with other dyads, then separate into classes of parents or children. Continuous enrollment during early childhood years offers a context that promotes group identity. In 2017, a social engagement platform designed with ECFE parents and staff was launched (Walker, 2017). Parentopia.org is a closed platform that promotes class and site (multi-class) discussion, private messaging, and general program information. ECFE's method of parent learning through facilitated group interaction, and introduction of a novel platform for engagement offered the chance to investigate the presence of Community of Practice elements in offline and online settings.

The study engaged parents at an urban ECFE site in which the parentopia platform was collaboratively designed. Only a few parents in the current year had been involved in platform creation. The sample purposely represented site families by class membership, ECFE experience (e.g., 6 were new to the program, 6 were in their 3rd year) and demographics. Parents reported between 1 and 6 children (mean = 2.7, SD = 1.7). Parent age ranged from 20-57 (mean = 35.3, SD = 1.5). Twenty five in depth, semi-structured interviews explored parents' perceptions about participation in the program and use of the platform. Interviews were conducted by trained research staff, then transcribed and open coded for sensitizing concepts related to domain, practice and community aspects using Wenger's (1998) definitions as a guide (LaRossa, 2005). Axial coding across all cases examined dominant themes. This confirmed evidence of CoP learning and identified features characteristic of this learner population and context, and explored the potentially complementary nature of the online platform.

Learning as Community of Practice offline and online

Two dominant themes in *domain learning* for ECFE parents who participated in the weekly program were 1) long term goals for their children (e.g., fostering the child to be his or her best self, nurturing a well-functioning citizen) and 2) immediate topical concerns of childrearing (e.g., child health, safety, managing tantrums, technology exposure). *Shared practice* themes were 1) strategies that promote their child's development and 2) self-care and development (e.g., to not ignore stress). *Community* themes (Table 1) included membership, relationship value, social learning processes, and context dimensions. Other parents as peer learners were dominant community members mentioned, yet parents' own children, the staff and other site families figured into characterizations of community infrastructure. Parents expressed value in seeing their own children learn, were motivated to attend ECFE because of their children, and enjoyed expanding their network with parents who were less familiar, yet who share the ECFE identity. Social learning processes involved sharing and

problem solving (with peers), and observation (of children), both skillfully facilitated by professionals. Relationships provided parents with emotional and practical support, extended into other life spaces (e.g., the neighborhood, the child's school), and helped reinforce the parenting identity. The learning context was described as one of safety, consistency, inclusion and democracy.

Table 1. Community themes evident in ECFE participation and/or in engagement with Parentopia

	ECFE participation	Parentopia engagement
Themes		
Membership	Own children Class parents Staff Parents in other classes	Own children Staff Class adults Parents in other classes
Social learning processes	Mutual problem solving Skilled facilitation Directed observation	Observation of annotated images Continued class conversation 1-1 contact with staff, parents
Relationship value	Supportive friendships Diverse perspectives Extend into community, w/child Shared identity	Diverse perspectives Reduced isolation Reinforce program, class identity
Context	Trusted, safe space Supportive tone	Private, secure, safe space Supportive tone

Most parents reported logging into parentopia, reading program information, viewing and/or creating posts in the two months since launch; four had not revisited after account creation. Comments offered little on CoP domain or practice dimensions, but related primarily to community (Table 1). Parents expressed joy at seeing images of their children shared by staff, the opportunity to continue conversation or make 1-1 contact or post in class or site wide forums for personalized problem-solving. Exposure to parents in site wide postings seen supported building connections and exposure to diverse perspectives. Parents appreciated the 'socially secure' nature of the platform that maintained membership and the supportive tone of ECFE, and protected information about their children. They often compared their experiences with Facebook, which felt less hospitable.

Though preliminary and limited by one sample, analysis from the voices of a diverse group of parents suggests that a weekly program with other families can promote learning through Community of Practice principles. Intentional design and implementation of a virtual platform to facilitate parent and staff connectivity and information sharing may extend CoP benefits for learning, identity and social support that promote competent parenting. A key lies in providing parents with online spaces that are secure, feel judgment free, are easy to navigate, include staff and provide safe access to visual, annotated information about their children.

References

Azar, S. T. (2003). Adult development and parenthood: A social-cognitive perspective. In J. Demick & C. Andreoletti (Eds.), *Handbook of adult development* (pp. 391-415). New York: Springer.

Campbell, D & Palm, G. (2018) *Group parent education: Promoting parent learning and support*. New York: Centgage.

LaRossa, R. (2005). Grounded theory methods and qualitative family research. *Journal of marriage and Family*, *67*(4), 837-857.

Laluvein, J. (2010). Parents, Teachers and the "Community of Practice."The Qualitative Report, 15(1), 176-195.

Marienau, C. & Segal, J. (2006). Parents as developing adult learners. *Child welfare*, *85*(5), 768-784.

Nieuwboer, C. C., Fukkink, R. G., & Hermanns, J. M. A. (2013). Online programs as tools to improve parenting: A meta-analytic review. *Children and Youth Services Review, 35*(11), 1823-1829.

Rogoff, B. (2003). *The cultural nature of human development*. New York, NY: Oxford University Press.

Walker, S. (2017). Creating Parentopia: Design-based research to develop an interface for parent learning communities and networks. *Proceedings of the 12th annual international conference on Computer Supported Collaborative Learning*, Philadelphia, PA, June 22.

Wenger, E. (1998). *Communities of Practice Learning, Meaning and Identity*, Cambridge University Press, Cambridge.

The Effect of Inhibiting Hand Gestures on Mathematical Reasoning

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Abstract: Gestures are associated with powerful forms of mathematical understanding. However, determining the causative role of gestures has been more elusive. In the present study, we inhibit students' gestures by restraining their hands, and examine how this impacts their problem-solving when presented with geometric conjectures to prove. We find no effect for gesture inhibition across a variety of measures.

Background

Embodied views of cognition posit that mental processes are rooted in perceptual and motor systems (Wilson, 2002). One way in which mathematical reasoning is embodied is through gesture. Learners' tendency to gesture predicts learning and performance in mathematics (Cook & Goldin-Meadow, 2006), and recent studies in geometry specifically have suggested that students who gesture more and who gesture in specific ways tend to communicate more accurate geometry proofs (Nathan et al., 2014; Nathan & Walkington, 2017). However, it is unclear from such prior work on gestures whether gestures are simply a byproduct of valid mathematical reasoning, or a causative factor. One way to experimentally manipulate gesture is through gesture inhibition.

Inhibiting gestures by having learners tap in patterns while solving problems leads to weaker performance (Hegarty et al., 2005). Inhibition methods where the hands are restrained have been found to impair simple recall (Frick-Horbury & Guttentag, 1998; Goldin-Meadow et al., 2001; Wagner et al., 2004) and fluency of speech with spatial content (Rauscher et al., 1996). Prior research has not examined how gesture inhibition impacts *mathematical reasoning,* which has important visual, spatial, and motoric properties. Research has also not examined whether effects vary based on learner characteristics. Here we examine how inhibiting gesture impacts mathematical reasoning and speech. Our research questions are:

1) How do speech patterns and recall vary when learners are inhibited or not inhibited from gesturing?

2) How does gesture inhibition impact performance on geometry proof tasks?

Methods

Undergraduate and graduate students (*n* = 107, 48 male and 59 female, 50 STEM majors) from a private university were recruited to participate. After pre-measures (geometry pre-test, spatial visualization test, phonemic fluency test), they were presented with 8 geometry conjectures to prove (e.g., the triangle inequality) while standing in an empty room. For 4 of the 8 conjectures, they were inhibited from gesturing by putting their hands in oven mitts attached to bottles attached to a music stand. When they completed all 8 conjectures, participants were asked to, while uninhibited, recall as many of the conjectures as possible.

Participants were video recorded and their speech was transcribed in Transana. Participants' oral proofs for each conjecture were scored 0/1 in terms of correct or incorrect using a codebook developed from the criteria for valid mathematical proofs given by Harel and Sowder (2005). Valid proofs involve (1) operational thought, where provers perform valid operations on mathematical objects and observe their results, (2) logical inference, where provers progress through a deductive structure, and (3) generality, where provers show the conjecture holds for all cases. Inter-rater reliability (kappa) of .80 was achieved. The transcripts of participant speech were entered into Coh-metrix (McNamara, Louwerse, Cai, & Graesser, 2013) and LIWC (Pennebaker et al. 2007).

Data were analyzed using mixed effects logistic regression models. Random effects included participant, conjecture, and order. Controls included gender, language status, and highest prior math course. Expertise variables included geometry pretest score, spatial visualization score, STEM/non-STEM major, and phonemic fluency score. Whether the participant was inhibited or not inhibited for the trial was the treatment variable of interest. Speech predictors were not tested in regression models, due to screening *t*-tests of 155 different language measures all showing null results for the difference between inhibited and uninhibited trials.

Results

Analyses showed that gesture inhibition had no impact on any of the 155 speech categories measured by the text-mining tools. Gesture inhibition had no effect on either conjecture recall or on participants' ability to

formulate a valid intuition (defined as a correct true/false judgment), insight (defined as a partially correct proof), or proof for a geometry conjecture. These results run counter to other gesture inhibition studies in other domains. There were no significant interactions between inhibition and student expertise or control variables.

Discussion and significance

Prior research has suggested relatively uniform, detrimental effects for gesture inhibition on language and recall tasks, but few studies have examined how being prevented from gesturing impacts complex problem solving in a domain like secondary mathematics. In addition, prior research has shown that gesturing is generally associated with formulating valid geometric proofs (Nathan et al., 2014), but here we directly manipulate gesture to make inferential claims. We discovered that gesture inhibition has no effect on a variety of outcome measures – including speech patterns when justifying geometric conjectures, tendency to be able to recall a conjecture, and giving valid intuitions, insights, and proofs for conjectures. Analyses of interaction effects suggested gesture inhibition had no effect regardless of gender, language status, geometry knowledge, spatial skills, phonemic fluency, college major, or math course-taking history. However, we did find that even when their hands were inhibited, participants still made mathematical gestures with their heads, eyes, shoulders, etc., suggesting that the utility of gesture inhibition through hand restraint may be somewhat limited.

One explanation for this set of findings is that gesture is merely a byproduct of – rather than a causative factor in – valid geometric reasoning. In other analyses, we found that students who tended to do better at these geometry tasks also tended to gesture more. But these results suggest their gestures were not *influencing* or *causing* their valid reasoning. Thus, promoting completely unstructured, undirected gesture may not be an ideal approach to support embodied reasoning. Instead, gestural interventions should consider carefully how students can be instructed to or encouraged to gesture in particular, productive ways.

References

Alibali, M. W., Kita, S., & Young, A. J. (2000). Gesture and the process of speech production: We think, therefore we gesture. *Language and cognitive processes*, *15*(6), 593–613.

Cook, S. W., & Goldin-Meadow, S. (2006). The role of gesture in learning: Do children use their hands to change their minds?. *Journal of cognition and development*, *7*(2), 211-232.

Frick-Horbury, Donna & Robert E. Guttentag (1998). The effects of restricting hand gesture production on lexical retrieval and free recall. *American Journal of Psychology*, *111*, 43–62.

Goldin-Meadow, S., Nusbaum, H., Kelly, S., & Wagner, S. (2001). Explaining math: Gesturing lightens the load. *Psychological Science*, *12*, 516–522.

Harel, G., & Sowder, L. (2005). Toward comprehensive perspectives on the learning and teaching of proof. In F. Lester (Ed.), *Second handbook of research on mathematics teaching and learning*, Reston, VA: National Council of Teachers of Mathematics.

Hegarty, M., Mayer, S., Kriz, S., & Keehner, M. (2005). The role of gestures in mental animation. *Spatial Cognition and Computation*, *5*(4), 333-356.

McNamara, D. S., Louwerse, M. M., Cai, Z., & Graesser, A. (2013). Coh-Metrix (Version 3.0) [Software]. Available from http://cohmetrix.com/

Nathan, M. & Walkington, C. (2017). Grounded and Embodied Mathematical Cognition: Promoting Mathematical Insight and Proof Using Action and Language. *Cognitive Research: Principles and Implications, 2*(1), 9.

Nathan, M. J., Walkington, C., Boncoddo, R., Pier, E. L., Williams, C. C., & Alibali, M. W. (2014). Actions speak louder with words: The roles of action and pedagogical language for grounding mathematical proof. *Learning and Instruction, 33,* 182–193.

Pennebaker, J. W., Booth, R. J., Boyd, R. L., & Francis, M. E. (2015). Linguistic Inquiry and Word Count (LIWC2015) [Software]. Available from http://www.LIWC.net/

Wagner, S., Nusbaum, H., & Goldin-Meadow, S. (2004). Probing the mental representation of gesture: Is handwaving spatial? *Journal of Memory and Language*, *50*, 395–407.

Wilson, M. (2002). Six views of embodied cognition. *Psychonomic Bulletin and Review, 9,* 625–636.

Acknowledgments

Measuring Students Epistemic Understanding of, and Beliefs About, Political Media

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Abstract: Media, information, and critical literacy have long been viewed as key to developing informed and active citizens. However, there has been little focus in civic education on developing young peoples' epistemic understanding of media used in politics or personal reflections on their own role in this media culture, both of which are key to effective youth engagement with politics in the media age. Quality models for measuring students' abilities to perform in these areas are virtually non-existent. Here we describe our measures of epistemic understanding of political media and self-efficacy for political engagement.

Introduction and context

Political and civic actions today occur as often through social media networks and commercial media as they do on the streets or in the voting booth. Further, the self-curation of information through social media and traditional media selection, the so-called "filter bubble" (Iyengar & Hahn, 2009; Pariser, 2011), has contributed to the effectiveness of propaganda, disinformation campaigns, and the rise of "fake news."

Numerous programs are currently attempting to address the recent "fake news" crisis in news literacy and civic online reasoning (e.g., McGrew, Ortega, Breakstone, & Wineburg, 2017). None of these models factor in the social or political contexts of how and why young people engage with particular sources in the first place – nor do they focus on young people's abilities to effectively take political action in the contemporary political environment. Here we describe our attempts to measure epistemic understanding of political media and their skills and self-efficacy for engaging in political action through media. We do this within the context of our Virtual Internship (VI) simulation, PurpleState Solutions. In PurpleState, students play the role of interns at a political communications firm to engage in developing skills and knowledge for democratic and media education. VI's are designed using the epistemic game model (Shaffer, 2006a, 2006b) to develop expertise in an environment modeled on communities of professional practice. In the VI, students learn political communications concepts and then design a media campaign for a special interest group to PurpleState voters for or against a proposed ban on hydraulic fracturing or "fracking" in Virginia (USA).

Measures

The open-ended measures of knowledge of the issue and epistemic understandings of political media and political media strategies were used in pre and post-questionnaires in all three iterations of the simulation in Virginia and Wisconsin (n=103 total) for this design-based research project. These measures were used to examine changes in participants' epistemic understandings of political media and role of media in politics and their ability to apply the media strategy they learned to a different but related context (near transfer). Open-ended tasks, such as evaluating different forms of political media, illustrated participants' understandings of how media is used to strategically persuade voters (e.g., use of evidence, persuasive techniques), and their epistemic understanding of political media.

The relationship between knowledge of the issue, why it is controversial, and having confidence in both their knowledge of the issue and confidence in being able to take action that is meaningful provides strong evidence that participants will be more likely to engage in the future (Levy, 2011). Therefore, we were also interested in studying the impact of the simulation on the participants' self-efficacy for political engagement (e.g., Levy, 2011; Morrell, 2005; Zhang, Torney-Purta & Barber, 2012). Over the three iterations we adapted previous scales of measures for self-efficacy for political engagement that better reflect the nature of political engagement represented in the current political context, and the rise of participatory media culture in general, as well as to align with the simulation (Chinn & Buckland, 2011).

Measures of issue knowledge and political media strategy transfer

Open-ended tasks were scored and showed significant increases among participants at each iteration (n=103) in their understanding of the issue, why it was controversial, and in their ability to apply media strategy to a new local policy issue. For example, we asked participants "Why is the use of the fracking process considered a controversial public policy issue in the US?" to assess their understanding of different perspectives on the issue.

In order to understand the media strategies used in the VI and their ability to transfer these strategies to a similar problem, we asked participants what media strategy advice they would give someone running for state office.

Measures of epistemic understanding of political media

We were interested in particular in participants' abilities to analyze political media utilizing political communications concepts (e.g., persuasive techniques) and in the behaviors related to epistemic understandings of political information. Two items in particular were used. The first is a series of items asking participants to analyze a political ad for its intended audience, message, and persuasive techniques used. The second is a social media post from a political group that includes polling data for how citizens of Maryland viewed the issue of fracking. This item asked students to evaluate the information it contained, as well as to identify and provide a rationale for their actions if they were to see this post in their social media. They first provided a ranked order of options (e.g., ignore, seek out corroborating sources, analyze the organization), and provide a rationale for why they made these choices. This item in particular gave us a sense of their epistemic aims with political media.

Measures of self-efficacy for political engagement

After utilizing commonly used measures for self-efficacy for political engagement (e.g., Levy 2011) for the first iteration of the VI, we realized that these items needed to be adapted to reflect contemporary political engagement and to better align with the simulation. In adapting the self-efficacy items for this study, we followed Bandura's (2006) recommendations on constructing self-efficacy items. Students' confidence for being able to engage politically was measured before and after participation in the Purplestate VI using a 10-item instrument [α=.89(t0), .95(t3)]. The tasks identified for civic engagement centered on: (1) discussing political issues and constructing good arguments (e.g., "how confident are you that you could construct good arguments about political issues?"); (2) critically navigating digital media spaces that contain political messages (e.g., "how confident are you that you could use social media to effectively communicate about controversial political issues?"); and (3) taking some sort of political action (e.g., "how confident are you that you could do something to get local officials to address a problem?"). These items do not comprise a comprehensive list of civic engagement activities. However, these 10 items were identified because they align with the central activities of PurpleState.

Discussion and implications for future research

If students are knowledgeable on controversial issues, understand why it is controversial, and feel confident about their understanding of the issue, there is a greater likelihood that they may be able to effectively take action on that issue (Levy, 2011). The measures developed here serve as a model for developing and adapting measures of epistemic understanding, self-efficacy, and behaviors related to contemporary political engagement and information literacy. They provide an update to traditional measures and a methodological example of how to develop measures that tightly align with a particular curricular intervention as part of a design-based study. Finally, these measures go beyond simple strategies for evaluating information common in the current news literacy approaches to understand young people's capacity for engaging in the contemporary and complex political environment.

References

Iyengar, S., & Hahn, K. S. (2009). Red media, blue media: Evidence of ideological selectivity in media use. *Journal of Communication, 59*(1), 19-39.

Levy, B. M. (2011). Fostering Cautious Political Efficacy Through Civic Advocacy Projects: A Mixed Methods Case Study of an Innovative High School Class. *Theory & Research In Social Education, 39*, 238-277.

McGrew, S., Ortega, T., Breakstone, J., & Wineburg, S. (2017). The challenge that's bigger than fake news: Civic reasoning in a social media environment. *American Educator, 41*(3), 4-9.

Morrell, M. E. (2005). Deliberation, democratic decision-making and internal political efficacy. *Political Behavior, 27*(1), 49-69.

Pariser, L. (2011). *The filter bubble: What the Internet is hiding from you*. London, U.K.: Penguin Press.

Shaffer, D. W. (2006a). *How computer games help children learn*. New York, NY: Palgrave MacMillan.

Shaffer, D. W. (2006b). Epistemic frames for epistemic games. *Computers & education, 46*(3), 223-234.

Stoddard, J. (2014). The need for media education in democratic education. *Democracy & Education, 22*(1). Retrieved from http://democracyeducationjournal.org/home/vol22/iss1/4

Zhang, T., Torney-Purta, J., & Barber, C. (2012). Students' conceptual knowledge and process skills in civic education: Identifying cognitive profiles and classroom correlates. *Theory and Research in Social Education, 40*(1), 1-34.

Tracking the Flow of Discussion Topics in an Inquiry Science Unit

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Abstract: Inquiry-based curricula may leverage distributed knowledge by interleaving individual, small-group, and whole class activities. We tracked topics across multiple activities to study how topics are distributed and consolidated in a science unit. Embedded prompts guided students' discussion toward key topics, while the teacher helped students take greater responsibility for managing whole class discussions over time. These findings demonstrate how embedded prompts and teacher facilitation can scaffold knowledge sharing across individual, small-group, and whole class levels.

Introduction

In inquiry-based curricula, students may build knowledge by interacting with people, tools, and technology over time (Pea, 1993; Hmelo-Silver et al., 2007). Cyclical processes of generating questions, researching concepts, and developing explanations help students to externalize, negotiate, and revise their thinking at the individual, small group, and whole class levels (Hmelo-Silver et al., 2007; Wertsch, 1984; Tabak & Reiser, 1997; Mercer et al., 2004). Interleaving individual and collaborative activities helps students to explore their own inquiry while developing deeper understandings than they could on their own, especially when teachers help students to connect their distributed knowledge (Mercer et al., 2004; Woodruff & Meyer, 1997; Tabak & Reiser, 1997).

To understand the distribution and consolidation of curricular topics during an inquiry-based science unit, we tracked how students discussed topics when using individual notebooks, researching in small groups, and participating in whole class discussions. We focused on e-textbook sessions that included cycles of generating questions, researching content, and sharing findings with the class. In particular, we examined how embedded inquiry prompts in the notebooks shaped students' research, and how teacher facilitation encouraged students' sharing in whole class discussions. Our research question was: *how do curricular topics move across individual, small group, and whole class levels over time, as supported by embedded inquiry prompts and teacher facilitation?* This question has implications for how students leverage others' research as topics flow from individual artifacts to a collective knowledge base in an inquiry classroom.

Methods

We selected three groups of students working in groups of four ($N = 12$) in an eighth-grade public school classroom, located in a small Midwestern U.S. city. As part of a larger study, students participated in *Make Your Own Compost*, an eight-week science unit that challenged students to design an ideal compost. To inform their designs, students participated in research sessions with an e-textbook (VidyaMap) at three points in the unit, which we selected for study. VidyaMap displays content about biology topics and the relationships between those topics. To help students navigate toward content about compost, we embedded inquiry prompts in students' notebooks to guide question generation about topics that might improve their designs (e.g., abiotic factors). Students then discussed their questions and research as small groups and the whole class. Collaborative activities (e.g., small group and whole class discussions) created opportunities for students to share, negotiate, and revise their understanding.

To analyze how topics moved across individual, group, and class levels, we tracked the presence of topics in students' individual notebooks (120 pages), small-group discussions (90 minutes), whole class discussions (129 minutes), and log data from VidyaMap (176 records). We included topics when they were part of a statement or question involving reasoning (for notebooks and discussion) or were viewed for a minimum of 10 seconds (for log data). Next, we created matrices of each topic discussed by each student, group, and the whole class. We then identified patterns across levels, which we considered to be salient topics for the class. We also looked at how the teacher engaged in class dialogue with students by generating Markov models for teacher and student turns of talk during the three whole class discussions.

Findings

First, we discuss how embedded inquiry prompts guided student's discussions. The prompt for Session 1 (What factors help decomposers break down matter?) resulted in individual notes about moisture and temperature, which were also discussed by small groups and the whole class. Groups added biotic factors, carbon, compost, ecosystems, and water to their research. In the whole class discussion, students emphasized temperature (15.1%

of turns) and abiotic factors (10.6%). Undiscussed topics in individual notes included air and oxygen. Next, the prompt for Session 2 (Where does the energy for life come from?) resulted in individual notes about plants, producers, and sunlight, which were also discussed by small groups and the whole class. Groups also researched energy and photosynthesis. In the whole class discussion, students emphasized conservation of energy and matter (36.1% of turns) and producers (27.8%). Undiscussed topics in individual notes included air and oxygen. Last, the prompt for Session 3 (What is an ecosystem?) resulted in individual notes about abiotic factors, biotic factors, compost, consumers, decomposers, ecosystems, and producers; these were also discussed by small groups and the whole class. Groups focused on compost and ecosystems in their research. In the whole class discussion, students emphasized dependence in food webs (70.9% of turns) as they discussed consumers, decomposers, producers, energy, plants, and soil. Undiscussed topics in individual notes included biodiversity, oxygen, and water.

Next, the Markov models of whole class discussions (Table 1) showed a decrease in teacher talk over time. The probability of a student following up after another student was 14% in Session 1, but this significantly increased to 46% in Session 2 ($z = -8.0995$, $p < 0.001$) and 50% in Session 3 ($z = -9.1975$, $p < 0.001$). Correspondingly, the probability of the teacher following up after a student decreased from 86% in Session 1 to 54% in Session 2 and 50% in Session 3. Overall, the teacher limited his interjections into student talk over time, indicating that students took on greater responsibility for managing their whole class discussions.

Table 1: Markov models of turns of talk during whole class discussions

Conclusion

Inquiry-based curricula may encourage students to access different resources and consolidate their knowledge as a class. In an effort to understand this process, we tracked how curricular topics moved across individual, small-group, and whole class levels during students' research sessions with an e-textbook in a science unit. We found that embedding inquiry prompts in individual notebooks helped guide students' inquiry toward important topics for understanding and improving their compost designs. Students also took on greater responsibility for managing their class discussions over time as the teacher facilitated increasingly student-centric discussions about topics related to the embedded prompts. This study creates an opportunity for further research about how embedded prompts, teacher facilitation, and e-textbook content can serve as synergistic scaffolds in a middle-school inquiry science unit.

References

Hmelo-Silver, C. E., Duncan, R. G., & Chinn, C. A. (2007). Scaffolding and achievement in problem-based and inquiry learning: A response to Kirschner, Sweller, and Clark (2006). *Educational Psychologist*, *42*(2), 99-107.

Mercer, N., Dawes, L., Wegerif, R., & Sams, C. (2004). Reasoning as a scientist: Ways of helping children to use language to learn science. *British Educational Research Journal*, *30*(3), 359-377.

Pea, R. D. (1993). Learning scientific concepts through material and social activities: Conversational analysis meets conceptual change. *Educational Psychologist*, *28*(3), 265-277.

Tabak, I., & Reiser, B. J. (1997, December). Complementary roles of software-based scaffolding and teacher-student interactions in inquiry learning. In *Proceedings of the 2nd international conference on Computer support for collaborative learning* (pp. 292-301). ISLS.

Wertsch, J. V. (1984). The zone of proximal development: Some conceptual issues. *New Directions for Child and Adolescent Development, 1984*(23), 7-18.

Woodruff, E., & Meyer, K. (1997). Explanations from intra-and inter-group discourse: Students building knowledge in the science classroom. *Research in Science Education*, *27*(1), 25-39.

Acknowledgments

Supporting the Development of Teacher Candidate Formative Assessment Practice

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Abstract: Formative assessment holds great promise as a strategy to support student learning (Black & Wiliam, 1998), however, it proves difficult for teachers to learn to do well (Box et al., 2015). This case study explores how a teacher candidate learned to enact formative assessment with the support of a community of practice.

Introduction

Formative assessment is used in the midst of instruction to draw out student ideas. Once ideas are surfaced teachers can interpret what students know and adapt instruction accordingly with the goal of improving teaching and learning (NRC, 2001). Since the publication of Black and Wiliam's 1998 review, many empirical studies have focused on supporting teachers as they learn to use formative assessment (e.g. Box et al., 2015; Furtak, 2012). However, few studies have focused on teacher candidates and how they might be supported as they learn about formative assessment. This case study aims to explore how one teacher candidate learned to enact formative assessment, using the tools and resources of her community, during her student teaching semester.

Theoretical and conceptual framework

I use a communities of practice (Wenger, 1998) framework to understand learning through participation. In communities of practice, individuals participate in, adapt and co-construct practices together, shaped by available tools and resources (Wenger, 1998).

Although research supports the use of formative assessment, studies have found that it can be difficult for teachers to learn to do well (Box et al., 2015). Some teachers are supported by learning communities (Furtak & Heredia, 2014) that provide a venue for teacher learning about new classroom practices such as formative assessment. Teacher candidates, just beginning to try the practices of their teacher preparation programs, rarely have opportunities to engage with this type of community. Given the established complexities, teacher candidates do not have the support they need to enact formative assessment in their own classrooms. Sustained support during the transition to student teaching and to the first year of teaching is essential to help teachers learn these practices.

To help illuminate how a teacher candidate might further develop knowledge and skills around formative assessment during student teaching, this case study investigates the outcome of one teacher candidate's participation with a community focused on the work of formative assessment in the context of a unit on natural selection. This study aims to respond to the following question:

How did a teacher candidate use collaboratively designed formative assessment tasks and classroom practices to draw out and respond to student ideas?

Methods

This case study is situated within a research project that took place at a large, culturally and socioeconomically diverse suburban high school in the western United States. The study focuses on a community of eight biology teachers and their development of formative assessments linked to a learning progression for natural selection. In the context of the research project, the biology teachers met monthly with university researchers over a two-year period to develop the learning progression and the associated formative assessments.

This case study focuses on Anna, a teacher candidate placed in the school during her student teaching semester. Anna had previously earned a bachelor's degree in biology and was enrolled in a post-baccalaureate teacher licensure program. During the spring semester of the second year of the research project, Anna taught two biology classes and participated as a member of the established teacher community.

The primary sources of data include the formative assessment tasks co-developed by the community of biology teachers, as well as video recordings of Anna's classroom enactments of these tasks. Anna enacted two different formative assessment tasks: *What gets passed on?* and *How did it come to be*? Video recordings of Anna enacting these tasks were made on three different days and total approximately two and a half hours of classroom instruction.

After viewing all of the classroom enactment video, episodes were identified where students were given an opportunity to share their thinking (Gotwals & Birmingham, 2016). This focus on students sharing their thinking revealed the connection between teacher questioning and student thinking, leading to a subsequent

analysis of the different types of questions asked by the teacher. The questions posed by the teacher candidate were coded by type, as either *what* or *how* questions. *What* questions took the form of simple, recall type questions such as "What was the selective force acting on the cheetah?" while *how* questions probed students to explain a mechanism such as "How did the cheetahs become so fast?". Following the classification of the question each questioning episode was further analyzed to determine how the student(s) responded to the questioning and how the teacher then responded to the student(s).

Findings and implications

Anna enacted the formative assessment tasks by, first, having students work individually, second, students discussed and refined their responses in groups and finally, a representative from each group shared their ideas. Anna used both the prompts designed by the community from the formative assessment tasks as well as her own prompts in questioning sequences with students.

During the enactment of *What gets passed on?* seven separate episodes of questioning sequences were identified. Two of these episodes began with questions that asked students *what* happened and five asked both *what* and *how* something happened. In each of the episodes, the students provided *what* answers and Anna responded to students by re-voicing, evaluating, explaining, and on one occasion, asking a clarifying question.

During the enactment of *How did it come to be*?, three episodes of questioning sequences were identified. One of these episodes began with a *what* question and two began with *how* questions. Students responded to the *what* question with *what* responses and to the *how* questions with *how* responses. Anna responded to students by re-voicing, evaluating, asking clarifying questions and giving feedback for answer improvement and explaining.

The most striking pattern that emerged during the analysis of the questioning sequences was that all of the *what* questions were asked in-the-moment, and the *how* questions were questions that had been prepared ahead of time by the community. The *what* questions provided students with an opportunity to demonstrate their ability to recall knowledge. The *how* questions provided students with an opportunity to share their thinking about how a mechanism occurs and thus an opportunity for Anna to surface the students' conceptual understanding of that mechanism.

Although Anna provided students with opportunities to share their thinking the students did not always take up that opportunity. In all of the five instances where Anna asked *how* questions while enacting *What gets passed on?,* students responded to those *how* questions with *what* answers. Further, when the students responded with *what* answers to *how* questions Anna did not press them to explain their thinking. In two of the episodes Anna explained the mechanism for the students rather than asking the students to do the explaining themselves. This suggests that, while perhaps a necessary first step, having the prepared *how* questions to draw out student thinking, in itself, is not always enough to get students to share their thinking. Continued professional development to support teacher candidates in learning how to respond to students through their practice could be beneficial in taking this next step.

References

Black, P., & Wiliam, D. (1998). Assessment and Classroom Learning. *Assessment in Education: Principles, Policy & Practice.*

Box, C., Skoog, G., & Dabbs, J. M. (2015). A Case Study of Teacher Personal Practice Assessment Theories and Complexities of Implementing Formative Assessment. *American Educational Research Journal*, *52*(5), 956–983. http://doi.org/10.3102/0002831215587754

Furtak, E. M. (2012). Linking a learning progression for natural selection to teachers' enactment of formative assessment. *Journal of Research in Science Teaching*, *49*(9), 1181–1210. http://doi.org/10.1002/tea.21054

Furtak, E. M., & Heredia, S. C. (2014). Exploring the Influence of Learning Progressions in Two Teacher Communities. *Journal of Research in Science Teaching*, *51*(8), 982–1020.

Gotwals, A. W., & Birmingham, D. (2016). Eliciting, Identifying, Interpreting, and Responding to Students' Ideas: Teacher Candidates Growth in Formative Assessment Practices. *Research in Science Education*, *46*(3), 365–388. http://doi.org/10.1007/s11165-015-9461-2

National Research Council. (2001). Inquiryandthe National Science Education Standards.Washington, DC:NationalAcademyPress.

Wenger, E. (1998) *Communities of practice: learning, meaning, and identity. Cambridge, U.K.; New York, N.Y.: Cambridge University Press.*

A Continuum of Knowledge Structures in an Observation-Based Field Geology Setting

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Abstract: Learning to make scientific observations can be challenging for learners and has sometimes been viewed as unproblematic in instruction. Using the theoretical framework of Knowledge-in-Pieces we examine the structures of learners' localized knowledge systems as they observed rock outcroppings. We document that along an observation-based geology learning trajectory, learners activate localized knowledge systems that exhibit varying levels of coherence and fragmentation, and quantity and relevance of the perceptual information.

Background and theoretical framework

Scientific evidence is central to classroom inquiry and observations are key to children's investigations and explanations, yet, children can struggle with observing unfamiliar phenomena (Eberbach & Crowley, 2009), and systematic observation of unfamiliar phenomena has often been underestimated by educators and researchers who mistakenly cast observation as an everyday skill (Chinn & Malhotra, 2001). Comparably, professional scientists engage in complex observation tasks where they observe detailed patterns based on their disciplinary knowledge (e.g. Knorr-Cetina & Amann, 1990). However, the question remains: how do learners build knowledge structures that may enable them to notice and recall various domain specific patterns? Specifically, little is known about the many micro level observations that can support learning to see complicated domain specific patterns, especially in content domains where complex observation is important, such as real-world geologic settings. This analysis employs Knowledge in Pieces (KiP) to examine the perceptual and inferential ways people read out characteristic information from the world (diSessa & Sherin, 1998).

Data and methods

Data were collected from a summer geology class for in-service science teachers that included a field-based learning experience. Using a scaffolded scientific inquiry, the participants observed rock formations and used their observations to construct an understanding of the historical geological record. The participants were 19 middle and high school science teachers in a master's program where they would earn an MS degree in physics with a focus on teaching, and this geology class was a program requirement. Participants had a range of expertise in geology, some teachers had their undergraduate degrees in Earth Science, while others were new to geology.

Data consists of audio recordings of participants' conversations while in the field along with field notes and photographs taken by the researchers. Using qualitative techniques, the audio conversations were sorted based on the degree of confidence with which teachers made observations and drew inferences, and the learning apparent in the observations. From this corpus we identified cases as representing well developed knowledge systems, moderately well-developed knowledge systems, and least well-developed knowledge systems.

Analysis: A continuum of knowledge structures related to observation

Here we illustrate the continuum of knowledge structures related to observational knowledge with three cases. We describe the structure of each knowledge system with respect to fragmentation, and quality and quantity of extractions and inferences.

In the first case, several teachers used a well-developed knowledge system to instantaneously recognize fossilized *ripple marks,* that were the result of water flowing over sediment. One teacher explicitly described what she saw (extraction) and how the ripple marks would have been created (inference) ("Yeah, the ripple marks are preserved// I know, I mean, metamorphic) and then added more specific details ("We think it's just plain sandstone that has been uplifted."). Other teachers agreed with similar extractions ("It's rippley like you are looking right at the bottom, right down from two feet of water at a beach.") They instantaneously extracted information about the existence of ripple marks, and they inferred correct and incorrect information about the formation being caused by uplifted sandstone and not metamorphic processes. Here there are relatively few extractions and inferences as the participants easily hone in on the relevant information, which suggests a more coherent and well-developed knowledge system in regards to these specific extractions and inferences.

The second case illustrates asymmetric expertise as a teacher (B) extracted a great deal of information, and struggled with two reasonable inferences, while the geology course instructor used a well-developed

knowledge system to make a determination. The conversation centers on whether a crisscrossing pattern represents fossilized mud cracks or fossilized animal trails (a trace fossil). B extracted information about the color and crisscrossing pattern in the rock ("some greys, like this here is grey and that is brown. The brown is obviously more, look at that, we've got a, more like a fossil of a mud flat. Kind of like that those things down there [referring to dried mud that is underfoot]") that were identified as features of mud cracks ("See how you have mud that cracks like that?"). Later B described the two options he had inferred ("either that is some sort of biological something going on, biological, like something making tunnels. Or this is a mud crack. A fossilized mud crack.") B carefully compared the observed patterns, noting that the mud crack was angular with chasms between the cracks ("it looks more angular, I guess. But you have like these little chasms in there") and had sharp curves in both rocks ("Curve, cut. We've got a curve, we've got a sharp cut.") But he also offered evidence for the fossilized wormhole hypothesis ("What makes me wonder if it's a wormhole though, is the depth at which that thing is cut.") To help decide among the possibilities, B calls the geology course instructor (H) over and she explains that the pattern on the rock was formed by an animal trail ("Just because it's got some rounded edges to it. Actually, I can see some tracks. That looks like a trace fossil to me// Some kind of critter.") The course instructor's coherent knowledge system used a limited number of extractions and inferences and she was able to quickly recognize it as a trace fossil. Comparably, B's knowledge structure contains more extractions as he over-generates possibly relevant observations in an attempt to hone in on the relevant information for determining the rock's formation.

The third case shows contrasting knowledge systems among two teachers working to determine rock composition. While looking at a shale formation, one teacher (A) quickly identifies the rock as shale and then works to help the other (N) arrive at the same determination. The first teacher (A) quickly identifies the rock as shale based on his extractions ("This is definitely too fine grain to be sand. I notice there's a pattern to how it's breaking.") For that teacher, intermediating inferences led to his determination ("it's what we call the fissile layers.") But, N connects the pattern of breaks in the rocks to clay, not shale ("it's all breaking the same way like those clay") and he does not mention grain size, which comparably for A is a key extraction. Furthermore, N mentioned that the rock "pulls apart real easy" as justification the rock being shale, but A attributes this flakiness to weathering, which is not a characteristic to identify the rock as shale. Here we see that A's knowledge structure has tight connections between extractions and inferences, which suggests that it is well-developed. In contrast, N's knowledge structure does not identify relevant inferences and has some unnecessary extractions, which suggests it is less coherent.

Discussion and conclusion

The results show a continuum from less well-developed knowledge systems to more developed knowledge systems in regards to the coherence of the localized knowledge system, and quantity and relevance of extractions. The ripple marks case involved a coherent knowledge structure and contains few extractions. Similarly, the instructor (H) in case 2 and the teacher, A, in case 3 both used knowledge structures that are more coherent, with few, but highly relevant extractions. Interestingly, across the continuum, the number of extractions follows a nonlinear path with few exhibited by either those with the least well-developed knowledge systems (e.g., N in Case 3) and the most well-developed knowledge systems, and those in the middle with moderately well-structured knowledge systems (e.g. B in case 2) generating the largest quantities of extractions. Perhaps participant's like B in case 2 have enough familiarity with the topic to be struggling to generate and connect pieces of information in meaningful ways, whereas less-experienced participants do not have the experience to identify potentially relevant extractions and inferences and more experienced participants easily identify relevant extractions and inferences. These results build on prior work (e.g. Eberbach & Crowley) to illustrate a nuanced relationship between observation and disciplinary knowledge. Supporting movement along the continuum may involve scaffolds to support participants in identifying relevant extractions and inferences when making micro-level observations.

References

Chinn, C. A., & Malhotra, B. A. (2002). Epistemologically authentic inquiry in schools: A theoretical framework for evaluating inquiry tasks. *Science Education*, *86*(2), 175-218.

diSessa, A. A., & Sherin, B. L. (1998). What changes in conceptual change?. *International journal of science education*, *20*(10), 1155-1191

Eberbach, C., & Crowley, K. (2009). From everyday to scientific observation: How children learn to observe the biologist's world. *Review of Educational Research*, *79*(1), 39-68.

Knorr-Cetina, K., & Amann, K. (1990). Image dissection in natural scientific inquiry. *Science, Technology & Human Values, 15*(3), 259-283.

How Do Kindergarten and Primary School Children Justify Their Decisions on Planning Science Experiments?

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Abstract: The ability to test questions and assumptions autonomously by systematic manipulation of variables in an experiment is a central aspect during designing and conducting scientific investigations. It is unknown if children already use the control of variable strategy (CVS) as their argumentation strategy for designing experiments. We compare which argumentation strategy children use to justify their decisions on planning science experiments. Primary school children more often chose non-confounded experiments compared to kindergarten children.

Introduction

Scientific thinking includes problem-solving procedures like formulating research questions, generating hypotheses, designing and conducting investigations and interpreting data as part of inquiry competences (Harwood, 2004). The ability to test questions and assumptions autonomously by systematic manipulation of variables in an experiment (Control of Variable Strategy; CVS) is a central aspect during designing and conducting scientific investigations (Klahr & Nigam, 2004).

Psychological studies have shown that children at the pre- and primary school age already can learn the basics of CVS and can in an easy way distinguish between confounded and non-confounded experiments (Sodian & Mayer, 2013). But is not known if children use the CVS as their argumentation strategy for designing experiments. They might also use another strategy, for example, a normative reference (Walton, Reed, & Macagni, 2013). Students need not only be able to distinguish between confounded and non-confounded experiments, but they need to be able to justify their decisions. It is possible that children choose the right answer and refer correctly to the CVS in their argumentation, but it may also happen that they choose the right answer by chance.

The research questions of this study are as follows:

RQ1: Which argumentation strategies do children in kindergarten and primary school apply?

RQ2: Having chosen a non-confounded experiment how often do children apply a wrong argumentation strategy?

Method

21 kindergarten children and 22 primary school children participated in the study. Kindergarten children`s mean age was 5.28 years ($SD = .72$) and 33.3% of the children were boys. The mean age of the primary school children was 9.18 years ($SD = .501$) and 54.5% were boys.

To assess children`s scientific thinking and argumentation strategies we introduced a scientific question of an everyday situation and showed the children confounded and non-confounded experiments to answer the question. The children had to decide which experiment is the best way to answer the question. Afterwards, we asked the children why they had chosen the respective experiment. We also asked the primary school children to design their own experiments to given scientific questions and justify their design. All tasks were constructed based on existing tasks (Sodian et al., 1991, Bullock & Ziegler, 1999, Schwichow, Christoph, Boone, & Härtig, 2016). The reliability of the scale for planning experiments was $\alpha = .67$ (primary school children; 12 items) and $\alpha = .73$ (kindergarten children 16 items).

We also assessed data about children's general cognitive skills (CFT, Weiß & Osterland, 2013). The knowledge of the kindergarten children was assessed by interviews, the knowledge of the primary school children with a paper-and-pencil test.

Open answers were coded into a categorization scheme (see Edelsbrunner & Deiglmayr, 2017) which has been complemented with additional categories. The complete data were coded independently by two trained coders who reached high inter-rater reliability (Cohen's kappa = .83). The scheme has seven main categories: tautological reasoning, normative reasoning, outcome-based reasoning, precise hint to experimental variation,

precise and correct hint to one factor, precise and correct hint to two or more factors, not possible to categorize. The categories "precise hint to experimental variation, precise and correct hint to one factor, precise and correct hint to two or more factors" were coded as right answers because the children showed a basic understanding of the CVS.

Results

Kindergarten and primary school children both used all argumentation strategies. Answers like "I don`t know" were excluded from the analyses. To compare kindergarten and primary school children we report percentages. The kindergarten children used a normative reasoning more often than the school children. Kindergarten children also mentioned more often a precise hint to one factor. Primary school children more often used tautological reasoning strategies and more often gave a hint to two or more factors.

There were also differences in the argumentation strategies in combination with right or wrong answers and argumentation strategies. Primary school children more often chose the right answer (68.94%) compared to kindergarten children (23.81%). Primary school children often did not use an argumentation strategy referring to the CVS (62.63%). If Kindergarten children chose the right answer, they used almost always the right argumentation strategy (83.33%).

There was a significant correlation between the general cognitive abilities and the skill "planning experiments" for primary school children ($r = .56$, $p = .006$) and also for kindergarten children ($r = .66$, $p = .006$).

Discussion

The results show that children in early years can already identify or plan non-confounded experiments but for primary school children it is difficult to use the right argumentation strategy. As children are able to use the CVS, one possible implication for the daily work in kindergartens and primary schools could be that teachers and educators should foster that children justify decisions with the CVS. For future research, it would be interesting to investigate how to support the teachers and educators in this task. We will increase the overall number of participants within the next few months to present more robust results at the conference.

References

Bullock, M., & Ziegler, A. (1999). Scientific reasoning: Developmental and individual differences. In Individual development from 3 to 12: Findings from the Munich Longitudinal Study (pp. 38-54). Cambridge University Press

Edelsbrunner, P. A., & Deiglmayr, A. (2017). Argumentation about the Control of Variables-Strategy: A large-scale Study in Primary School. Talk at the 17th Biennial Conference of the European Association for Research in Learning and Instruction. Tampere, Finland.

Harwood, W. S. (2004). A new model for inquiry—is the scientific method dead? Journal of College Science Teaching, 33 (7), 29 – 33.

Klahr, D., & Nigam, M. (2004). The equivalence of learning paths in early science instruction: Effects of direct instruction and discovery learning. Psychological science, 15(10), 661-667.

Schwichow, M., Christoph S., Boone W. J., & Härtig H.(2016): The impact of sub-skills and item content on students' skills with regard to the control of-variables strategy, International Journal of Science Education, 38 (2). S.216-237, doi: 10.1080/09500693.2015.1137651

Sodian, B., Zaitchik, D., & Carey, S. (1991). Young children's differentiation of hypothetical beliefs from evidence. Child Development, 62(4), 753-766.

Sodian, B., & Mayer, D. (2013). Entwicklung des wissenschaftlichen Denkens im Vor-und Grundschulalter. In M. Stamm & D. Edelmann (Hrsg.), Handbuch frühkindliche Bildungsforschung (pp. 617-631). Springer Fachmedien Wiesbaden.

Walton, D., Reed, C., & Macagno, F. (2008). Argumentation schemes. Cambridge University Press.

Weiß, R., & Osterland, J. (2013). Grundintelligenztest Skala 1. Hogrefe

Transporting Knowledge: A Case Study of Meaning Making on the Pathways of Science Communication

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Abstract: In this paper I study scientists, reporters, and news readers as they produce and/or interpret scientific texts. Imagining all of these actors as *science learners* allows me to compare across their individual understandings to follow ideas through the pathways of science communication. I provide a case study of how one scientist's understandings causes difficulties for a reporter and two news readers. This case problematizes popular assumptions about the causes of public misunderstandings of science.

Popular science texts and readers

In this paper, I address a topic usually considered the realm of research in science communication—how science knowledge moves from scientist to the public—using tools and methods more common in the learning sciences, in order to construct a model of how the various actors and texts shape each other's understanding of science in the moment. In particular, I present findings from a study that used video-based observation, semi-structured clinical interviews, think aloud protocols, and textual analysis of scientists, university news staff, and members of the general public as they interacted—in person and through various texts—in an attempt to make sense of new scientific research in order to produce or consume popular science news articles. Scientific knowledge changes as it flows through the pathways of science communication mediated by these various actors (Cloître & Shinn, 1985) and socially-constructed texts (Bazerman, 1983). So, how do various actors interact with one another and with texts in order to make sense of and construct knowledge about scientific research?

Data collection and analysis

To begin addressing the research question I recruited twenty adult participants (aged 24–67) from a large US city, four scientists from a large university, and three university news reporters around three pieces of recently published scientific research. Each news reporter was interviewed about his or her assigned research both before and after writing their story. Additionally, I recorded their interactions with the scientist and collected copies of all texts, including article drafts and email exchanges. At the same time, I interviewed the scientists about their research. Next, the twenty adult participants were asked to think aloud as they read one of the news stories about the focal pieces of research. Finally, the participants were interviewed about their interpretation and understanding of the article's content. From this data, I present a case study constructed from content logs, transcripts, and thick descriptions of the observations and interviews, and content analysis of relevant texts. In order to analyze the in-the-moment sense making of each actor, I adopt the dual lenses of *knowledge analysis* (e.g. diSessa & Sherin, 1998)—which catalogs the resources of knowledge used moment by moment with the assumption that they are being drawn on from a complex mental ecology of resources based on contextual factors—and *interaction analysis* (Jordan & Henderson, 1995)—which describes interactions that shape thought and behavior.

A case study of an idea moving along a pathway of science communication

The research central to this case study is a biomedical study which—using data from a veterans' hospital—conclude that prescriptions of protein pump inhibitors (PPIs) are overprescribed to veterans at higher doses and for longer than recommended by experts. This is, of course, a very simplified description of the research, but it is enough to highlight how the various actors make sense of its meaning.

During my interview with Shannon—a writer and editor for the university's news service—I ask her to describe the research she gave me a general overview and then began explain her particular interpretations of the research. At one point, she said the following: "*This is in the veteran population and I think the point of that is this is, like, taxpayer money and we need to kind of know what's going on.*" The detail that the population of the study was veterans became a very important and hard to interpret idea. Here, Shannon latches onto this idea the veterans' healthcare is paid by taxes, and, thus, the over prescription of PPIs would result in wasteful tax spending. Later, when Shannon is interviewing Jacob—a research fellow at the university's medical school and co-author of the focal research—they have a conversation about the research. During their discussion they both casually mention the study being about veterans, but neither make an attempt to explain *why* the study is about veterans. Jacob does not provide any warrants or justifications for this detail. He does, however, frequently mention that PPIs are the most common prescription drug in the U.S "*in terms of number of prescriptions and the amount of money.*" When Jacob mentions money, Shannon sees her opportunity to bring up her idea about the importance

of the veteran population being supported by taxpayers: "*U.S. tax dollars too, right?*" Jacob does not seem to know how to react to this suggestion, as this was not a part of his research. He responds with mild confusion, and Shannon drops the idea of using the taxpayers as an angle and it does not appear in her finished story. However, Jacob does not recognize that the reason Shannon is able to make such an inference is that he fails to make clear why he chose veterans as his study population. Shannon is confronted with an unexplained detail (veteran population) and a framing of cost, and so she reasonable tries to reconcile these details to make sense of the research, using what she knows about this population and healthcare costs. Her framing of taxpayer money is much the result of Jacob's underdetermined explanations. Shannon's final text appears much like Jacob's description—she mentions the population of veterans, but does not provide explanations, instead focusing on the popularity of PPIs. So, how do her readers make sense of this text?

During my observations and interviews with members of the general public, the idea that the population in the study was veterans became problematic. Steven, a 24-year-old high school graduate, noticed this fact almost immediately while reading the story. After reading the title, headline, and first paragraph, Steven thinks aloud, "*Oh, veterans in particular, huh?*" Here, Steven is trying to make sense of veterans being the chosen population of study. This statement shows that he is inferring that the population was chosen for a reason, but he cannot determine this reason. Later, during my interview with Steven, I asked him what the least important aspect of the study was and he mentions the "*emphasis placed on these patients being veterans.*" Steven never finds a reason for the emphasis to be placed on veterans, so he struggles to make sense of the research. He suggests a possible journalistic angle that the story is trying garner sympathy for an at-risk population, but he ends up rejecting that inference, and simply deciding that the choice of population does not make sense and so is not important. A similar reaction can be seen with Alyssa, a 32-year-old college graduate. While reading the lead paragraph, Alyssa says, "*I'm thinking about my dad, because he used to get heartburn pretty regularly.*" Here, Alyssa is drawing on a personal experience to make sense of the research. Later, during the interview Alyssa incorrectly states that the researchers were the one's giving the drugs to the veterans. When asked why the chose veterans she concluded, "*A lot of veterans experience heartburn.*" While, Alyssa obviously struggles to make sense of the research, I argue that at least part of the problem is the lack of specificity in the description of the study design choices. This lack of specificity allows Alyssa to make inferences about the study based on personal experience: drawing a connection between her father's heartburn and the heartburn of the veterans. What explains this lack of explanation about such a seemingly important detail?

During my interview with Jacob, I asked him the most important part of his research for the public to understand. He replied: "*For me the most important part is that it gives insight into how these prescriptions are initially prescribed and continued over time.*" Not only does Jacob not mention the veteran population here, he hardly mentions them directly during the whole interview. They simple are not an important part of the study for him. Actually, more than that, when I ask him about weaknesses of his study, Jacob replied: "*It was done at a V.A. which can be a disadvantage.*" So, not only does Jacob not highlight the focal population, he actively believes it to be a weakness of the study. What is going on here? Jacob's interest in the study is the over prescription of drugs, and the veterans are a convenient sample based on the funding (Veteran's Affairs). Of course, tradeoffs like this are common in the social work of science, and must be communicated in the science literature. However, when this detail goes beyond the rhetoric of science, Jacob does not provide any explanation for his sampling of veterans. This places the responsibility of justifying this detail and evaluating the validity of claims solely on the audience. It is then not surprising that the news reporter and both members of the general public assert their own inferences about the detail. Without seeing Jacob's role in creating a space for these inference, it would be easy to dismiss other actors sense making as unreasonable, but seeing the interaction of all actors allows us to see how the system of science communication is actually an interconnected web of science learners who directly influence each other's interpretation of scientific research. This is obviously an imperfect first step in understanding the impact of individuals on one another on the pathway of science communication. However, continuing work will allow us to piece together a grander picture of how people learn from popular science texts throughout their lives.

References

Bazerman, C. (1983). Scientific writing as a social act. In P. Anderson, R. Brockman, & C. Miller (Eds.), *New Essays in technical writing and communication.* Farmingdale, NY: Baywood

Cloître, M., & Shinn, T. (1986). Enclavement et diffusion du savoir [Restriction and diffusion of knowledge]. *Information sur les Sciences Sociales, 25,* 161-187.

diSessa, A. A., & Sherin, B. (1998). What changes in conceptual change? *International Journal of Science Education, 20*(10), 1155-1191.

Jordan, B., & Henderson, A. (1995). Interaction analysis: Foundations and practice. *Journal of the Learning Sciences*, *4*(1), 39–103.

Connected Cosplay: Fan Work as Pathways Toward Opportunity

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Abstract: Connected learning explains how people can build learning pathways that connect their interests, relationships with others, and formal learning to lead toward future opportunities. However, most learning systems are not set up ideally for connected learning. This paper analyzes two case studies of cosplayers—hobbyists who make their own costumes of media characters to wear at fan conventions—who benefited from a well-developed connected learning ecology. Cases were drawn from a larger interview study and further analyzed as compelling examples of connected learning. Important themes that emerged included sponsorship by family, friends, and adult mentors; unique pathways that start with a difficult challenge; and comparisons with formal school experiences. This has implications for how we can design connected learning ecologies that support all learners on unique pathways toward fulfilling futures.

Introduction

Connected learning (Ito et al., 2013; Ito, Salen, & Sefton-Green, in preparation) is a framework that helps us to conceptualize learning related to youths' interests and relationships with others in a way that connects to future-oriented opportunities like school, higher education, careers, and political clout. However, we know very little about how learners navigate these pathways in ways that could inform the future design of educational learning environments. One way to do this is to turn to retrospective case studies (e.g., Maltese & Tai, 2010) to gather histories of how adults have successfully built on their passions toward meaningful future career opportunity.

Cosplay (Bender, 2017)—the depiction of characters from media properties through costumes and roleplay (thus the portmanteau, "cosplay")—usually at fan events like conventions—provides an interesting case study of how learning can be connected to future opportunity. As part of this hobby, cosplayers are motivated to pursue their interests, learn numerous skills, connect with mentors and networks, and enrich their experience of life. Sometimes they are fortunate enough that their hobby leads them down pathways toward career opportunities. In these cases, cosplayers have benefited from a successful connected learning ecology. But the system is not always set up to legitimize the skills they are learning in their hobby, connect their school learning to it, or broker career opportunities related to their skills. By looking at differences between positive connected learning in cosplay and examples of disconnected learning, we may glean insights into how we can redesign learning ecologies at all levels to support unique pathways toward future opportunity for all learners.

In investigating the perspectives of cosplayers on their practice, we ask: What sorts of learning pathways exist in cosplay? How can it connect cosplayers to future opportunities? How can we make it—and learning ecologies in general—work better for those who do not experience connections between their extracurricular interests and future opportunities?

Methodological approach

The lead author was situated as an embedded ethnographer in the cosplay community as part of a research project on the math inherent in textile crafts funded by the National Science Foundation. Ten cosplayers participating in regional fan conventions were interviewed, using a semi-structured interview protocol that asked how the participants had learned the skills needed for cosplay, what drove them to participate in this hobby, stories about particular projects, the role communities played in their practice, and their experiences with their current occupation and with school. Interviews were transcribed and coded according to the connected learning spheres and theoretical principles. Two cosplayers were selected as cases illustrating the positive potential of cosplay as a connected learning practice that can lead toward future-facing opportunities. They also had similar negative experiences with math classes, which they both viewed as *dis*connected from their lives. While not representative of *all* cosplayers, these two are models of "positive deviance" (Pascale, Sternin, & Sternin, 2010) that provide suggestions for how a well-developed connected learning model could be scaled to address wider-reaching systemic problems with traditional schooling inequities.

Results

Lexi (all names are pseudonyms) had been cosplaying for 9 years and was 31 at the time of the interview. With her artist mother as a sponsor of learning new craft skills and her friends encouraging her to join their cosplay group, Lexi dove right in to the hobby with a costume that was a big challenge to sew. Now, she uses the knowledge she gained about clothing from cosplay in her job for a large intimate-wear company. She continues to seek opportunities to express fashion creatively through designing for local fashion shows and freelance fashion consulting work. In contrast, she said her math classes "had no basis in reality," unlike math in cosplay that is applied directly to a real, tangible project.

Tim's interest in entertainment design was supported early by his enrollment in a performing arts school that he now, at 33 during the interview, works for as a sculpture teacher. Like Lexi, he began to cosplay in order to join friends at fan conventions and to express his love for particular characters. He also took on a big challenge early: making a costume for which there were few existing online resources. Now he is paying forward the sponsorship he received and is encouraging others' interests in art and cosplay; he lets students bring cosplay projects into his class, sometimes even brings his own to class, and allows friends to use his studio at home to work on cosplay and learn techniques from him. He too lamented about how math classes are irrelevant to students' interests.

Discussion and implications

Tim and Lexi's experiences with learning how to cosplay were positive primarily because they connected to important aspects of their lives, as the connected learning framework would suggest. Relationships with peers motivated their initial engagement, and adult sponsors provided access to materials and skills, whether in person or online. They both began their cosplay journeys with a challenge that "should" have been beyond their current skill levels, but they managed it and continued to challenge themselves. This contrasts with conventional views of learning as following a step-by-step trajectory from easier to more difficult, suggesting that when appropriately motivated, learners will surmount challenges "beyond their level." Both cosplayers were also fortunate to be able to apply their cosplay experiences to their careers, but they also felt a sense of fulfillment from opportunities beyond their careers in which they could sponsor others' interests in cosplay and clothing. Finally, they both recognized how disconnected their math classes has been from their lives, and contrasted that with the way math in cosplay did connect to their interests and goals, suggesting that school should do the same.

To create a more equitable learning system that values all learners' interests and skills and orients them toward economic and political opportunities, these cosplayers show us that we need to legitimize learners' interests rather than dismiss them as frivolous, support their relationships with peers as positive motivators, act as sponsors who provide access to skills and resources, support youths' goals even if they seem beyond their current skill level, and recognize opportunities outside of careers as ways to enhance creative expression and meaningful relationships with others. Considering how disconnected most traditional schooling is from the rest of youths' lives, these cosplayers also suggest that school learning should be applied to contexts that matter to students' interests and future plans. Only when we create supports for unique pathways both in and out of school, throughout the lifespan, will equitable connected learning be accessible to all.

References

Bender, S. (2017). Cosplay. In K. Peppler (Ed.) *The SAGE encyclopedia of out-of-school learning* (pp. 155-157). Los Angeles, CA: Sage Publications.

Ito, M., Gutiérrez, K., Livingstone, S., Penuel, B., Rhodes, J., Salen, K., ... & Watkins, S. C. (2013). *Connected learning: An agenda for research and design.* Irvine, CA: Digital Media and Learning Research Hub.

Ito, M., Salen, K., & Sefton-Green, J. (Eds.) (in preparation) *The Connected Research Network: Reflections on a decade of engaged scholarship.*

Maltese, A. V., & Tai, R. H. (2010). Eyeballs in the fridge: Sources of early interest in science. *International Journal of Science Education*, *32*(5), 669-685.

Pascale, R. T., Sternin, J., & Sternin, M. (2010). *The power of positive deviance: How unlikely innovators solve the world's toughest problems.* Boston, MA: Harvard Business Press.

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An Enhanced Framework for Scale Cognition Leveraging Visual Metaphor Theory and Analogical Reasoning Theory

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Abstract: Frameworks for size and scale cognition are synthesized, then enhanced by theory on visual metaphor and analogical reasoning. Future directions developing scale worlds in virtual reality are presented.

Introduction

Cutting-edge science is conducted at extremes of scale, e.g., nanotechnology. Scale is critical in science education too. USA science standards posit scale as a *crosscutting concept* (NRC, 2012). However, students have difficulty comprehending (Tretter et al., 2006a, 2006b) and representing (Delgado & Lucero, 2015) scale, and hold inaccurate ideas about the size of scientific entities (e.g., Delgado, 2009). This paper synthesizes frameworks for scale cognition from STEM education, and enhances these with theory on metaphor and analogy in visual design. The resulting framework can guide research into and development of learning environments for scale.

Background

STEM education research by Tretter et al. (2006a,b) examined conceptual boundaries of scale conceptions and the accuracy of estimation of size of objects/distances. They focused on groups of learners and did not examine individuals' thinking. Delgado (2009) introduced a framework for ways of thinking about scale, influenced by Piaget (e.g., Inhelder & Piaget, 1969), with two qualitative (ordering, grouping) and two quantitative types (relative, absolute size). Magana et al. (2012) added logical proportional reasoning (LPR): using similarity between one ratio of sizes (A:B) and another (C:D), i.e., A:B::C:D (A is to B as C is to D). Kong et al. (2011) developed similar categories starting from nanoscale engineering students' ideas, but with subtypes for ordering and grouping, plus nanoscale-specific "definition" (being able to define nanometer and nanoscale).

Metaphors are foundational tools for learning about the world. In metaphor, aspects of a familiar *source concept* are conceptually mapped onto a less familiar *target* (Lakoff & Johnson, 1980). Conceptual metaphors have an experiential and embodied foundation (Johnson, 1987; Gattis, 2004). Phillips and McQuarrie (2004) identified three structures found in *visual* metaphor: juxtaposition, fusion, and replacement. Placing a car next to a jet (juxtaposition) relates the *target* car to the *source* jet, which has the attributes of being *well-engineered* and *fast*. Visual metaphors have conceptual power, and are linked to attention, elaboration, pleasure, and liking (Phillips, 2003). Peterson (in press) has further developed theory on visual metaphor. Peterson et al. (2015) demonstrated how visual metaphor can elucidate the abstract phenomenon of heat transfer. Visual metaphor theory is relevant for scale cognition because LPR (A:B::C:D) is a type of metaphor.

Analogy conveys that two otherwise distinct situations or domains share relational structure (Gentner & Markman, 1997). For instance, a roughly thousand-fold difference in size (a relational structure) is present in each of the following A:B pairs, despite including diverse, non-overlapping objects: height of human to ant; diameter of EPCOT's dome to diameter of a racquetball; diameter of bacterium to thickness of DNA. The literature does not achieve consensus on how analogies and metaphors differ, but this does not impact our synthesis since we deal with *visual* expressions, where their expressions are roughly equivalent. Metaphor and analogy in general are efficacious in science education (Christidou et al., 1997; Gentner & Wolff, 2000).

Synthesizing scale cognition and visual interpretation theories

LPR operates on ratios, a specific type of structural relationship. The size relationship between ant and human (~1000x) is familiar and thus it can serve as the *source* in a metaphor, to better understand the relationship of bacterium to DNA, a potential *target*. Examples of visual metaphor include *nesting*, where one source–target mapping is then treated as a unit and jointly mapped onto another target. The development of conceptual knowledge in conceptual metaphor theory also involves nesting. Connecting ratios through the use of a common element might be particularly meaningful and powerful for learners. Tretter et al. (2006b) found that scientists construct for themselves *scale worlds* including their everyday, human-scale world and a scale world for their scientific research (e.g., a *nanoscale world*). And yet, scientists felt the need to retain a *connection* among the various worlds. The implication for LPR is that chained ratios with a common element – *nested* LPR (NLPR) – might be more powerful for learning: instead of directly linking A:B::C:D, which lacks a common element, an

A:B::*B*:C::*C*:D chain features connections throughout. E.g., human-to-ant size ratio is similar to ant-to-bacterium, which in turn is similar to bacterium-to-DNA. This sharing of an element across ratios in an analogy is called *cross-mapping* (Gentner & Markman, 1997), and has been seen as a mere coincidence and possible distraction (Yuan, Uttal, & Gentner, 2017); however, we speculate that it might instead be a leverage point for understanding scale, if pairs are *systematically* connected to one another.

NLPR raises intriguing possibilities for mediated instruction in size and scale. Virtual reality (VR) holds great potential for scale cognition because it can provide new *direct* experiences. The familiar is used as source in metaphor, and VR can familiarize learners with entities that are otherwise impossible to directly experience. We envision converting the logarithmic scale into a set of virtual rooms populated by scientific entities at corresponding scales. A student's avatar can stand next to (juxtaposition) or become (fusion) a VR ant, and look at an enormous human, or a minuscule bacterium (now directly visible and manipulable). Additional sensory cues can be incorporated, e.g., using grayscale at sizes smaller than the wavelength of visible light for representations and environments, haptic feedback to represent vibration at the nanoscale, or dramatic echoes for large spaces. An expanded framework for scale cognition represents an opportunity to improve STEM education, with learners' own experiences generating new conceptual knowledge.

References

Christidou, V., Kouladis, V., & Christidis, T. (1997). Children's use of metaphors in relation to their mental models: the case of the ozone layer and its depletion. *Research in Science Education, 27*(4), 541–552.

Delgado, C. (2009). *Development of a research-based learning progression for middle school through undergraduate students' conceptual understanding of size and scale.* Unpublished dissertation, University of Michigan, Ann Arbor.

Delgado, C., & Lucero, M. (2015). Scale construction for graphing: An investigation of student resources. *Journal of Research in Science Teaching, 52*(5), 633–658.

Gattis, M. (2004). Mapping relational structure in spatial reasoning. *Cognitive Science, 28*, 589–610.

Gentner, D., & Markman, A. B. (1997). Structure mapping in analogy and similarity. *American Psychologist, 52*, 45–56.

Gentner, D., & Wolff, P. (2000). Metaphor and knowledge change. In E. Dietrich & A. B. Markman (Eds.), *Cognitive dynamics: Conceptual change in humans and machines* (pp. 295–342). Mahwah, NJ: LEA.

Inhelder, B., & Piaget, J. (1969). *The early growth of logic in the child, classification and seriation*. (E. A. Lunzer & D. Papert, Trans.). New York: W. W. Norton & Co.

Johnson, M. (1987). *The body in the mind: The bodily basis of meaning, imagination, and reason.* Chicago, IL: University of Chicago Press.

Kong, Y., Douglas, K. A., Rodgers, K., Diefex-Dux, H., & Madhavan, K. (2017). A size and scale framework for guiding curriculum design and assessment. *Journal of Engineering Education, 106*(3), 431-453.

Lakoff, G., & Johnson, M. (1980/2003). *Metaphors we live by.* Chicago, IL: University of Chicago Press.

Magana, A. J., Brophy, S. P., & Bryan, L. A. (2012). An integrated knowledge framework to characterize and scaffold size and scale cognition. *International Journal of Science Education, 34*(14), 2181–2203.

NRC (National Research Council). (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas.* Washington, DC: National Academies Press.

Peterson, M. (in press). Aspects of visual metaphor: An operational taxonomy of visual rhetoric for research in advertising. *International Journal of Advertising.*

Peterson, M., Wise, K., Lindgren, R., Cox, D., & Mathayas, N. (2015). Understanding and implementing visual metaphor [white paper]. Urbana, IL: Illinois Learning Sciences Design Initiative. Retrieved from http://textimage.org/indexing/pdf/Understanding-Visual-Metaphor.pdf.

Phillips, B. J. (2003). Understanding visual metaphor in advertising. In L. Scott, & R. Batra (Eds.), *Persuasive imagery: A consumer response perspective* (pp. 297–310). Mahwah, NJ: Lawrence Erlbaum Associates

Phillips, B. J., & McQuarrie, E. F. (2004). Beyond visual metaphor: A new typology of visual rhetoric in advertising. *Marketing Theory,* 4, 113–136.

Tretter, T., Jones, G., Andre, T., Negishi, A., & Minogue, J. (2006a). Conceptual boundaries and distances: Students' and experts' concepts of the scale of scientific phenomena. *Journal of Research in Science Teaching,* 43, 282–319.

Tretter, T. R., Jones, M. G., & Minogue, J. (2006b). Accuracy of scale conceptions in science: Mental maneuverings across many orders of spatial magnitude. *Journal of Research in Science Teaching,* 43(10), 1061–1085.

Yuan, L., Uttal, D., & Gentner, D. (2017). Analogical processes in children's understanding of spatial representations. *Developmental Psychology,* 53(6), 1098–1114.

Visualizing Complex Classrooms Through Real Time Observations

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Abstract: Analyzing video data is a complex problem for social science researchers. This study explored the use of an analytical visualization method to support the process of narrowing a video data corpus—focusing on meaningful moments for further qualitative analysis. We used the real-time observational coding tool to examine students' activities and engineering design practices in a STEM curriculum. The findings suggest that using this tool supports time-efficient analyses of large corpuses of video data.

Keywords: visualization, video analysis, engineering design, human-centered robotics

Introduction

Video data is one of the most complex types of data in empirical social sciences research, making it challenging to work with (Mondada, 2006). Even a few minutes of recording includes a massive quantity of information, such as visual, acoustic, and gestural data that needs to be transcribed and coded for analysis. Video thus creates issues of data management, retrieval, and selection for researchers. In particular, methodological and practical questions arise when trying to balance micro and macro-levels of analysis (Knoblauch et al., 2006). Because video analysis is so time consuming, it may not be useful for timely feedback during instructional interventions.

To address issues of managing timeliness and balancing micro- and macro-analytic approaches to analyzing video data, this study investigated the use of a real-time observational coding tool called the Generalized Observation Reporting Protocol (GORP; UC Davis Center for Educational Effectiveness, 2016). GORP is a web-based system that allows observers to record data using a customizable interface (see Figure 1). The coded data are systematically stored and organized in the cloud for future analysis. GORP allows users to gain an overview of the class activities and track aspects of students' learning activities. We tested this in a human-centered robotics (HCR) curriculum that focuses on the design of robots to serve human needs, thus helping learners make connections between the social and technical aspects of science and engineering (Schaal, 2007; Gomoll et al., 2017). Specifically, we captured students' collaborative activities as they engaged in HCR design processes (Gomoll et al., 2016). This poster presents our use and analysis of GORP data to support iterative video analysis—moving from the high-level picture of group engagement to the finer-grained analysis of specific video segments that highlighted collaborative activities and engineering design practices.

Methods

Data were collected from public schools in two U.S. states. Participants included ten eighth graders and six seventh graders taking an elective science class in a public middle school. The inquiry-based HCR unit took place over five weeks with 35-50 minute daily class sessions. We videotaped and observed two focal groups with two males and two females per group. The coding scheme included two major categories and a total of ten codes (see Figure 1): 1) Student actions (e.g., solo work, hands on material, off-task) (purple codes), and 2) Engineering Design practices (e.g., ask questions, imagine, collection information) (green codes). One observer per focal group coded in three-minute increments. Within a three-minute increment, each code in Figure 1 could be applied once. All observers achieved inter-rater reliability above 85% on a 60-minute classroom video from a previous implementation before entering the classroom to code.

Using the output of the GORP coding, we constructed a visualization, the Chronologically-Ordered Representation of Discourse and Tool-Related Activity (CORDTRA) to help us move from macro- to micro-level of analysis (Hmelo-Silver et al., 2011). CORDTRA diagrams provided visual representations which can aid in interpreting complex patterns and analyzing students' activities in collaborative learning environments. CORDTRA analysis included the real-time codes that quantify different types of learning activities. This creates a chronological picture in which multiple processes were represented in parallel on one timeline (see Figure 2). We created the CORDTRA diagrams to provide macro-level visualizations of our GORP coding results.
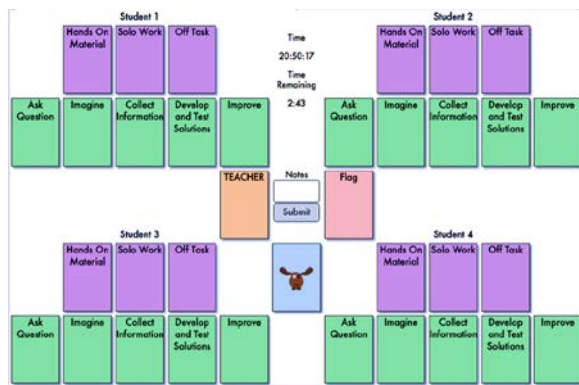
Figure 1. GORP interface displayed on a smartphone, tablet, or laptop (green codes: student actions; purple codes: engineering design practices).
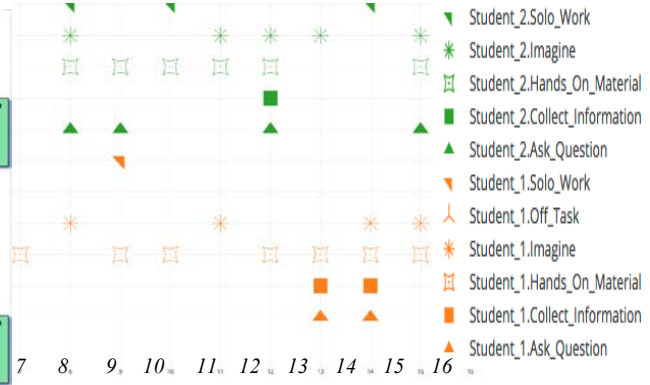
Figure 2. An excerpt of CORDTRA output (21 minutes period) of two students from Focus Group 1 at the Designing Robot Bodies class session.

Findings

Using CORDTRA visualizations to explore GORP data, we were able to highlight specific patterns of design practices across our robotics unit and to pinpoint moments for further exploration in video and interaction analysis data sessions. The CORDTRA diagrams were generated quickly via R programming software and provided a macro level picture of all engineering design codes occurring for each student group in small increments of time. Figure 2 shows an excerpt of two students' activities and engineering design practices in one class section in which we identified rich collaboration and use of engineering design practices while they built their robots. Through the analysis of the GORP coding, we were able to zoom in to deepen our exploration of patterns of students' collaborative engineering design practices throughout the HCR curriculum. For instance, if we are interested in understanding how the engineering design practices, such as collect information, were performed by students 1 and 2 in Figure 2 informed group activity, we could zoom in on segments (e.g. 12-14). Collaborative data analysis sessions informed by CORDTRA diagrams unpacked these interactions.

Discussion

Future work will explore how sharing real-time observational data with students and teachers can help them to develop engineering design practices *in situ*. Since GORP data can quickly generate CORDTRA diagragms, these have potential for formative evaluation. Adaptations of this real-time coding tool provide a time-efficient approach to analyzing data and have the potential to support creative examinations of learning in a variety of disciplines and contexts. In future work, CORDTRA visualization shows a promising approach for reducing large corpuses of video data. The visualization provides a high-level view of activity over time and help research teams to zoom in on intriguing moments and patterns.

References

Gomoll, A., Šabanović, S., Tolar, E., Hmelo-Silver, C. E., Francisco, M., & Lawlor, O. (2017). Between the social and the technical: Negotiation of human-centered robotics design in a middle school classroom. *International Journal of Social Robotics*, 1-16. Doi: 10.1007/s12369-017-0454-3.

Gomoll, A., Hmelo-Silver, C. E., Šabanović, S., & Francisco, M. (2016). Dragons, ladybugs, and softballs: Girls' STEM engagement with human-centered robotics. *Journal of Science Education and Technology*, *25(6)*, 899-914. Doi: 10.1007/s10956-016-9647-z

Hmelo-Silver, C. E., Jordan, R., Liu, L., & Chernobilsky, E. (2011). Representational tools for understanding complex computer-supported collaborative learning environments. In Analyzing interactions in CSCL (pp. 83-106). Springer US.

Mondada, L. (2006). Video recording as the reflexive preservation-configuration of phenomenal features for analysis. In Hubert Knoblauch, Bernt Schnettler, Jürgen Raab & HansGeorg Soeffner (Eds), Video analysis. *Methodology and methods. Qualitative audiovisual data analysis* (pp.51-68). Bern: Lang.

Knoblauch, H., Schnettler, B., and Raab, J. (2006) Video Analysis. Methodological Aspect of Interpretive Audiovisual Video-Analysis in Social Research. In Knoblauch, H., Schnettler, B., Raab, J. and Soeffner, H. (Eds.), *Video Analysis: Methodology and Methods*, Oxford: Peter Lang.

Schaal, S. (2007). The new robotics—towards human-centered machines. *HFSP Journal, 1*(2), 115-126.

Learning With *Songo*: The African Board Game

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Abstract: This paper explored learning in the African *Songo* board game environment to understand how learning occurs through audience-player interactions. The study revealed this space enhances collaborative and argumentative scaffolding. Further examination of such space is important to rethink learning in the digital age.

Introduction

The conception of games as learning spaces is no longer questioned. A growing body of literature demonstrates that games are environments that facilitates literacies (Steinkuehler, 2007), and useful for understanding learning and literacy (Gee, 2003; Squire, 2005) as it occurs in different cultural contexts and with different learners. Yet, few studies have empirically examined African board games, and particularly *Songo*

Songo (see Figure 1) is an African board game (Bayeck, 2017) from Central Africa, played in countries like Cameroon, Congo, Gabon (Meka, 2008). The game is a long board with 14 holes, 70 seeds, played by two players who take turn to consecutively distribute seeds in holes in a clockwise direction (Owona, 2004). A capture is made on the opponent's side of the board when a pebble falls into a hole with only one, two or three counters (Owona, 2004). In Cameroon, which is the context of this study, the player with 40 seeds wins the game (Meka, 2008). *Songo* represents the Beti/Fang ethnic group philosophical approach to life (Meka, 2008), and the gameplay a true metaphor of social interactions (Owona, 2004).

From a sociocultural perspective, learning occurs in social interactions as interactions enhance the co-construction of ideas (Peppler, Danish, & Phelps, 2013). Board gameplay supports interactions such as collaboration, and cooperation (Peppler et al., 2013). Given the role of interactions in learning, and board gameplay, this study explores interactions between players and the audience. The study examines how the audience participates in the gameplay to start uncovering learning within the space of *Songo* board game.

Figure 1. *Songo* board game adapted from Owona (2004*)*

Learning and board games

Compare to research on video games, research on board games and learning is still limited (Carter, Gibbs, & Harrop, 2014). Board games are disregarded in modern game research despite their contribution to the development of digital games (Carter et al., 2014). Yet, some studies report that these games enhance collaboration, decision making, computational thinking (Berland & Lee, 2012), and foster communication, and players' social skills (Hromek & Roffey, 2009). However, available research on *Songo* is mostly descriptive, and mainly in the fields of anthropology, or ethnomathematics (Njock, 1985).

Method

From a sociocultural perspective, the author explores learning as it occurs through audience-player interactions in the *Songo* game space. This microethnography, uses video data in this paper to interpret audience-player interactions during gameplay (Derry et al., 2010). Clips of videos were watched multiple times, salient episodes of player-audience interactions selected, transcribed, and discussed as preliminary findings using thematic analysis. The data were collected in Yaoundé, Cameroon, during a gameplay where six male adults were interacting Given its colonial history, Cameroon is a bilingual country, with French and English as official languages, but participants here were all French speakers. The names used in this paper are pseudonyms.

Findings

Two major themes emerged from the preliminary analysis of the video clips: collaborative and argumentative scaffolding.

Collaborative scaffolding: occurred multiple times as spectators collaboratively scaffold disadvantaged players during the game. As in this excerpt, of Paul and Eric's gameplay, where Paul in the middle of the game

looks at the board, taking more time than usual to make a move, obviously hesitant because he is on the brink to lose the game. At his moment, two spectators intervene:

Fonand: Pardon, mets tes pions là, tu vas gagner *[please, drop your counters here, you will win]*.

(Paul did not make any move)

Vince: ici *[here]* (Points to the *Songo* board, and with his hand showed Paul which hole he should play).

Acting upon that suggestion, Paul captured three counters from his opponent side. This interaction demonstrates collaborative scaffolding as Paul received helped from two spectators. This scaffolding is situated and responds to Paul's need in the game.

Argumentative scaffolding involves discussion between players and the audience where each party tries to justify the decision taken or suggestion given during the game. The excerpt below shows how involved spectators become during the game giving more suggestions and arguing with the player.

Fonand: tu as gagné le match, mets ici, c'est fini *[you've won the game, drop the counter here, it is finished]* (using his finger to designate a hole on the board)

Paul: non, je dois accélerer d'abord avec ceci *[no, I must quickly move with this one first]*

(rejects the suggestion and points at a different hole)

Fonand: non, mets seulement *[no, just drop it]*

(insists on his previous suggestion, and points to the hole where Paul should play from)

Doul: mets seulement *[just drop it]*

(this spectator insists as Paul hesitates)

Fonand: c'etait un but, il devait bien casser *[it was a goal, he should have cut it well]*

(reacts to Paul's rejection of his suggestion, and decision to plays pebbles a different hole)

Paul: non il ne faut pas dire ca, c'est que quand on m'indique je m'embrouile *[no don't say that, the fact is that I am confused when I am directed]*

Arguing with Paul, while guiding him evidences complex learning situations that *Songo* gameplay affords to participants as they share their knowledge and encourages reflection on a player's gameplay.

Conclusion

The preliminary findings discussed in this paper give insights into forms of interactions important for understanding learning in the 21st century and could contribute to the learning sciences rethinking of learning in the digital age.

References

Bayeck, R. Y. (2017). A review of five African board games: is there any educational potential?. *Cambridge Journal of Education*, 1-20.

Berland, M., & Lee, V. (2012). Collaborative strategic board games as a site for distributed computational thinking. *International Journal of Game-Based Learning, 1*(2), 65–81.

Carter, M., Gibbs, M., & Harrop, M. (2014). Drafting an army: The playful pastime of Warhammer 40,000. *Games and Culture, 9*(2), 122-147.

Derry, S. J., Pea, R. D., Barron, B., Engle, R. A., Erickson, F., Goldman, R., Sherin, B. L. (2010). Conducting video research in the Learning Sciences: Guidance on selection, analysis, technology, and ethics. *Journal of the Learning Sciences, 19*(1), 3–53.

Meka, O. J.M. (2008). *Le jeu du songo : Reflets du social.* Cameroun : L'Harmattan

Njock, G. E. (1985). Mathématiques et environnement socio-culturel en Afrique Noire. *Présence Africaine, 3*, 3-21.

Peppler, K., Danish, J. A., & Phelps, D. (2013). Collaborative gaming: Teaching children about complex systems and collective behavior. *Simulation & Gaming, 44*(5), 683-705.

Owona, S. M. (2004). *Le jeu de Songo*. Paris, France: L'Harmattan.

Hromek, R., & Roffey, S. (2009). Promoting social and emotional learning with games: "It's fun and we learn things". *Simulation & Gaming, 40*(5), 626-644.

Acknowledgments

Defining Alternative as More Than At-Risk: Youth Defined Outcomes and Emerging Identities in Alternative Schools

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Abstract: In tackling the challenge of re-engaging youth in school, youth are often ascribed deficit labels, such as "at-risk". This poster explores ways to redefine youth on the margins of education by looking at why youth enrolled in the alternative high schools and definitions of success in those schools. Findings include that youth sought and found opportunities to explore their identities and have an authentic impact on others.

Major issues addressed

In tackling major challenges, such as dropout rates or student disengagement and disaffiliation in school (Rumberger, 2011), students are often ascribed deficit narratives, labeling them as "at-risk", "unmotivated", or "lacking skills" (Lee, 2009; te Riele, 2007). Doing so positions youth in relation to conventional schooling and definitions of success in those institutions (Eckert, 1989). Historically, alternative schools have been developed as an intervention or option for youth who are designated "at-risk" of dropping out (Tierney, in press). While many alternative schools cater to youth designated "at-risk", this is not always the case and never a simple story. Because of the complicated history many youths have with schooling and the labels that have been assigned to them, the work of alternative schools is equal parts academics and identity development (Tierney, in press). As such, it is important to understand a) the reasons that youth are leaving conventional schools and enrolling in alternative schools and b) how success is defined and supported in alternative schools.

Potential significance

In thinking about the ways that public scholarship can help educate diverse democracies, it is important to a) learn from the stories of those on the margins of education, both the youth and the schools, b) to critique the, often unintended, negative labels and narratives that are given to youth who do not fit into the normative definitions of success, and c) to create new narratives of success within public education. While this submission does not focus on technology or the digital age, it looks specifically at how the learning sciences can continue to rethink learning and definitions of education. This paper focused squarely on expanding definitions of learning and education to include youth and contexts on the margins of public education.

Theoretical and methodological approaches

In this study, identity development is viewed as a dynamic process that is social in nature, developing in and across contexts and communities (Dreier, 2009; Nasir, 2012; Wenger, 1998). Additionally, I consider how educational structures help produce youth identities, defining and framing success and failure for students, and promoting certain practices and identities and marginalizing others (McDermott, Goldman, and Varenne, 2006). These studies show how the definitions of success and identity development are embedded in the contexts, structures, and communities of the schools in which they exist.

Data for this analysis was taken from a larger ethnographic longitudinal study of youth attending two alternative high schools over the course of one academic year. All incoming transfer (10th-12th grade) students were invited to participate in the study. All consented youth participated in surveys and initial interviews (N=31). Case study youth were selected by observing their participation during orientation, their responses on a survey, and their initial interview. Cases were chosen because they were representative of the youth in the study in terms of survey responses and class participation. Case study youth were observed and interviewed in multiple classes, school activities, and out-of-school contexts. Additional relevant participants (e.g., teachers, mentors, other students) were also interviewed in each context. To explore youth processes of identity development and resources for identity development in the alternative schools, analysis consisted of qualitative coding of 50 hours of interviews and 70 hours of observational notes.

Major findings

Results from this study indicate that students choose to attend alternative schools for multiple, complex, and interwoven and often included aspects unseen by adults in their former schools. One youth, DJ (all names are pseudonyms), discussed that, while he was a good student in school, after school hours he was getting in trouble, drinking, and smoking marijuana on a daily basis. He chose to enroll in the alternative school to

distance himself from his friends at his former school. Another youth, Penelope, described how she felt both invisible and anxious at her former school – that the anxiety and social pressures of the school made her physically sick. However, she still earned high grades and did not arouse the concerns of adults at the school. In addition, contrary to narratives of at-risk youth, most of the youth in the study connected to one or more teachers in their former school. Further, a number of the youth had adult mentors outside of school. However, despite these adult connections, youth in the study felt constrained and unsuccessful in the structure of their former schools. For example, Penelope discussed her former school, saying: "It was very hard to feel individual when you're just mushed into this area with thousands of other students" (Penelope Interview, 10/8/14). In her interviews, Penelope made a connection between the lack of choices and her perceived lack of individuality. In this way, the school confined the space in which Penelope could explore her identity. These narratives seem to indicate that re-engagement in school may require more than adults who care, but that youth also need opportunities for agency, individuality, and to explore their identities.

In contrast to their former schools, where nearly every youth in the study defined by high grades, success within the alternative school included academic achievement, but focused primarily on personal development, personal expression, and community membership and participation. These definitions of success were framed by the teachers at the school and reified by students. At one of the alternative programs, youth reflected on their leadership style and identity as a leader as they mentored sixth graders. At the other school, most school projects were creative acts, where older students modeled that practice and possibilities for newer students. These definitions of success were bi-directional – not just given to student, such as earning grades – in the alternative schools, youth success impacted the youth, but also impacted the schools. DJ described his goals a leader, "What I really want from my kids is I want to inspire them so that they become leaders of themselves and their schools or whatever they want to do… I'm not here for myself." (DJ Interview, 2/2/15). Interwoven with the definitions of success, both alternative schools provided youth agency in the valued practices of the school. This extends the concept of putting oneself into practice (Nasir, 2012), since youth not only had the agency for self-expression, but they felt their personalized actions had actual impact and significance.

At both school sites, youth left their former schools to have new and greater opportunities to explore and redefine their identities. Connected with these motivations were desires to attend a school where their individual presence mattered. By broadening definitions of success and providing youth with agency of choice and impact, the alternative schools support youth to positively develop their academic identities. This work contributes to literature on dropout prevention (Rumberger, 2011), by examining the ways in which normative definitions of success may constrain opportunities for identity development, contributing to disengagement in school. In addition, this study adds to literature on identity development, by examining the interplay of school communities (Wenger, 1998), definitions of success (McDermott et al., 2006), and authentic youth roles (Nasir, 2012) linked to those definitions of success. Finally, this work contributes to the design of alternative school learning environments by a) identifying practices that support youth re-engagement, identity development, and academic success and b) disrupting the stereotypical narratives of youth in alternative schools (te Riele, 2007).

References

Dreier, O. (2009). Persons in structures of social practice. *Theory & Psychology, 19*(2), 193- 212.
Eckert, P. (1989). *Jocks and burnouts: Social categories and identity in the high school*. New York: Teachers College Press.
Lee, Carol D. (2009). Historical Evolution of Risk and Equity: Interdisciplinary Issues and Critiques. *Review of Research in Education, 33*(1), 63-100.
McDermott, R., Goldman, S., & Varenne, H. (2006). The cultural work of learning disabilities. *Educational Researcher, 35*(6), 12-17.
Nasir, N. S. (2012). *Racialized identities: Race and achievement among African American youth*. Stanford, California: Stanford University Press.
Rumberger, R. W. (2011). *Dropping out: Why students drop out of high school and what can be done about it*. Cambridge, Mass.: Harvard University Press.
te Riele, K. (2007). Educational alternatives for marginalised youth. *The Australian Educational Researcher, 34*(3), 53-68.
Tierney, G. (in press). Alternative Schools in the United States: How History, Policy, and Definitions of Success Define Alternative Schools and the Youth Who Attend Them. In McCluskey, G. & Mills, M. (Eds.) *International perspectives on alternative education: Policy and practice.* To be published by Institute of Education (IOE) Press, London.
Wenger, E. (1998). *Communities of practice: Learning, meaning, and identity*. Cambridge, U.K.; New York, N.Y.: Cambridge University Press.

Neurocognitive Task Analysis: What Happens as Medical Students Develop Perceptual Abilities?

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Abstract: Cognitive task analyses help educators identify the knowledge, skills, and abilities that comprise successful performances and thereby develop relevant learning experiences. Here we argue that it is now possible, and helpful, to investigate the neuro-cognitive bases of performance.

Diagnostic imaging is a central component of modern medical practice, with millions of images ordered and read daily. The differences between normal and abnormal results are subtle, and interpreting images accurately and consistently is difficult even for experienced clinicians. The ability of medical educators to impart this ability to trainees is uneven, as multiple meta-analyses have concluded (Rourke, Oberholtzer, Chatterly, & Brassard; 2015; Rourke, Leong, & Chatterly; 2018).

One problem, we argue, is that medical educators construe the ability as a cognitive one that draws on declarative knowledge and clinical reasoning rather than a visual skill drawing on cortical networks tuned sharply to the task. Thus, training emphasizes the acquisition of a large amount of basic knowledge along with some clinical experience, but it marginalizes the visual categorization diagnostic images.

Researchers in the cognitive neurosciences have studied visual experts from a number of domains including birders, dog-show judges, lepidopterists, handwriting and fingerprint analysts, mycologists, and chicken sexers. Some of the researchers have demonstrated convincingly that many instances of visual expertise are stimulus driven, bottom-up, forms of processing that occur very quickly after the onset of an image—too quickly to involve top-down, attentional and conceptual input in any substantial way.

If diagnostic image interpretation is isomorphic with these forms of visual expertise, training should include guided, structured visual categorization in addition to the acquisition of basic knowledge. Unfortunately, image interpretation has rarely been conceptualized or studied in this framework. Moreover, there are many reasons to think that image interpretation is different—behaviorally, cognitively, and neurally—than other forms of visual expertise. Briefly, images such blood smears or skin lesions are unlike the other stimuli that have been studied (cars, birds, dogs, etc.,) in that they do not have a natural top-bottom orientation, they are not small variations of a central prototype, and the task of the expert is not to individuate stimuli that are otherwise homogeneous.

In our study we asked cardiologists and pulmonologists to read electrocardiograms and chest xrays—one being their specialty and the other a general ability—while we recorded their brain activity using scalp electroencephalography. We found patterns of activity similar to those of previously studied visual experts while the physicians read images from their area of expertise, but not while they read the other category of images. This suggests, provisionally, that reading diagnostic images is isomorphic with other forms of visual expertise and therefore should be trained and assessed in the same manner that other types of visual experts are trained.
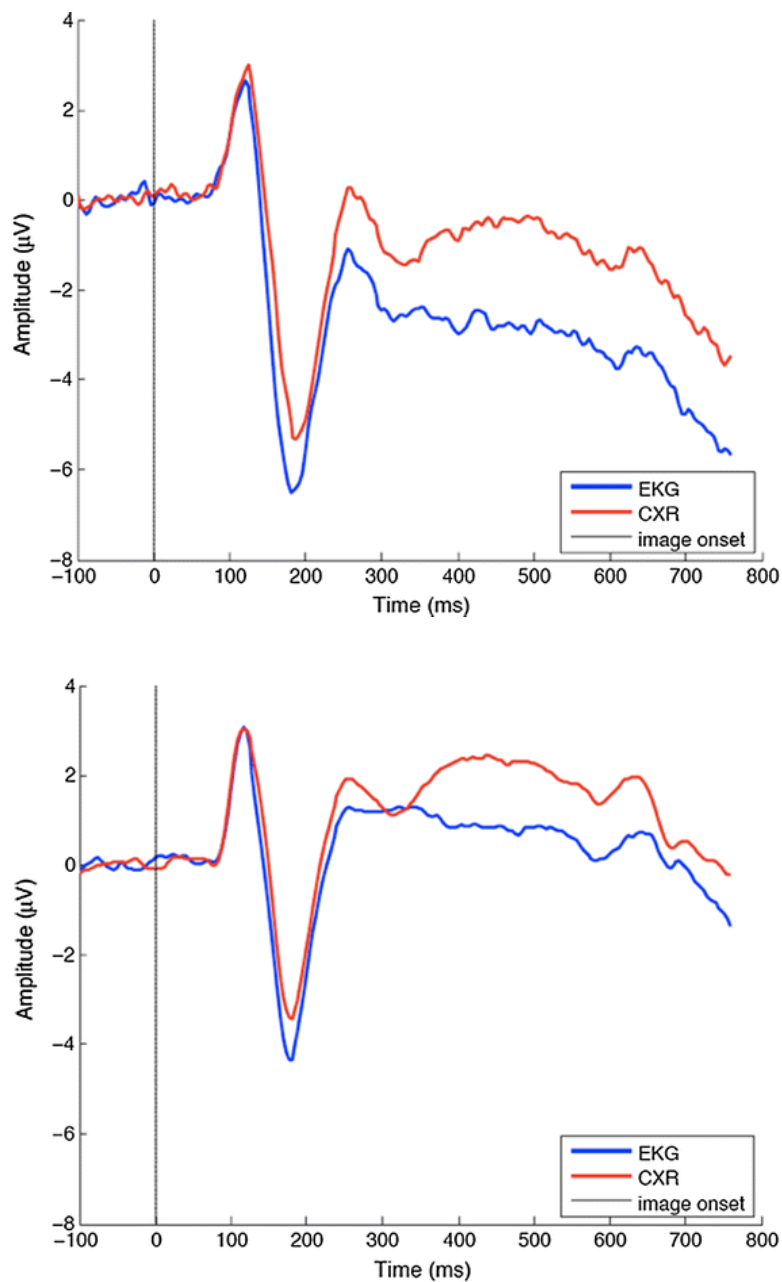
Figures 1 and 2. Wave plots of the cardiologists' (Fig 1) and pulmonologists (Fig 2) brain activity as they read 64 EKGs and 64 chest radiographs. The plots represent the grand average of the N170 ERP recorded at channels T5 and T6 across the 520 trials that were performed by each of the participants.

References

Rourke, L. (2018). Conditions-based learning theory as a framework for comparative-effectiveness reviews. *Teaching and Learning in Medicine*, 30.

Rourke, L. (2015). Learning to detect, categorize, and identify skin lesions: a meta-analysis. JAMA dermatology, 151(3), 293-301.

GenEvo - An Emergent Systems Microworld For Model-Based Scientific Inquiry in the Context of Genetics and Evolution

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Abstract: In this poster, we discuss GenEvo, a learning environment that we have designed to engage students in scientific inquiry practices in the context of genetics and evolution. GenEvo belongs to a class of constructionist learning environments that we call Emergent Systems Microworlds (ESM) which combine two design approaches: agent-based modeling of emergent systems and constructionism. An increased emphasis on learning scientific inquiry practices through the use of models has created demand for model-based curricula that incorporate authentic disciplinary inquiry practices. We argue that the design of GenEvo allows students to engage with disciplinary ideas central to modern biology, as well as complex systems thinking that is crucial in contemporary biological research. We also demonstrate that GenEvo makes advanced disciplinary ideas accessible to students in two very different global research settings.

Introduction

There is a huge disparity between high school biology instruction and the research practices of modern biologists (Wilensky & Reisman, 2006). Our work seeks to address this gap by combining two powerful design approaches in learning sciences, namely, agent-based modeling of emergent systems and constructionism (Wilensky & Rand, 2015; Kafai, 2006). We call our design approach Emergent Systems Microworlds (ESM). We use this approach to make cutting-edge ideas in modern biology such as molecular genetics and genetic regulation ideas accessible to middle and high school students in different global settings (India and the United States), by engaging them in the research practices of computational modeling and complex systems thinking.

Emergent Systems Microworlds

In this paper, we are coining the term Emergent Systems Microworlds (ESM) to describe the learning environments that are designed by combining two design approaches, agent-based modeling of emergent systems and constructionism. In agent-based modeling environments, an agent is a computational object with particular properties and actions. An 'emergent' phenomenon, is modelled in terms of agents and their interactions (Wilensky & Rand, 2015). Prior research has demonstrated agent-based modeling to be a powerful approach for explaining and understanding emergent phenomena across a wide range of domains, including the natural sciences (e.g., Blikstein & Wilensky, 2004; Levy & Wilensky, 2006). In order for students to explore and learn about emergent phenomena, we use computational models that are designed in the form of a microworld. Microworlds are encapsulated open-ended computational exploratory environments in which a set of concepts can be explored, through interactions that lead to knowledge construction (Papert, 1980). In the use of a microworld, a learner is expected to manipulate the objects and execute specific operations instantiated in the microworld, in order to induce or discover their properties and the functioning of the system as a whole (Edwards, 1995). ESMs are a specifically designed to support students in creating, exploring, and sharing virtual models of dynamic systems that exhibit emergent phenomena. ESM-based curricula engage students in personally meaningful model construction and debugging processes. In addition, these curricula are also designed for students to share their constructions with their classmates and benefit from interacting with each other.

The GenEvo curriculum as an ESM-based curriculum

Our ESM-based curriculum GenEvo uses NetLogo to model emergent phenomena (Wilensky, 1999), an agent-based modeling platform which is intentionally designed to foreground emergent systems modeling for educational and research purposes (see Wilensky & Reisman, 2006). This curriculum focuses on making explicit connections between three organizational levels in biology, namely the cellular, the organismic, and the population level. Interactions between agents, like DNA and proteins at the molecular (micro) level result in an emergent phenotype at the cellular or organismic (macro) level. Competition between organisms (micro) results in the emergence of fitter traits at the population (macro) level. We have designed computational models in the form of microworlds that allow students to explore emergent systems across these three levels. Students investigate these models through a series of scaffolded, playful explorations. When students set initial conditions by changing the values of sliders and run the simulation, they observe agent level behaviors in the environment.

The computational interface also contains several plots where students can observe changes at the system level such as changes in energy of the cell over time. As students design and conduct computational experiments in the ESM learning environment, they collectively build the ideas about emergent properties in the ESM.

Research design and results

Given the relative novelty of ESMs and their effectiveness in supporting learners, we became interested in how these tools and curricular materials that use these tools work differently across global settings. In pursuit of this goal, we partnered with two institutions, one in the US and one in India. The data presented in this paper is from a Computational Modeling in Biology course taught at both institutions. Participating students in these programs ranged from 11 to 14 years of age and were intellectually advanced based on their academic performance. In the United States cohort, there were 14 students (6 female, 8 male) of mixed racial and ethnic backgrounds (6 White non-Hispanics, 4 Asians, 1 White Hispanic, 1 American Indian or Alaskan Native, 2 identifying as Other). In the summer residential program in India, 15 students participated (8 female, 7 male), all of Asian Indian origin. We used mixed-methods analysis to investigate whether students learned disciplinary core ideas through their participation in ESM-based curricula and how students engaged in scientific inquiry practices. In this poster we present the qualitative analysis of learning gains.

We performed quantitative analysis to investigate learning of disciplinary core ideas (DCIs) in Genetics and Evolution. All the students who consented to participate in the research study took both a pre- and a post-test. These tests were a series of randomly assigned multiple choice questions that tested students' understanding of the DCIs. We find significant learning gains ($p < 0.005$) comparing pre-post scores in both the US (n = 14) as well as in India (n = 15) (See Figure 1). These gains establish the effectiveness of the ESM-based GenEvo curriculum in teaching advanced biological core ideas in both the settings.

Figure 1. Pre- and post- tests comparison showing that both the courses showed significant learning gains.

In this paper, we have discussed the design and effectiveness of GenEvo as an ESM-based constructionist curriculum. We are in process of conducting qualitative analysis to characterize student learning and participation to develop insights into how an ESM-based curriculum supports learning of scientific and complex systems thinking.

References

Blikstein, P., & Wilensky, U. (2010). MaterialSim: A constructionist agent-based modeling approach to engineering education. In Designs for learning environments of the future (pp. 17-60). Springer US.

Dabholkar, S. & Wilensky, U. (2016). GenEvo Systems Biology curriculum. http://ccl.northwestern.edu/curriculum/genevo/. Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL.

Edwards, L. D. (1995). Microworlds as representations. Computers and exploratory learning, 127-154.

Kafai, Y. B. (2006). Constructionism. The Cambridge handbook of the learning sciences. Cambridge University Press, New York.

Levy, S. T., & Wilensky, U. (2006, April). Emerging knowledge through an emergent perspective: High-school students' inquiry, exploration and learning in Connected Chemistry. In annual meeting of the American Educational Research Association, San Francisco, CA (Vol. 11).

Papert, S. (1980). Mindstorms: Children, computers, and powerful ideas. Basic Books, Inc.

Wilensky, U. (1999). NetLogo [computer software]. Evanston, IL: Center for Connected Learning and Computer-Based Modeling, Northwestern University. http://ccl.northwestern.edu/netlogo.

Wilensky, U., & Reisman, K. (2006). Thinking like a wolf, a sheep, or a firefly: Learning biology through constructing and testing computational theories—an embodied modeling approach. Cognition and instruction, 24(2), 171-209.

Wilensky, U., & Rand, W. (2015). An introduction to agent-based modeling: modeling natural, social, and engineered complex systems with NetLogo. MIT Press.

Re-Engaging Youth: Using Discourse Analysis to Explore Individual Agency and Community Belonging

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Abstract: One of the perennial challenges in public education is how to re-engage youth on the margins of education. One of the strategies for re-engaging youth is guiding them into alternative schools. Using Thematic Role Analysis, this paper examines the ways and timeframes that youth identify as agents and members in two alternative school communities.

Major issues addressed

Currently in the United States, alternative high schools exist as one of the primary mechanisms in public education for supporting "at-risk" youth (Tierney, 2016). When educational systems, officially and unofficially, define success and failure, marginalization and inequity of participation become part of the process of school (Vadeboncoeur, 2009). In this way, alternative schools often serve youth who, in some way or another, have been marginalized, and possibly unsuccessful, in school. The role of alternative schools then becomes to not only support youths' academic success, but also helping youth redefine their academic identities and their role in school (Tierney, 2016). This paper explores the ways youth discuss themselves as participants in education and within the specific learning communities in two alternative schools.

Potential significance

Work on re-engaging youth in education often focuses on either changing the youth or changing the contexts and influences of youths' lives (te Riele, 2007). In both instances, youth are acted upon without a significant voice in the process. This paper looks specifically at how youth discuss themselves and uses discourse analysis to explore the ways they do or do not talk of themselves as active agents in their lives and connected members to their schools. When rethinking learning, the Learning Sciences need to continue to explore new ways to broaden participation and narrow the margins of public education.

Theoretical approaches

Previous research has explored how agency and authenticity can impact youth identity development, providing opportunities for youth to put parts of themselves into their participation in school (Nasir, 2012). Participation in a community of practice simultaneously shapes the identity of the participants and also the community of practice itself (Wenger, 1998). Membership can thus be observed through shifting engagement in the practices and values of a community. Youth discourse was analyzed using thematic role analysis (Finegan, 2011) to look at the timeframes in which youth developed membership in the communities.

Methodological approaches

The data for this paper is from a larger ethnographic study that explored youth identity development throughout youths' first year in two public alternative high schools, Pathways and Redwood (all names in this paper are pseudonyms). This paper reports on findings from a thematic role analysis (Finegan, 2011) that was completed to complement qualitative analysis on youth participation and discourse, reported in Tierney (2016). Pathways is a small one-year high school program (approximately 50 students) where youth school are leaders at the district-run wilderness camp, leading visiting groups of sixth graders. Redwood is a larger high school (approximately 350 students), without grades and with a focus on personalized learning and democratic education. At both schools, students either self-selected into the schools, seeking a learning alternative, or were guided into the schools because of credit deficiency, truancy, etc. At both schools, all incoming transfer students were recruited for the study and case youth were chosen because of previous experiences with marginalization in school. Case youth were interviewed throughout the school year (five to seven hours each) and were observed in multiple school classes and contexts (approximately 20 hours each). Initially, data was qualitatively coded to examine resources and processes of youth identity development (Tierney, 2016). Following that, thematic role analysis was used to reexamine interviews and surveys. The analysis focused specifically on the agents used in their responses ("I", "we") and the action (verbs) connected to the agents. Specifically, interviews from two comparison cases were chosen for analysis – DJ from Pathways High School and Penelope from Redwoods High School. Interviews from the beginning of the year (October), midyear (February), and end of year (May) were used to see shifts in discourse over time. Survey data and interviews from two additional cases were then

analyzed. Surveys were completed by all consented youth in September, following orientation, and focused on their previous education and reasons for enrolling in the alternative schools.

Major findings

As reported in Tierney (2016), while the two sites shared many similar resources for supporting youth identity development, they approached the role of the individual and community differently. Teachers and youth at Redwood focused on personalized learning (self-guided learning, personal responsibility for learning) and community participation (school committee participation). While teachers and youth at Pathways focused on the individual as part of the community (community leadership, team building). Analysis identified differences in how youth oriented to the school community and the timeframe it took to do so.

"I" and "we": Differences in use and action

Throughout the interviews in the study, youth used the pronouns "I" and "we". However, how they used those pronouns differed in relation to whether or not they described themselves as active agents and what goals their use of "I" and "we" were connected to. The use of "I" as an agent followed a similar pattern across the two cases, indicating that both youth talked about themselves as active agents at the alternative schools. Throughout the year, both students employed a range of verbs in relation to the alternative schools, including opinions, observations, and a number of actions for what they saw themselves as able to do in school.

While there were some minor differences across the two cases in how they used "I" as an agent, the bigger difference occurred in the use of "we" as an agent. DJ used "we" to describe actions that the students had done, but also when describing Pathways ("We're all trying to get to know each other and we always call each other family"). Penelope, on the other hand, used "we" when describing actions they had done in class, out-of-school activity (horseback riding), and her experiences at her previous school ("We just wrote whatever the teacher wanted us to"), never when describing Redwood. At the middle and end of the year both DJ and Penelope regularly used "we" as the agent when talking about the alternative schools. However, Penelope typically used "we" to describe actions she and other students took in and out of classes, while DJ used "we" to describe actions he and other students took, but also to describe Pathways and more abstract practices done at the school ("It's because we get to think about how to be a better you"). This use of "we" seemed to show the shared repertoire and alignment with the communities that Penelope developed over the year and that DJ had developed early and then maintained. A second round of analysis focused on surveys interviews from two other cases and produced primarily similar results, with the Pathways students talking about themselves as community members very early in the year.

The patterns that case youth used shows how, over the course of the year, the various ways that discourse around agency and community membership shifted. These findings seem to indicate that the learning contexts of the two schools influenced how youth talked about themselves, specifically how they spoke of themselves as a part of the learning community. This contributes to work that examines trajectories of community membership and belonging (Wenger, 1998), resources for identity development (Nasir, 2012), the utility of discourse analysis to examine engagement and membership (Finegan, 2012), the design and implementation of alternative schools (Tierney, 2016), and the re-engagement of youth as they reframe school and their role in it (te Riele, 2007; Vadeboncoeur. 2009). With the goal of supporting the learning and identity development of diverse, and often marginalized, youth in education, future work would benefit from examining youth discourse on identity development and community membership and the specific community and identity resources available for youth in and across learning environments.

References

Finegan, E. (2012). *Language: Its structure and use* (6th ed.). Boston, MA: Wadsworth Cengage Learning.

Nasir, N. S. (2012). *Racialized identities: Race and achievement among African American youth*. Stanford, California: Stanford University Press.

te Riele, K. (2007). Educational alternatives for marginalised youth. *The Australian Educational Researcher, 34*(3), 53-68.

Tierney, G. (2016). Agency outside the margins: Identity development of youth attending alternative high schools (Doctoral dissertation). University of Washington, Seattle, Washington.

Vadeboncoeur, J. (2009). Spaces of Difference: The Contradictions of Alternative Educational Programs. *Educational Studies, 45*(3), 280-299.

Wenger, E. (1998). *Communities of practice: Learning, meaning, and identity*. Cambridge, U.K.; New York, N.Y.: Cambridge University Press.

Empowering Transformative Agency Through Critically Experimenting With Arts in Public Schooling

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Abstract: The learning sciences face the challenge of conceptualizing how power suffuses educational contexts. By examining how artists and teacher partnerships design and implement arts-integrated curricula in public school classrooms, I take a step toward theorizing how power affects local systems of activity. Through applying lenses from cultural-historical activity theory, I argue arts-integration provides unique opportunities for students to exercise transformative agency as they critically experiment with bringing their broader sociocultural contexts into their classrooms.

Introduction

This writing serves as an initial reaction to a paper published earlier this year by The Politics of Learning Writing Collective, who challenged "that the rise of nationalism across the globe demands more explicit attention to how power imbues the purposes, mechanisms, and consequences of learning" simultaneously troubled our line of inquiry and resonated with the data in which we were immersed (p. 92). The research program presented here occurred at the behest of the Chicago Arts Partnerships in Education (CAPE) focusing on their Artist/Researcher Partnerships (ARP) Program, which pairs artists with teachers to create arts-integrated curricular units for students in CPS. By tracing the trajectory of experimental practices starting from opportunities for resistance (contradictions in activity) to the ultimate exhibition of their students' work at Convergence (CAPE's culminating exhibit for the ARP), the following analysis aims to provide a theoretical conceptualization of arts-integration practices as an empowering pedagogy that amplifies AR partnerships' and their students' resistance to power through critical experiments of learning.

Theoretical framework

Cultural-historical activity theory (CHAT) supports analyses of power and resistance due to its focus on theorizing local contexts to support the generation of concrete solutions to unsustainable problems. From a presentation of CHAT as a theoretical framework by Sannino, Engeström and Lemos (2016), I employ three conceptual lenses in this analysis: (1) *object(s)* of activity; (2) *expansive learning through practical experimentation*; and (3) *transformative agency.* First, the defining feature of any human activity is its *object*, "a historically developing entity that is never fully attained or complete … an object carries in itself the pervasive contradictions of its given socioeconomic formation" (Sannino, Engeström & Lemos, 2016, pp. 602-603). These contradictions require critical experimentation to resolve and transform, manifesting as *expansive learning* in the activity system, changing its components, their interrelationships or both. Expansive learning requires engaging in the practices of resistance and transgression through critical experimentation that abstracts meaningful tools from the contradictions confronting them. Ultimately, experimenting and expanding with activity requires empowering *transformative agency*, where participants "[break] away from the given frame of action and [take] the initiative to transform it" (Virkunnen, 2006, as cited in Engeström, Sannino & Virkunnen, 2014, p. 124). Within our context of arts-integration in public schooling, this theorization of power and learning serves as the conceptual basis for our research question: How do teachers and artists integrate the arts in their instruction to support the development of students' transformative agency?

Methodology

During the 2015-2016 and 2016-2017 school years, we conducted a multi-site case study of AR partnerships participating in the ARP for CAPE. This report focuses on the work of two partnerships in two distinct schools, one for each school year of the research conducted to date. As an exploratory and comparative multi-case study, the following analysis applied an analytical framework outlined by Engeström and Sannino (2011) on four primary data sources: (1) pre-/post-implementation interviews, (2) classroom observations, (3) student artifacts, and (4) documentation created by the partnerships for their work with CAPE. Within their framework, the authors identified discursive manifestations of contradictions, two of which are represented here: (1) *conflicts*, which "take the form of resistance, disagreement, argument and criticism," (p. 373); and (2) *critical conflicts*, which are the "situations in which people face inner doubts that paralyze them in front of contradictory motives unsolvable by the subject alone," (p. 374). As we argued above, contradictions represent opportunities for

critical experimentation, so it follows that discursive manifestations of these contradictions point to potential arenas of resistance and transgression for the participating artists and teachers.

Findings

From the two cases presented here, enacting arts-integrated curricula required teachers and artists to both bring into focus the inherent contradictions of public schooling while providing students the opportunity to experiment with the conceptual and artistic tools employed in their curricula. This manifested in (at least) two distinct ways: (1) by focusing creative activity around addressing potential *critical conflicts of cultural/historical divides*, and (2) by expanding learning through experimenting with the *conflict of educational purpose*. The partnership at Sorenson Math and Science Academy (Sorenson; all names are pseudonyms) understood their project as a continuation of earlier confrontations between students and their local history, which challenged them to re-interpret contemporary issues of social justice through musical composition and choral performance. The director of the *A Capella Choir* at Sorenson, Robert Arzt, described their curriculum as exploring the question of "What can we learn through the process of investigating unfamiliar cultures through music?" Ultimately, they collectively chose to respond to former presidential candidate Gary Johnson's infamous question of "What is Aleppo?" By learning and singing traditional Arabic songs taught to them by an Arabic musician, they could collectively resist that representation and powerfully rebuke the ignorance and antipathy towards refugees represented by that candidate. Confronting students with these *critical conflicts of cultural/historical divides* while providing them with new tools to transform their position from feeling powerless (e.g., not being able to vote) to having the agency to publicly resist allowed students to transform their performance into a display of solidarity with Syrian refugees. The partnership at McCrae Elementary Academy (McCrae) have gradually expanded the object of their curriculum, representing another way that arts-integration has developed students' transformative agency. The artist of this AR partnership, José Alcides Rodriguez, described the progressive development of their curriculum, *Children Communicating Social Activism Through the Lens of Indigenous Art and Practices*, by stating, "In the beginning … [we used art] as a symbol to communicate an idea … [Now we're asking students] how can we use it now as a form for change?" The gradual integration of new artistic disciplines—here the creation of *neirikas,* artwork based on indigenous beadwork—into the traditional curriculum by an artist with indigenous ancestry allowed the partnership to resolve the *conflict of educational purpose* by expanding the object of students' learning from a basic exploration of symbolic representation to creating art that critically examines the problems troubling students outside of the classroom. As a result of this expansion, 4th and 5th grade students researched and represented global and local issues that they publicly exhibited, challenging audiences to grapple with concerns such as hate crimes, terrorism, dog fighting, and immigration.

Conclusion

The critical and transgressive experimentation of the two AR partnerships here fundamentally involved CAPE's challenge of re-/presenting students breadth of experiences within the cultural and historical constraints of a traditional schooling. These teacher-artist partnerships *empower resistance* within their classrooms by providing opportunities for students to develop and enact their transformative agency. The conceptual and practical tools of artistic disciplines allow for students' to expand classroom activity, confronting and resisting the normalizing power that consistently marginalizes, censors, and dismisses them. By deliberately designing curricula that expose students to underlying contradictions inherent in their classroom situations, we can allow students to exercise their agency to resist the normalization of the world as it is and transform it into the new possibilities they imagine and create.

References

Engeström, Y. & Sannino, A. (2011). Discursive manifestations of contradictions in organizational change efforts: A methodological framework. *Journal of Organizational Change Management, 24*(3): 368-387.

Engeström, Y., Sannino, A. & Virkkunen, J. (2014). On the methodological demands of formative interventions. *Mind, Culture & Activity, 21*(2), 118-128.

Sannino, A., Engeström, Y. & Lemos, M. (2016). Formative interventions for expansive learning and transformative agency. *Journal of the Learning Sciences, 25*(4), 599-633.

The Politics of Learning Writing Collective. (2017). The learning sciences in a new era of U.S. nationalism. *Cognition & Instruction, 35*(2), 91-102.

Identifying Shifts in Agency by Analyzing Authority in Discussion

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Abstract: Increasing students' agency influences their persistence and has ramifications for their views of the nature of science. The idea of agency is closely tied to issues of authority and power. Here we study how classroom group conversations are directed and who has the authority to direct the conversation. We present a narrative analysis of a whole class discussion, analyze discourse patterns to infer the distribution of authority amongst relevant subgroups and demonstrate a shift toward a more equitable distribution and an increase in student agency.

Introduction

Increasing learners' agency, particularly in science, is dramatically important for their future persistence (Calabrese Barton and Tan, 2010). Here we introduce the idea of *inchargeness*: an individual or subgroup with high inchargeness is in a position to steer the conversation by setting the topic or choosing who speaks next.

The context for this study is a pre-enrollment summer program that seeks to improve retention in STEM degrees for incoming STEM undergraduates, specifically first-generation college (FG) students and Deaf and hard-of-hearing (DHH) students; the university studied is about 20% FG and 8% DHH overall. Participation is gender-balanced and racial distribution roughly matches the population of the United States. Participants develop models of climate change, write reflective journals, and engage in activities to improve their metacognitive skill and sense of community. In 2014, there were 20 participants: four who identified American Sign Language (ASL) as their primary language ('signers'), three who identified as DHH but did not use ASL as their primary language, and thirteen hearing students. All of the whole-group discussions employed simultaneous interpretation in ASL.

For this study, we analyzed video of a whole-group discussion in which students created a sign for the word "metacognition," which does not exist in ASL. The creation of new signs happens regularly in ASL, with varying degrees of formality. We chose this activity because the instructor and researchers noted an increase in student agency throughout the activity. We draw from Positioning Theory to explore the role of authority as this mixed group negotiated developing a new sign. Positioning Theory is "the study of local moral orders as ever-shifting patterns of rights and obligations of speaking and acting" (Harré and Van Langenhove, 1998, p.1). Positioning Theory involves three core ideas: communication acts, positioning, and storylines. Communication acts are the socially negotiated meanings of linguistic and paralinguistic (facial expression, gestures, etc.) actions. Storylines are the patterns by which interactions develop and through which discursive actions are understood. Positioning is the process by which participants take up or are assigned positions. These three ideas interact dynamically. Participants interpret communication acts based on the storylines at play and their positions within them. These acts impact both the relevant storylines and the relative positioning of participants within those storylines. In addition, for most interactions, there are multiple positions and storylines at play which occur over many timescales. We used the communication acts in each episode to infer the positions of individuals and subgroups with regard to their authority in the conversation by comparing these patterns to common storylines.

We introduce the concept of *inchargeness*, which is associated with directing the flow of conversation. An individual or subgroup with high inchargeness is positioned such that they are more likely to have successful bids to steer the conversation. Inchargeness is a deliberately volatile measure; a person's inchargeness is intimately tied to their current positioning, the positioning of the other participants, and the communication acts all engage in. Different storylines will promote different inchargeness distributions, from hierarchical to distributed.

Inchargeness is not the same as expertise, nor is it about the amount of participation, but instead the character of participation. There is no single discursive indicator of inchargeness, but we infer it based on patterns of who proposes, sets, or limits the topic(s) of conversation; whether talk is sequential or overlapping; types of discourse; and to whom speech and/or questions are addressed. We use a combination of behavioral markers to identify communication acts and infer the distribution of inchargeness by looking at positions within storylines. We analyze our data from the perspective of inchargeness and show a change in the distribution over time.

Analysis of inchargeness

We divided the discussion into five episodes with distinct discourse patterns and characterized the communication acts and inferred storylines within each episode. Given the nature of the activity, we were particularly attuned to similarities and differences between how the instructor, signers, and non-signers (including both hearing students

and non-signing DHH students) engaged in the discussion during each of these episodes. Here we present a very condensed narrative of the activity highlighting the results for how we characterized inchargeness in each episode.

Episode 1: The instructor began by eliciting information about ASL from the signers. The pattern of communication acts is similar to a "panel discussion" storyline, where a moderator (instructor) has high inchargeness, panelists (signers) have some inchargeness, and an audience (non-signers) has little inchargeness.

Episode 2: The instructor then asked all of the students to define metacognition. This episode shows a "call-and-response" storyline common in classrooms. In this storyline, the instructor still has the highest inchargeness, but now the signers' expertise is no longer relevant and there was no distinction between how the signers and non-signers engaged in discussion. Thus, all students have a similar level of inchargeness.

Episode 3: The instructor redirected the conversation toward ASL and then removed himself from the conversation. The storyline here feels more emergent: the students are engaged in making sense of this problem collaboratively, in contrast with the more constrained communication acts earlier. Students did the majority of the speaking and built each other's ideas, suggesting higher inchargeness than Episode 2, but there was again a clear difference in how signers and non-signers participated, such that signers had higher inchargeness than non-signers.

Episode 4: One of the non-signers redirected the conversation back toward metacognition and led the discussion like the instructor in Episode 2 ("call-and-response" storyline), indicating she had more inchargeness than her peers. However, the other students (with no distinction between signers and non-signers) did not respond in the same way they did to the instructor (e.g., comments directed to the group and not just to her), indicating her inchargeness was less than the instructor's and the other students had more inchargeness than in Episode 2.

Episode 5: The conversation returned to the task of creating a sign and took on a free-for-all character with overlapping talk and many task-related side conversations, like an "informal dinner party" storyline. The difference between participation of signers and non-signers was much less noticeable than in Episodes 1 and 3, suggesting a more similar level of inchargeness. At one point, the instructor tried to redirect the conversation, but students quickly returned to their earlier conversations, suggesting that he had equal inchargeness to the students.

Discussion

Inchargeness, as we have introduced it here, is about one's position within a group to direct a conversation and the degree to which one's voice is heard and acknowledged. Thus, it directly relates to agency, as well as equity.

We saw a variety of storylines represented, including some that were fairly constrained and recognizable (e.g., panel discussion, classroom call-and-response). Others were more emergent (Episode 3), where the students were collaboratively engaged in making sense of the task. The informal dinner party storyline in Episode 5 is the most interesting and unexpected for a classroom environment. Most classroom storylines position the instructor with a high level of inchargeness. However, in Episode 5, the students treat the instructor's bids to control the conversation without any particular deference, as if he has no more or less inchargeness than anyone else.

With regard to agency, this last episode suggests that by treating the instructor as another peer, the students are exhibiting more agency in this storyline than in earlier storylines where they positioned themselves with less inchargeness than the instructor. While we do not claim that any individual has an increased sense of agency, we believe the group eventually transitions to a storyline where they collectively have more agency.

Finally, inchargeness can potentially give us insight into issues of equity in group discussions. Equity is about "a fair distribution of opportunities to learn or opportunities to participate" (Esmonde, 2009). This suggests that storylines with a flatter distribution of inchargeness may be more equitable than those with a more hierarchical distribution. In this case, our shift toward greater agency may also be associated with a shift toward greater equity. We plan to explore this connection by comparing inchargeness to other measures of equity.

References

Calabrese Barton, A. and Tan, E. (2010). We Be Burnin'! Agency, Identity, and Science Learning. *Journal of the Learning Sciences, 19*(2):187–229.

Esmonde, I. (2009). Ideas and Identities: Supporting Equity in Cooperative Mathematics Learning. *Review of Educational Research*, *79*(2), 1008–1043.

Harré, R. and Van Langenhove, L., (Eds.). (1998). *Positioning Theory: Moral Contexts of International Action*. Wiley-Blackwell.

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A Method for Determining the Extent of Recent Temporal Context in Analyses of Complex, Collaborative Thinking

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Abstract: This study presents an empirical method for measuring recent temporal context in collaborative interactions, which can be used to warrant a choice of window length in moving window analyses of complex, collaborative thinking and other interactive learning processes.

Keywords: recent temporal context, moving window, collaborative learning, discourse analysis, epistemic network analysis

Introduction

In the learning sciences, complex thinking is often conceptualized as a process of developing cognitive connections among concepts. In collaborative work, individuals make connections not only within their own contributions but also to the contributions of their collaborators (Shaffer, 2017). To model complex, collaborative thinking, researchers need to identify the context in which such connections are meaningful. Prior work has approached this problem using *moving windows* (Siebert-Evenstone et al., 2016), where each turn of talk in a collaborative conversation is associated with some prior segment of the discussion that forms its *recent temporal context* (Suthers & Desiato, 2012).

A key challenge for window models of complex, collaborative thinking is selecting a window length that is sufficiently long to capture the recent temporal context but not so long as to overrepresent connections that are not meaningful. This study presents a novel empirical method that minimizes the need for human annotation while providing both qualitative and quantitative warrants for determining a window length to analyze collaborative connection-making. We evaluate the method by analyzing conceptual connectivity in the same dataset using different window lengths to explore the effects of window length on the resulting models.

Methods

We analyzed the collaborative interactions of students in the engineering simulation *Nephrotex* (Chesler et al., 2015). In *Nephrotex*, students interact in 4-5 member teams with their engineering advisor through an online instant message program (chat), and the system automatically records all chat conversations for subsequent analysis. *Nephrotex* takes approximately 15 hours to complete. Chat conversations ($N = 54{,}896$ chats) were collected from 20 implementations of *Nephrotex* at five institutions in the United States. Participants ($N = 652$) were first- and second-year college students using *Nephrotex* as part of an engineering course. To measure recent temporal context in this setting, we randomly selected 200 utterances from the 54,896 chats in the *Nephrotex* dataset. For each chat, two independent raters identified all immediately preceding chats in the conversation to which the given chat referred. These annotations indicate the window containing a given utterance and its recent temporal context, where window length is the number of chats from the referring utterance to the earliest referent, inclusive.

To calculate agreement between the two independent raters, we computed Cohen's κ (kappa) for each window length. Kappa was calculated for each window size, x, by assigning a "1" to any utterance that a given rater determined to have window length x and a "0" to all other utterances. Kappa thus indicates the extent to which the two raters agreed in their assessments of which utterances' recent temporal context could be modeled with the same window size. To determine whether kappa scores could be generalized to the population from which they were drawn ($> 50{,}000$ chats), we computed Shaffer's ρ (rho) to estimate the expected Type I error rate of kappa given the sample size (Shaffer, 2017). This method (a) allows researchers to empirically determine an appropriate window size by rating a small sample of utterances, and (b) provides a statistical warrant for generalizing from the sample to the population as a whole.

We then tested our technique for empirically determining window length by analyzing a portion of the *Nephrotex* dataset using *epistemic network analysis* (ENA) (Shaffer, 2017). Specifically, we used ENA to model data from two implementations of *Nephrotex* (48 students; 5,757 chats) at window length x for each $x \in \{1, 2, \ldots, 13\}$, and for each window length, we compared the networks of (a) students using an engineering virtual

internship for the first time (novices; $n = 24$), and (b) students using *Nephrotex* after using a different engineering virtual internship (relative experts; $n = 24$).

Results

For all window lengths up to nine, agreement between the two raters was statistically significant for $\kappa > 0.65$ (all $\kappa \geq 0.84$, N = 200, $\rho(0.65) < 0.05$), which indicates that the level of agreement between the two raters would have been $\kappa > 0.65$ for those window lengths had they evaluated the entire dataset. Of the 200 chats examined, 49 (24.5%) made no reference to prior chats, and 51 (25.5%) referenced only the previous chat. However, it is not until a moving window with a length of seven (MW7) that the relevant connections were captured for more than 95% of the sample utterances. No utterance required a window length of more than 18 chats.

To evaluate this method, we computed ENA models at each window length to determine (a) at what window size(s) the model indicates a statistically significant difference between the novices and relative experts that is consistent with our qualitative analysis of the data, and (b) at what window size the ENA metric space stabilizes, such that increases in window size produce no significant changes in the space and thus no changes in model interpretation. While the ability of ENA to discriminate between novices and relative experts is relatively robust to window length, MW7 was one of the best models, and the ENA metric space stabilized at MW7.

Discussion

Our goal was to develop a method that (a) provides both qualitative and quantitative warrants for determining the optimal window length for use in moving window analyses of conceptual connectivity, while (b) minimizing the number of items requiring human evaluation. To assess this approach, two independent raters analyzed a random sample of 200 student chats (< 0.01% of the 54,896 chats in the dataset). This method identified MW7 as the most appropriate window length for analyzing these data. We then constructed ENA models of the data that differed only in the choice of window length. This analysis confirmed that a model with MW7 both (a) provides statistical discrimination between groups hypothesized to exhibit different patterns of conceptual connectivity based on a qualitative analysis and (b) provides a stable interpretation of the ENA model.

As a result, we argue that annotating a subset of data for *furthest referents* makes it possible to analyze recent temporal context and thus determine an appropriate window length to be used in analyses of complex, collaborative thinking. Importantly, this method minimizes the need for human annotation while providing both qualitative and quantitative warrants for choosing a particular window length. While we describe this method by presenting results from one learning context (*Nephrotex*) and one learning analytic technique (ENA), we believe that a similar approach of annotating data by furthest referents will be compatible with different learning settings, different theories of collaborative discourse, and different methods for modeling conceptual connectivity using moving windows. Of course, future research should test our method by repeating this study using other data and models of connectivity. Critically, this method provides a warrant for making generalizations to the population from which the hand-annotated sample was drawn, making it suitable for analyses of complex, collaborative thinking at scale.

References

Chesler, N. C., Ruis, A. R., Collier, W., Swiecki, Z., Arastoopour, G., & Shaffer, D. W. (2015). A novel paradigm for engineering education: Virtual internships with individualized mentoring and assessment of engineering thinking. *Journal of Biomechanical Engineering, 137*(2), 024701:1-8.

Shaffer, D. W. (2017). *Quantitative ethnography*. Madison, WI: Cathcart Press.

Siebert-Evenstone, A. L., Arastoopour, G., Collier, W., Swiecki, Z., Ruis, A. R., & Shaffer, D. W. (2016). In search of conversational grain size: Modeling semantic structure using moving stanza windows. In C.-K. Looi, J. Polman, U. Cress, & P. Reimann (Eds.), *Transforming learning, empowering learners: The International Conference of the Learning Sciences (ICLS) 2016* (Vol. I, pp. 631–638).

Suthers, D. D., & Desiato, C. (2012). Exposing chat features through analysis of uptake between contributions. In *45th Hawaii International Conference on System Science* (pp. 3368–3377). IEEE.

Acknowledgments

Rituals, Explorations, and Cultural Resources in the Mathematics Classroom: When Arguing Does Not Help Learning

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Abstract: This study examines "ritual" and "explorative" participation in math classroom. We use the case of adult ultra-Orthodox studying algebra for the first time, to present a rare example of ritual teaching which is responded to by explorative participation. We explain it by addressing students' "intellective identities" as they stem from students' experience in Talmud studies, a main practice of the ultra-Orthodox culture. We conclude by discussing the potential relevancy of the case to mathematics education.

Objective and theoretical framework

"Rituals" and "explorations" are described by the commognitive framework (Sfard & Lavie, 2005, Sfard, 2008) as mathematical routines, distinguished from each other by (A) learners' goals, (B) the objects that are being talked about, (C) learners' flexibility in use of the routines, (D) authority, and (E) whether the focus is on steps and procedures, or on producing new mathematical narratives. Explaning the necessity of rituals as a stage towards explorative routines, Sfard & Lavie (2005) suggest that rituals are "probably the only possible departure points toward a meaningful discourse" (p. 283). In a recent work, Heyd-Metzuyanim and Graven (2016) have broadened this lens to link between ritual participation, South African post-apartheid context and learners' identity. The current paper continues this line of inquiry, aiming to examine connections between the ultra-Orthodox culture, which has some known explorative characteristics, and participation in mathematics learning. This relation is examined on adult Ultra-Orthodox males studying secondary mathematics for the first time in their lives at a preparatory college program.

Research context and method

For religious and political reasons, most ultra-Orthodox males in Israel do not study mathematics after the age of 11-12. Instead, they devote all their time to the study of the Talmud, the central holy text of Judaism. The Talmud is a Jewish anthology of texts – mostly conversational - from 200-500 AD, with later critical interpretations of these discussions. The text usually present conflicting viewpoints and describes the process by which participants in the discussion have arrived at their conclusions. Doubts, questions, challenges, disagreements, clarifications, and even humor are all legitimate parts of conversations (Schwarz, 2015).

Pre-academic programs are the means for young adults that have completed their Yeshiva studies to access post-secondary education and employment. The episode presented here is taken from a study of a classroom of 10 men in such a program. The study followed the last 4 months in a 12 months course instructed by the first author. Collected data included six video-recorded lessons and four interviews with 3 students regarding their experience as Talmud and math learners. All data is originally in Hebrew and has been translated by the authors.

Previously (Ehrenfeld & Heyd-Metzuyanim, in press) we have analyzed how cultural resources from both Talmudic and the mathematics studies, were used by students to construct a new hybrid discourse, and the relation of this process to students' intellective identities (Greeno, 2002). In this paper we use a complementary theoretical framework: explorative vs. ritual partcipation (Sfard, 2008). The commognitive lens (Sfard, 2008) conceptualizes mathematics learning as participation in a discourse characterized by certain routines. Two types of routines are relevant for our study: ritual and explorative. Ritual routines aregeared towards connecting with others or being identified as a competent learner while explorative routines are geared towards constructing mathematical narratives for their own sake. Building on Greeno (2002), and Sfard & Prusak (2005), we link students forms of participation (ritual vs. explorative) to their *intellective identities*, which are those narratives that participants use (or refer to tacitly) to describe themselves (and others) as competent or incompetent. We then suggest how the relation between participation and intellective identities can inform our thinking about cultural resources in the classroom.

Results and scholarly significance

Our data shows that some students in the rather traditionally-set mathematics preparatory classroom were bringing with them Talmudic discourse practices to the teacher-directed lessons. In particular, the authority structure of Talmudic studies, where the students argue with each other over the text without the interference of a teacher,

could be seen occurring spontaneously, even while the teacher did not plan (or implicitly opposed) any discussion to occur.

Our analysis of such episodes shows a mixture of ritual and explorative routines, with a surprisingly prominent aspect of explorative ones. However, the prominence of explorative interactional routines, where students question each other and the teacher's mathematical claims, did not always lead to productive learning. At times, it actually raised obstacles for the lesson. These are exemplified in a case where students were introduced to the use of 'f(x)' instead of 'y'. The teacher's rational for introducing 'f(x)' was that the new sign might visually support students' in learning derivatives. The new convention was described by the teacher as mere "convenience". Yet, the ultra-Orthodox students resisted dealing with symbols unrelated to the mathematical meanings. For example, Joshua (pseudonym) marked, half humorously: "and why? because the sky is blue" (Hebrew: "ve'lama? Kova af la'gova."), an idiom that signs accepting something without reason. The fact that Joshua mentions he accepts a change without an explanation is evidence that this process is a conscious rather than automatic one. While the teacher attempted to avoid substantiating his usage of mathematical signifiiers, students' discourse continued to be focused on the rationale for using the f(x) sign instead of y. For example, Abraham asked "what did you gain?" , and Micky asked "why didn't you do f of y?".

We acknowledge that for some readers, this might seem as ideal students' participation since students actively seek reasons for certain mathematical actions. However, we suggest a different point of view. Given the teacher's plan to teach derivatives, these explorative tendencies come at a particular time of the lesson where ritual rule following might actually have been more conducive for the students. This episode, as well as others observed in this study, may support Sfard's (2008) claim that certain types of learning need to progress from ritual to explorative participation since to engage with talking about certain mathematical objects, learners first need to familiarize themselves with these objects through thoughtful imitation of more experienced others. Our data thus points to the occasional necessity of balancing students' explorations, in particular due to what we hypothesize as the importing of Talmudic authority structure and "cultural preference for disagreement" (Blum-Kulka, Blondheim, & Hacohen, 2002).

We gained insight into some of the students' insistence on questioning and arguing with the teacher through interviews that explored their intellective identities. Through these interviews, we found that the ultra-Orthodox students' idea of learner competency was imported by them from the Talmudic world to mathematics. For example, one of the students referred to Talmud learning as endless exploration, telling about the Talmudic habit of constantly asking 'why?': "Anything you learn, you ask yourself 'why'? And then you try to obtain a book, and whatever it says about it, you also ask 'why'? And that's something that is endless. It's very enjoyable and very nice." We found a link between students' reported insistence on questioning and arguing in Talmudic studies, and their repeating of these interactional routines in the mathematics classroom. This link points to intellective identities and cultural resources as important domains for inquiry in the search for mechanisms by which learners become critical and explorative thinkers. Furthermore, the uniqueness of ultra-Orthodox students' cultural preference for disagreement might enhance our thinking of both opportunities and constraints that such discursive moves can place on mathematics learning.

References

Blum-Kulka, S., Blondheim, M., & Hacohen, G. (2002). Traditions of dispute: From negotiations of talmudic texts to the arena of political discourse in the media. *Journal of Pragmatics*, *34*(10–11), 1569–1594.

Ehrenfeld N. & Heyd-Metzuyanim E. (in press). Intellective Identities in the Construction of a Hybrid Discourse: the Case of an Ultra-Orthodox Jewish Mathematics Classroom. *International Journal of Science and Mathematics Education*.

Greeno, J. G. (2002). Students with competence, authority, and accountability: Affording intellective identities in classrooms. *The College Board*, 1–29.

Heyd-Metzuyanim, E., & Graven, M. (2016). Between people-pleasing and mathematizing - South African learners' struggle for numeracy. *Educational Studies in Mathematics*, *91*(3), 349–373.

Sfard, A. (2008). *Thinking as communicating*. New York: Cambridge University Press.

Sfard, A., & Lavie, I. (2005). Why cannot children see as the same what grown-ups cannot see as different? — Early numerical thinking revisited. *Cognition and Instruction*, *23*(2), 237–309.

Sfard, A., & Prusak, A. (2005). Telling identities: In search of an analytic tool for investigating learning as a culturally shaped activity. *Educational researcher*, 34(4), 14-22.

Schwarz, B. B. (2015). Discussing argumentative texts as a traditional Jewish learning practice. In L. B. Resnick, C. Asterhan, & S. Clarke (Eds.), *Socializing Intelligence Through Academic Talk and Dialogue*. American Educational Research Association.

Investigating Third Grade Students' Collaboration in Project-Based Learning to Inform Curriculum Design

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Abstract: This case study examines the extent to which the Multiple Literacies in Project-based Learning Curriculum supported students to (a) understand scientific concepts (b) engage in scientific inquiry and (c) collaborate successfully. It examines two dyads collaborating over several months to construct, test, and re-design a toy rocket. Although the collaborative process was not without limitations, students were generally positively engaged, used executive thinking to support scientific inquiry, and showed conceptual growth on pre/post assessments.

Keywords: Collaboration, Project-based Learning, 21st Century Skills, Science and Engineering

Introduction

Collaboration is regarded as an essential "21st century" skill (Griffen, Care, & McGaw, 2010). Collaborative learning refers to learning in which students both (a) engage in cooperation and b) engage with the same problem, building on one another's ideas (Webb and Palincsar, 1996). In addition to the benefits offered by cooperation (Gillies, 2016), collaboration additionally supports students to engage in distributed cognition by providing a "joint problem space" where students can reason together (Roschelle & Teasley, 1995). By focusing on the same work and building on each other's ideas, collaborating students can, hypothetically, accomplish more together than any individual could have accomplished alone. Nevertheless, although collaboration has significant potential, it can also play out in ways that are neither enjoyable to students nor conducive to their learning (Salomon & Globerson, 1989). Hence, it is essential to examine how students' experiences with collaboration unfold "on the ground" as they engage in sustained inquiry over time. This study contributes to that examination, guided by the following research questions:

(1) How do the children in a 3rd-grade classroom environment engage in and interpret a goal-oriented collaborative endeavor involving both science and engineering?

(2) What is the evidence regarding how these experiences and opportunities influenced student learning?

Methods and theory

The theoretical framework for this study draws from socioconstructivist theory (Palincsar 1998), which views learning as highly influenced by social interactions. The study was conducted in a third-grade classroom at a school in rural Michigan, which was engaged in a year long, project-based learning curriculum integrating science, literacy, and mathematics. Participants were four focal students, who worked in partnerships to build rockets, model their rockets' motion, test and improve their rockets, and prepare a design portfolio. Data sources include: (a) video recordings of collaboration, (b) student and teacher interviews, (c) pre/post tests, (d) student artifacts, and (e) student attitude surveys. Transcripts were coded by interaction type and conceptual content. A second, trained, rater coded a randomly selected 20% of the data (94% agreement for levels of conceptual talk; 84% for interaction type; 83% for whether questions received response). Analytical memos examined student engagement in inquiry.

Results and interesting points for discussion

This study found mixed results regarding student collaboration. Collaboration provided a venue for students to (a) engage in self-direction and executive-thinking, (b) engage in disciplinary practices such as describing and modeling the rockets movement (literacy), discussing force, pressure, and friction (science) and comparing distances that the rocket traveled (mathematics), and (c) practice and improve collaboration skills. During interviews and on the attitude survey, all focal students reported enjoying the collaborative process. Together with the relatively low levels of conflict (5% of talk turns) and off-task behavior (11% of talk turns), this suggests that students were typically engaged, respectful, and enjoying themselves. Furthermore, the pre- and post- assessments showed learning gains across all four focal students. Nevertheless, the students' collaboration was marked by unbalanced participation and a scarcity of conceptual talk (7% of total talk). Participation was most symmetric when students worked hands on with the rocket, or when students worked in distinct partnerships, rather than

joining together to work as a group of four. Conceptual talk, when it occurred, was often supported by discussions surrounding how to answer questions in the science notebook (see Figure 1, below).

Figure 1. Example of one student's science notebook

Implications

There may be a benefit to teachers and curriculum designers balancing small-group collaborative learning opportunities with whole-class, teacher-guided learning opportunities. During the collaborative activities, the teacher must, by necessity, yield some control to the students. When students have control, they may not be as conceptually-oriented as the teacher would be. On the other hand, if the teacher always has control, the students will not have the opportunity to build collaborative and executive thinking skills or to independently discuss concepts. This suggests benefits to a balance of whole-class and collaborative time. Furthermore, it may be beneficial for curriculum designers to include scaffolds to support students' conceptual talk, during collaboration. In this study, the science notebook was particularly important in prompting conceptual talk. Additionally, the hands-on learning opportunities supported more balanced participation. In curriculum design and planning, guiding questions may be key to supporting student conceptual talk, while diverse learning opportunities may be key to supporting student engagement and participation. Future research might focus on identifying additional scaffolds to support conceptual talk or considering ways that students might use additional mediums (such as blogs, film, etcetera) to respond to guiding questions.

References

Gillies, R. (2016). Cooperative learning: Review of research and practice. *Australian Journal of Teacher Education*, 41(3), 3.

Griffin, P., Care, E., and McGaw, B. (2012). The Changing Role of Education and Schools. In: Griffin, P., McGaw, B., Care, E. (eds). *Assessment and Teaching of 21st Century Skills.* Springer, Dordrecht.

Palincsar, A.S.(1998). Social constructivist perspectives on teaching and learning. Annual review of psychology, 49(1), 345-375.

Roschelle, J., & Teasley, S. D. (1995). The construction of shared knowledge in collaborative problem solving. *Computer supported collaborative learning* (pp. 69-97). Springer Berlin Heidelberg.

Salomon, G. & Globerson, T. (1989). When teams do not function the way they ought to. *International Journal of Educational Research*. 39 (1-2), 89-99.

Webb, N. M. (1989). Peer interaction and learning in small groups. *International Journal of Educational Research.* 13(1), 21-39.

Webb, N. M., & Palincsar, A. S. (1996). Group processes in the classroom. In D. C. Berliner, R. C. Calfee, D. C. Berliner, R. C. Calfee (Eds.) *Handbook of educational psychology* (pp. 841-873). New York, NY, US; London, England: Macmillan Library Reference Usa.

Acknowledgements

Exploring Teacher Presence During Social Regulation of Learning in Science Classrooms

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Abstract: We studied the extent to which teacher presence relates to social regulation of learning in a collaborative model-based learning task in two high school physics classrooms. We found that groups engaged in argumentation discourse without the teacher actively monitored their understanding and used adaptive regulation strategies. The groups in which the teacher was present during the discussion relied on the teacher for regulation of learning. We discuss the implications for science teachers and teacher educators.

Introduction

In this qualitative study, we aimed to illuminate how teacher presence relates to high school students' social regulation of learning during collaborative work in a model-based learning task in physics. Science educators have increasingly relied on collaborative learning in small groups as a preferred way to foster to foster students' argumentation and subsequent learning, because it has been shown to promote both individual and group knowledge gains (Scardamalia & Bereiter, 2014). Students' interpretations of the work of others, supported by the use of evidence, such as interpretations of models in science, are one example of group knowledge creation (Scardamalia & Bereiter, 2014). Thus, science teachers have strived to engage their students in collaborative model-based reasoning. However, researchers have found that, without instruction and support, students in groups will struggle to work together successfully and take control of their learning. Therefore, teachers need to be able to facilitate students' knowledge building and engagement in productive argumentation discourse by orchestrating and scaffolding effective collaborative activities (Hmelo-Silver & Barrows, 2008). Additionally, researchers have shown that successful collaborative learning necessitates that group members have good regulative skills (i.e., planning, monitoring, controlling and evaluating their learning). In collaborative settings, group regulation skills and enactment are defined as social regulation of learning (Hadwin, Järvelä, & Miller, 2018).

Current theories and models of social regulation of learning have emphasized that regulation is socially situated and combines individual and social processes (Hadwin et al., 2018). Thus far, researchers have focused on emergence of regulation in small collaborative groups, as well as the challenges groups experience and their subsequent adaptive responses (Panadero & Järvelä, 2015). In some situations, teachers are also a part of the collaborative group, but the ways in which such groups' social regulation of learning may vary due to the teachers' presence remain under researched. Thus, we strived to contribute to the body of knowledge on social regulation of learning through a naturalistic study of two high school physics teachers and their students. Our study was framed by the following research question: *How does presence or absence of the teacher during a collaborative model-based learning task in high school physics relate to groups' social regulation of learning?*

Methods

Our study was a part of a larger, federally funded project carried out in a large, public high school located in a small city in the northeastern United States. Participants were two physics teachers and their students. The school's student population was predominantly Caucasian (91%) with a large proportion of students who qualified for the free or reduced-price lunch program (57%). About half of the students in the school were female (49%).

For this particular study, we focused on the first learning task in a yearlong curriculum and used video data of the small groups as our primary data source. We purposefully selected four teacher-formed, heterogeneous groups of students in two physics classrooms and investigated students' social regulation of learning. Both teachers were male. For the two groups in the first classroom (i.e., Group A, $n = 6$, and Group B, $n = 5$) the teacher was present at the group's table for the whole discussion. The two groups in another classroom (i.e., Group C, $n = 3$, and Group D, $n = 3$) carried out the discussion independently while the teacher circulated the classroom, stopping by each group intermittently. The lesson focused on why a reusable hotpack released heat after clicking the activation disk. To answer this essential question, teachers gave students readings, guiding questions, an argument scaffold, and a hotpack. Students then engaged in small group argumentation discourse to evaluate a scientific model of this phenomenon and determine the merit of the model claims, using reasons and evidence.

For our data analysis, we employed video analysis according to the guidelines for research in the learning sciences (Derry et al., 2010). Researchers separately watched videos of each of the four groups and then met to discuss them. We wrote time-indexed notes about each group's session and partially transcribed interesting episodes. We discussed our observations of the students' social regulation (i.e., planning, monitoring, controlling, and reflecting) as well as how it differed due to the teacher's presence, until we reached agreement on themes.

Results and discussion

During the four group discussions, we found that the quality of discussion and social regulation differed between groups with and without the teacher. In the two groups with the teacher present (i.e., Groups A and B), the teacher prompted the students to consider each of the three claims separately, and to use reasons and evidence to support their views until they reached consensus on each claim. During these discussions, the students responded mostly to the teacher prompts and questions, with very limited interaction occurring between students. Thus, the enacted discursive engagement aligned with a version of the traditional initiation-response-evaluation pattern. All of the regulation was external to the group (i.e., initiated by the teacher), with limited opportunities for students to regulate on their own. Students in these two groups did not experience joint construction of task understanding and had limited engagement in monitoring of their content understanding or evaluation of the task completion.

Groups C and D had quite different discussions. In these groups, the teacher visited the groups intermittently. In both groups, he visited at the beginning to make sure they understood the task, during the middle of the discussion to make sure they were on the right track, and at the end to determine if they had finished the task. The rest of the unsupervised time, the students engaged in conversations about task understanding, monitored their understanding of the content using phrases such as "I don't understand", sought help from the teacher (e.g., "I need help") when he came by to check on them, evaluated their task completion, and engaged in argumentation discourse as they determined the merit of the three claims. These groups also, however, engaged in more off-task behavior than the groups with the teacher consistently present.

Our findings revealed that for our four groups, when teachers were more present, there were fewer opportunities for students to regulate their own learning, but students were generally more on task than students in the groups with less teacher presence. Importantly, we found that in groups in which the teacher was less present, students more actively monitored their understanding and used adaptive regulation strategies (e.g., seeking help), as opposed to their counterparts in groups with more teacher presence. We believe that in the absence of the teacher the control shifted to the group members as the lesson required the students to engage in regulation. Our findings have implications for teachers interested in fostering social regulation in small group discussions. Teachers should teach, scaffold, and support students' interpretative authority through direct engagement as well as intentionally designed lessons. Additionally, these findings are relevant for teacher educators working to improve teachers' use of effective science teaching and discursive practices.

References

Derry, S. J., Pea, R. D., Barron, B., Engle, R. A., Erickson, F., Goldman, R., …Sherin, B. L. (2010). Conducting video research in the learning sciences: Guidance on selection, analysis, technology, and ethics. *The Journal the Learning Sciences, 19*, 3-53.

Hadwin, A., Järvelä, S., & Miller, M. (2018). Self-regulation, co-regulation, and shared regulation in collaborative learning environments. In D. H. Schunk & J. A. Greene (Eds.), *Handbook of self-regulation of learning and performance* (2nd ed.). New York, NY: Routledge.

Hmelo-Silver, C. E., & Barrows, H. S. (2008). Facilitating collaborative knowledge building. *Cognition and Instruction, 26(1)*, 48-94. doi:10.1080/07370000701798495

Panadero, E., & Järvelä, S. (2015). Socially shared regulation of learning: A review. *European Psychologist, 20*(3), 190-203. doi:10.1027/1016-9040/a000226

Scardamalia, M., & Bereiter, C. (2014). Knowledge building and knowledge creation: Theory, pedagogy, and technology. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (pp. 397-417). New York, NY: Cambridge University Press.

Acknowledgments

Influence of Perceptions of Past Collaborative Experiences on Quality of Pre-service Collaboration and Outcomes

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Abstract: This qualitative interpretive study used content and discourse analysis to examine pre-service teachers' (N=24) perceptions of past collaborative experiences influenced current collaborations. Analysis identified pre-service perceptions of past collaboration as either a flexible orientation or inflexible orientation toward collaboration. The flexible orientation to collaboration supported higher quality interactions and collaborative outcomes than the inflexible orientation.

Introduction

Professional teachers often work collaboratively in various settings with multiple colleagues on improving instruction (Gellert, 2008). Such collaboration is associated with positive outcomes for teachers and students (Vescio, Ross, & Adams, 2008). Thus, pre-service teachers need to learn and practice collaborative interactions employed by teachers (Dobber et al., 2014). The quality of collaboration and outcomes may be influenced by beliefs and perceptions about the significance or effectiveness of collaboration (Khosa & Volet, 2014). Pre-service teachers may have only vague ideas of how teachers collaborate, and their expressed beliefs may not match actual in-service practices. Furthermore, teacher education typically affords little reflection or assessment of collaboration with peers (Ruys, Van Keer & Aelterman, 2010).

The current study is part of a larger program of research that takes a social metacognitive perspective on pre-service collaboration (Molenaar, Sleegers, & van Boxtel, 2014). In a previous mixed methods study, pre-service teachers were distinguished in terms of whether they held only *simple beliefs* that professional teachers cooperatively share expertise, ideas, resources, and planning, or held *expanded beliefs* that professional collaboration also includes collective assessment, analysis and evaluation (Brown & Jordan, 2017). Students with expanded beliefs collaborated through higher quality interactions that included collective development and evaluation. The current qualitative study builds on these results, by examining pre-service perceptions of past collaborative experiences and how perceptions influenced the quality of collaborative interactions. Our two research questions were: (RQ1) What are pre-service teachers' perceptions of their previous collaborative experiences? and (RQ2) How do pre-service teachers' perceptions of their previous collaborative experiences influence the quality of interactions during design and delivery of a collaborative instructional project?

Methods

Participants were first-semester pre-service students (N=24) collaborating in four-member groups across five sessions to design and implement instruction for classmates. Using a qualitative interpretive design (Miles, Huberman & Saldana, 2014), data was collected from written-reflections on students' past collaborative experiences, semi-structured interviews, and audio-video observations of collaborative work sessions. Quality of the instructional projects was evaluated through independent ordinal ranking of the projects by both researchers.

To understand how students perceived past collaborative experiences (RQ1), we applied content analysis to students' written reflections and the semi-structured interviews. To interpret the extent to which students' perspectives of past collaborations influenced the quality of their current collaborative interaction (RQ2), we applied conversational discourse analysis (Jordan & Daniel, 2010) and interaction analysis (Jordan & Henderson, 1995) to the audio-video recorded observations. The quality of collaborative interaction was examined first by individuals, and then by group as a collective. We used the framework of heedful interrelating to operationalize the quality of collaborative interactions among group members. *Heedful interrelating*, developed by organizational theorists Weick and Roberts (1993), describes individual and group interactions in collective tasks focusing on the quality of three types of actions: *representing*, *contributing*, and, *subordinating*. Further, we drew on Jordan and Daniels (2010) coding scheme for discourse markers indicating heedful interrelating to code transcripts of groups' interactions before comparing the quality of interaction across individuals and groups. Finally, all analyses were compared to the ordinal ranking of groups' collaborative instruction, which was independently coded by both researchers.

Results

Content analysis indicated perceptions of previous collaborative experiences supported either *flexible orientation* to collaboration or *inflexible orientation* to collaboration (RQ1). The flexible orientation described collaboration as a dynamic experience requiring their own careful, attentive and integrative efforts toward the group and the project, and as improving with practice and experience. In contrast, students with an inflexible orientation described collaboration as a static experience in which their effects exerted minimal influence on group interactions or product, and expected their experiences to remain similar and unchanging over time.

Conversational discourse and interaction analyses indicated that students' orientation toward collaboration influenced the quality of their interactions during the collaborative project (RQ2). During all phases of collaboration, students with a flexible orientation to collaboration interacted with higher quality and greater variety, depth and richness in their talk. Students with an inflexible orientation used fewer and lower quality interactions, and less descriptive or explicit talk. Group members with a flexible orientation attempted to integrate their interactions with the group and the current state of the project, and support their group mates' efforts to do the same. In contrast students with an inflexible orientation were less likely to attempt to integrate with the group. Some contributed very little, while others over-contributed monopolizing group work sessions. Group members with a flexible orientation more carefully considered topic ideas, pedagogic strategies for topic instruction, and probed for depth of comprehension of both content and pedagogy. In contrast, students with an inflexible orientation less deeply considered topic ideas or pedagogic strategies using few details and often used described topics or pedagogy as "thing" or "it." Finally, collaborative groups with more members having a flexible orientation created and implemented higher quality collaborative instructional projects than did groups composed solely of members with an inflexible orientation.

Discussion

This research contributes an important step toward understanding factors that influence the quality of pre-service collaboration. The study suggests that students' orientation toward collaboration influenced the quality of individual interactions, and therefore, the quality of group interaction and collaborative outcomes. Better understandings of pre-service perspectives of teacher collaboration and the beginning and end of teacher preparation can inform preparation programs.

Future research should continue to explore factors that impact the quality of pre-service interaction as they learn to collaborate. Studies might include examining changes in students' perspectives on the quality of their collaboration across the phases of a task, and comparing student-reported to researcher-observed quality of interaction as it relates to collaborative instruction. Implications for educational practice includes support of pre-service collaborative programs and continued exploration of how to best address student needs in collaborative processes as they prepare for their critical careers.

References

Brown, D. & Jordan, M. (2017). *Is the quality of pre-service teachers' collaborative interactions influenced by their belief about in-service collaboration?* Presented at the SCIPIE conference, Las Vegas, NV.

Dobber, M., Akkerman, S.F., Verloop, N., & Vermunt, J.D. (2014). Regulating collaboration in teacher education. *Research Papers in Education, 29*(1), 69-92. doi:10.1080/02671522. 2012.7

Jordan, M., & Daniel, S. (2010). Heedful interrelating in the academic discourse of collaborative groups. *Journal of Classroom Interaction, 45*(2), 4-19.

Khosa, D. K., & Volet, S. E. (2014). Productive group engagement in cognitive activity and metacogntive regulation during collaborative learning. *Metacognition and Learning.* doi:10.1007/s11409-014-9117-z

Miles, M. B., Huberman, A. M., & Saldana, J. (2014). *Qualitative data analysis*. Los Angeles, CA: Sage.

Molenaar, I., Sleegers, P., & van Boxtel, C. (2014). Metacognitive scaffolding during collaborative learning. *Metacognition and Learning.* doi: 9:309–332 DOI 10.1007/s11409-014-9118-y

Ruys, L., Van Keer, H., & Aelterman, A. (2010). Collaborative learning and preservice teacher education *Educational Studies, 36*(5), 537–553.

Turner, J. C., Warzon, K. B., & Christensen, A. (2011). Motivating mathematics learning: Changes in teachers' practices and beliefs during a nine-month collaboration. *AERJ, 48*, 718–762.

Vescio, V., Ross, D. & A. Adams (2008). A review of research on the impact of professional learning communities on teaching practice and student learning. *Teaching and Teacher Education, 24*, 80–91.

Weick, K.E. & Roberts, K.H. (1993). Collective minding in organizations: heedful interrelating on flight decks. *Administrative Science Quarterly*, 38, 357–381.doi:10.2307/239337

Playing With Fractions on an Interactive Floor: An Exploratory Case Study in the Math Classroom

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Abstract: The notion that engaging the body brings additional value in learning has lead researchers in evaluating technology-enhanced, whole-body learning experiences. Yet, we still need compelling evidence for the applicability of relevant tools and methods in school classrooms. We conducted an exploratory case study with 20 elementary-school students using three interactive floor applications in a typical school setting. Results demonstrated positive emotions; yet, cognitive phenomena require more careful investigation.

Introduction

Interactive spaces and surfaces such as interactive tabletops, interactive walls, interactive floors, and interactive rooms afford embodied forms of interaction. In this case, digital information can be manipulated directly with fingers, feet, and body movements, or through a physical intermediary such as token, pen, or other tractable object (Evans & Rick, 2014). Such technology-enhanced, whole-body experiences may promote learning, enabling the reunification of body, action, and the mind. Yet, we need compelling evidence for the applicability and effectiveness of such technologies and methods in formal educational settings. This study aimed to examine: (i) how students react to a whole-body, game-based learning experience on an interactive floor in a typical math lesson and (ii) what types of interaction design and learning design approaches might be considered for establishing meaningful integration of such technology and methods.

Background work

Interactive spaces and surfaces offer several potential advantages for whole-body learning experiences. They support direct interactions by groups of collocated participants, can engage children in playful learning, and can provide links between physical action and digital artefacts which might, then, lead to increased engagement, exploration, and reflection (Price & Rogers, 2004).

The idea of whole-body learning experiences can be considered through the lens of Embodied Cognition, as a theoretical framework that tries to understand how being in a body and interacting with a physical world shapes and impacts the development of thinking, problem solving, and learning (Wilson, 2002). This embodied perspective asserts that human cognition is deeply connected to our sensorimotor system and the body's interaction with the physical environment and therefore, plays a central role in understanding of the world (Johnson-Glenberg et al., 2011).

The last 30 years has been a period of renewed interest in the issue of embodiment in learning. SMALLab work constitutes the most systematic research in formal educational settings concerning learning benefits of embodiment. Studies by SMALLab indicate that there are significant achievement gains and therefore positive impact on collaborative learning when students can work with their whole body in mixed reality environments, compared to traditional learning (Johnson-Glenberg et al., 2011). Despite the enthusiasm for these technologies as well as widespread conviction that embodiment brings about additional value to users, findings are still inconclusive (Malinverni &Pares, 2014) whilst we miss compelling evidence for the applicability of such methods in typical school classrooms (i.e., without the cost of a SMALLab).

Methodology

This exploratory case study was conducted with 20 fourth-grade students (aged 9-10; 11 males, 9 females) at a public elementary urban school in Cyprus.

A down-pointing projector was mounted on a special (portable) tripod and was connected to a laptop. The visual output was projected on the floor (as in Figure 1) and the students could move around the periphery of or directly on the visual output. Visual and auditory feedback was given on the projected display.

Three applications on fractions were created. The goal in the first app was to identify fractions as part of a whole (played individually). The goal in the second app was to recognize equivalent fractions (played in a group). The third app was about adding and subtracting fractions with common denominators (played individually).

Multiple video cameras were setup in the classroom to capture facial expressions, physical movement, social interactions and verbal communication around the interactive floor.

Results and discussion

In this exploratory case study we first aimed to examine how students react to a full-body, game-based learning experience on an interactive floor in a typical school setting. First, the results demonstrate that it is possible to integrate such methods in the math classroom. Judging from the preliminary results of the study, these types of learning experiences appear to have value in terms of students' positive emotions; excitement and participation were overwhelmingly evident. These results confirm outcomes of previous research that relates physical activity to positive emotions (Bianchi-Berthouze et al., 2007; Kosmas & Ioannou, 2017; Price & Rogers, 2004).

Figure 1. Whole-body interactive floor experience.

We further sought to understand design elements, in terms of interactions and learning, for meaningful integration of such technology in school lessons. Despite the excitement, cognitive phenomena were scarce. A few students played the game only for fun and their choices were incidental selections with no evidence of cognitive engagement. We think that our design choice to allow for multiple selections, until the correct answer was chosen, let students make random choices at no cost. On the other hand, inquiry learning approaches to lesson design -- in which students are guided to solve problems, collaborate, then interact with the floor game -- might encourage cognitive engagement.

Overall, this work revealed opportunities for the integration of novel methods in classroom environments and provided ideas for future work in terms of interaction design, learning design and integration strategies. In future studies we aim to capitalize on the properties of the interactive floor and deepen into the relationship between physical activity and cognitive engagement and redesign the apps to truly enact cognitive engagement through play. Future work should aim to understand possible links between cognitive phenomena and design elements, focusing on patterns of thought and behaviour. Studies of longer duration are also necessary to eliminate novelty effects and allow the researchers to assess the true impact of technology use.

References

Bianchi-Berthouze, N., Kim, W., & Patel, D. (2007). Does body movement engage you more in digital game play? And Why? Affective computing and intelligent interaction, 102-113.

Evans, M. A., & Rick, J. (2014). Supporting learning with interactive surfaces and spaces. In Handbook of research on educational communications and technology (pp. 689-701). Springer New York.

Johnson-Glenberg, M. C., Koziupa, T., Birchfield, D. (2011). Games for learning in embodied mixed-reality environments: Principles and results. In C. Steinkuehler et al. (Eds.), Proceedings of the Games+ Learning+ Society Conference (pp.129–137). Pittsburgh, PA: ETC Press.

Kosmas P., Ioannou A., Retalis S. (2017). Using Embodied Learning Technology to Advance Motor Performance of Children with Special Educational Needs and Motor Impairments. In: Lavoué É., Drachsler H., Verbert K., Broisin J., Pérez-Sanagustín M. (eds) Data Driven Approaches in Digital Education. EC-TEL 2017. Lecture Notes in Computer Science, vol 10474. Springer, Cham

Malinverni, L., & Pares, N. (2014). Learning of Abstract Concepts through Full-Body Interaction: A Systematic Review. Educational Technology & Society, 17 (4), 100–116.

Price, S., & Rogers, Y. (2004). Let's get physical: The learning benefits of interacting in digitally augmented physical spaces. Computers & Education, 43(1), 137-151.

Wilson, M. (2002). Six views of embodied cognition. Psychonomic bulletin & review, 9(4), 625-636.

Mapping Student Reasoning in Support of Mathematics Teacher Candidate Digital Learning

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Abstract: Using design-based research, we are developing a series of video-based online learning modules to engage mathematics teacher candidates in analyzing cases of secondary students' mathematical reasoning. We describe our process for developing a student reasoning framework for a task that requires the coordination of two relationally specified quantities, which provides a basis for selecting module content and analysis of candidates' attention to student reasoning as they engage with the online modules.

Introduction

The Video Case Analysis of Student Thinking (VCAST) project entails the design and integration of a series of video-based online learning modules into undergraduate teacher preparation coursework, with the intent of supporting secondary teacher candidates' mathematical reasoning and attentiveness to students' ideas (Carney, Cavey, & Hughes, 2017). Each online module features a distinct mathematical task with the potential to (a) highlight components of quantitative reasoning, and (b) elicit a range of observable secondary student performance. Appropriate curation and sequencing of secondary student evidence for inclusion in the online modules requires researcher knowledge and application of secondary students' reasoning. In this poster, we describe how we analyzed secondary students' performances related to a quantitative reasoning task, both as preparation for and as a precursor to creating and analyzing candidate work with the VCAST learning modules.

Methods

The 23 participants were mathematics students (grade 7 or 8) from a rural district located in the western United States. Our intent was to gather enough data to represent a range of responses to the task, as doing so is necessary both to build our understanding of student thinking and to inform our development of the online learning module. Each volunteered, with parental permission, to participate in an interview conducted by members of the research team. The interviews consisted of each student completing three mathematical tasks while being video recorded.

The bus stop task asks students to think about the relationally specified quantities of height and age for a group of seven individuals presented pictorially and then to match each person to a point plotted in a Cartesian graph (See Figure 1). This task was intended to elicit students' ability to work with a collection of ordered pairs as a mathematical model of a relation between two quantities, and to interpret and make connections between multiple representations of the data associated with the situation being modeled (Stephens, Ellis, Blanton, & Brizuela, 2017).
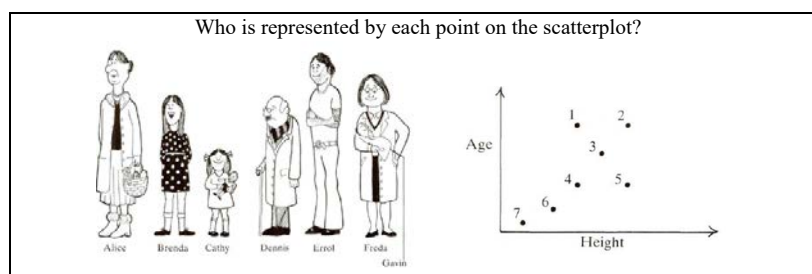
Figure 1. The Bus Stop Task (Swan, M. 1985).

Analysis of the bus stop task data occurred in four distinct phases and involved open coding informed by the literature on quantitative reasoning and grounded theory (Strauss & Corbin, 1994). Phases 1 through 3 involved applying and revising codes. In phase 4, following full application of the coding scheme, we examined

frequencies within and across categories and trends in responses. This led to the development of a student reasoning framework for tasks involving graphing relationally specified quantities, along with general descriptors and labels for each primary code. Then we ordered the reasoning descriptors in a hypothesized hierarchy based on observed trends seen in our analysis. For example, we hypothesized that the ability to compare points with a common horizontal or vertical coordinate was more sophisticated than comparing points positioned along a diagonal within the coordinate plane.

Results

The results of our analysis yielded a framework for the levels of sophistication in students' learning performances with the bus stop task. Examples from the data will be provided in the poster to illustrate observable performances for each aspect of inferred student reasoning. This framework will be used as a starting place to analyze candidates' own mathematical work, to describe aspects of student reasoning candidates attend to during online module engagement, and to provide the basis for a key element in the articulation of a learning performance trajectory for candidates' attentiveness.

Table 1: Student Reasoning Framework

Label	Descriptor	Observable Student Performances
Relational Ordering	Ordering a relationally-specified quantity	Compares and orders relative heights and/or ages that do not have assigned numerical values.
1-D Graphing	Observing one-dimensional graphing conventions	Exhibits knowledge that moving up (or right) corresponds to increasing values, while moving down (or left) corresponds to decreasing values.
1-D Comparing	Comparing values for a single quantity graphically	Articulates that points to the right (or above) represent greater heights (or greater ages).
Coupling	Coupling two quantities graphically	References both age and height when determining which person is represented by a given point.
2-D Diagonal Comparing	Comparing values of coupled quantities graphically	Coordinates relative horizontal and vertical position of two points to compare both height and age for points diagonally positioned in the plane.
2-D Aligned Comparing	Comparing values for vertically (or horizontally) aligned points	Exhibits knowledge that points with the same vertical (or horizontal) coordinate represent people who are the same age (or height).

Conclusion

We posit that to improve secondary mathematics teacher candidates' ability to recognize, describe, and analyze secondary student work requires examination of how secondary students reason within mathematical domains. Our explicit articulation of a student reasoning framework informs the research related to these topics, the instructional module design for our project, and the future testing and refinement of our hypotheses about candidates' learning. With respect to module design, we see the importance of contrasting the relative ease with which students can compare points diagonally positioned in the plane with the challenge of comparing values for vertically (or horizontally) aligned points. Thus, the outcomes from the analysis not only contribute to the next phases of our work but also potentially inform the work of others in mathematics education.

References

Carney, M. B., Cavey, L., & Hughes, G. (2017). Assessing teacher attentiveness to student mathematical thinking. *The Elementary School Journal, 118*(2), 1-29.

Sherin, M. G., & van Es E. A. (2005). Using video to support teachers' ability to notice classroom interactions. *Journal of Technology and Teacher Education*, *13*(3), 475-491.

Simon, M. A. (1995). Reconstructing mathematics pedagogy from a constructivist perspective. *Journal for Research in Mathematics Education, 26(2)*, 114–145.

Stephens, A., Ellis, A., Blanton, M., & Brizuela, B. (2017). Algebraic thinking in the elementary and middle grades. In J. Cai (Ed.), *Compendium for research in mathematics education* (pp. 386-420). Reston, VA: NCTM.

Swan, M. (1982). *The language of functions and graphs: An examination module for secondary schools.* Nottingham, UK: Shell Centre for Mathematical Education.

Straus, A., & Corbin, J. (1994). Grounded theory methodology. In N. Denzin & Y. Lincoln (Eds.), *Handbook of qualitative research* (pp. 273-285). Thousand Oaks, CA: Sage.

The Visual Test of Science Identity (VTSI)

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Abstract: In science identity perception research, there is a need for tests that can estimate student beliefs without presenting a reading burden for young students and low-proficiency readers. We respond to this challenge by developing a visual assessment, employing photos to query opinions about scientists' gender and ethnicity/race. In two samples, adults (n=162) and children (n=42), we found a bias: males chose images of men more than females chose women. Future directions are discussed.

Introduction

Young students' perceptions of themselves and others as scientists impact the coursework they might later choose in secondary school and higher education. In particular, female students and students of color often stay away from the natural sciences (National Science Foundation, 2017). This imbalance has compelled the US Institute of Educational Sciences (IES) to prioritize investigating methods by which to change this trend and encourage students traditionally underrepresented in STEM disciplines to consider pursuing those areas (Chen, 2013). It is also widely recognized that K-12 education must support students to gain vital STEM competencies and to develop a sense of self-efficacy in learning and reasoning within STEM domains (Collins & Halverson, 2009). To support the engagement of students in STEM fields, we require not only assessments of students' understanding of the nature of those disciplines, but also assessments of students' STEM identity (Stets, Brenner, Burke, & Serpe, 2017; Taconis & Kessels, 2009). Toward building capacity to make changes in demographic underrepresentation among scientists, this report describes our development and evaluation of an instrument, the Visual Test of Science Identity (VTSI), designed to measure students' identity in science using a visual modality. Using less verbiage than traditional verbal-modality assessments, the visual modality can open participation opportunities for younger students (Chambers, 1983; Losh, Wilke, & Pop, 2008; Walls, 2012) and for low-proficiency readers of the assessment language, as well as lessening potential linguistic and cultural biases (Creswell & Miller, 2000; Guba, 1981).

Visual tests of science identity

Visual assessments hold great promise, as they can potentially reveal student thinking with low linguistic demands. A visual mode of querying has also been useful in breaking up typical language-based modes of assessment (Walls, 2012). Further, incorporating visuals in assessments can decrease construct irrelevant variance by maintaining students' interest when they might otherwise have felt the assessment to be too lengthy.

While previous work in visual assessments has been limited, there have been efforts that offer suggestions for our development of image-based survey items. In the Draw a Scientist Test (DAST; Chambers, 1983), for example, students who were asked to draw a scientist often drew iconography associated with prototypical scientists (Chambers, 1983; Losh et al., 2008; Walls, 2012) – perhaps because iconography is what students thought the people testing them would recognize (Reinisch et al., 2017) – and did so to the extent that Losh et al. (2008) believed that the DAST assessed stereotypes. Walls' (2012) Identify a Scientist (IAS) tool addressed the Nature of Science concurrently with science identity by asking students to choose one person among groups of gender- and ethnicity-balanced photos who they thought was a scientist, revealing a student preference for science iconography (e.g., 96% of students believed scientists wore glasses). Chapman and Feldman (2017) obtained mixed results when using the IAS task to gauge differences in perceptions about who can be a scientist before and after an inspirational intervention led by a female scientist. After the intervention, more students selected their own demographic as the scientist, but fewer selected women. Recently, Reinisch and colleagues (2017) called for the development of closed-ended testing solutions to remove threats to validity.

Method: Instrument development, sample, and results

The VTSI was developed to build on Walls' (2012) IAS design in a manner that excluded science iconography from the interpretation of results, leaving gender and ethnicity/race. Like the IAS, photographs were collected for the 10 categories of the fully crossed factors of gender (at two levels: male, female) × ethnicity/race (at five levels: Black, White, Latinx, East Asian, South Asian). The VTSI further categorizes photographs to enable the construction of 10-photo panels that control for science iconography, e.g., differences in lighting, subjects' ages,

eyeglasses, formality of attire, and males' facial hair. Presented with a panel of 10 photographs, participants were asked to identify which person was most likely to be a scientist and the degree to which they thought each person was a scientist. Multiple panels were administered to support reliably interpreting results.

Two samples were collected. A pilot study was performed on adults to test the VTSI for flaws before use on the higher-stakes sample of interest, children. We recruited 154 adults (male=80, female =74), of whom 65% were White ethnicity/race. No changes were needed after the VTSI pilot. Next, 41 middle- and secondary-school students (male=29, female=12) were recruited from demographics underrepresented in science as part of an existing after-school program, with an ethnic composition of 17 Black, 19 Latinx, 1 White, and 4 students of other ethnicities. The analysis of both the adult and student samples was conducted using McNemar's test for related nominal groups to compare the choices made by different gender and ethnicity groups, e.g., women and girls were related to photos of female scientists, and men and boys to photos of male scientists.

Results and discussion

For the adult pilot test, results indicated women were less likely to choose photographs of females as scientists than men were to choose male scientists ($\chi^2 = 9.23$, $p < 0.01$). This result held up for the sample of students, in which girls chose females as scientists less frequently than boys chose men ($\chi^2 = 10.83$, $p < 0.001$).

The efforts to control factors in photos other than gender and ethnicity appeared to have been successful, because when students were taking the VTSI, many expressed not knowing how to choose. When students did choose a photo, the results were still biased in favor of men. However, our study found that students did not appear to disproportionately select White ethnicity/race photos ($\chi^2 = 5.08$, $p = 0.28$). Even so, many students still did not endorse photos of people of their own ethnicity as scientists.

Future validation for the VTSI will ask students the reasons for their photo choices, to ensure that science iconography is not among the reasons. Future developments for the VTSI will continue to leverage the visual mode by incorporating controlled interactions between existing photos of *people*, imagery of *tools* of science, and *settings* in which science is performed. Accompanying interviews would elicit students' beliefs as to what the people depicted in photographs would do with the tools in the settings depicted.

In this work, a practical tool with many potential applications has been developed for the measurement of beliefs held by people of many ages – young children through adults – concerning who is a scientist; by removing traditional "science" iconography, gender and ethnicity/race remained to elicit responses. This method can be easily ported to other fields where similar questions are being asked.

References

Chambers, D. W. (1983). Stereotypic images of the scientist: The Draw-A-Scientist Test. *Science Education, 67*(2), 255-265.

Chapman, A., & Feldman, A. (2017). Cultivation of science identity through authentic science in an urban high school classroom. *Cultural Studies of Science Education, 12*(2), 469-491.

Chen, X. (2013). *STEM attrition: College students' paths into and out of STEM fields. Statistical analysis report*. (NCES 2014-001). Jessup, MD: National Center for Education Statistics.

Collins, A., & Halverson, R. (2009). *Rethinking education in the age of technology: The digital revolution and schooling in America*. New York, NY: Teachers College Press.

Creswell, J. W., & Miller, D. L. (2000). Determining validity in qualitative inquiry. *Theory into practice, 39*(3), 124-130.

Guba, E. G. (1981). Criteria for assessing the trustworthiness of naturalistic inquiries. *Educational Technology Research and Development, 29*(2), 75.

Losh, S. C., Wilke, R., & Pop, M. (2008). Some methodological issues with "Draw a Scientist Tests" among young children. *International Journal of Science Education, 30*(6), 773-792.

National Science Foundation. (2017). *Women, minorities, and persons with disabilities in science and engineering: 2017 digest*. (NSF 17-310). Arlington, VA: National Science Foundation.

Reinisch, B., Krell, M., Hergert, S., Gogolin, S., & Krüger, D. (2017). Methodical challenges concerning the Draw-A-Scientist Test: A critical view about the assessment and evaluation of learners' conceptions of scientists. *International Journal of Science Education, 39*(14), 1952-1975.

Stets, J. E., Brenner, P. S., Burke, P. J., & Serpe, R. T. (2017). The science identity and entering a science occupation. *Social Science Research, 64*, 1-14. doi:http://dx.doi.org/10.1016/j.ssresearch.2016.10.016

Taconis, R., & Kessels, U. (2009). How choosing science depends on students' individual fit to "science culture". *International Journal of Science Education, 31*(8), 1115-1132.

Walls, L. (2012). Third grade African American students' views of the nature of science. *Journal of Research in Science Teaching, 49*(1), 1-37.

Creating a Visual Representation of Expert Strategies to Inform the Design of Digital Tools for Citizen Science

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Abstract: Tools supporting citizen scientists in learning complex observational tasks like taxonomic identification scaffold expert practice by specifically attending to the aspects of expertise relevant to citizen science. This poster describes our process for developing a visual representation that characterizes observational practices and moves entomologists make when identifying unknown organisms. We outline how this work is guiding the design of a digital teaching collection of freshwater insects, macroinvertebrates.org, to support citizen based water quality assessment activities.

Introduction

Citizen science volunteers engaging in complex data collection tasks such as aquatic macroinvertebrate identification (ID) for water quality monitoring require a vernacular understanding and associated set of scientific skills to generate reliable and useful data (Snyder et al., 2017). Volunteers often "fail to see" and have difficulty recovering from errors in taxonomic work (Nerbonne and Vondracek, 2003). When volunteers are unable to reliably generate accurate data, it can lead to a "taxonomic bottleneck" that limits the impact and effectiveness of some citizen science projects. We are developing an innovative digital teaching collection based on explorable, high-resolution annotated images with supplemental multimedia in order to support the development of citizen science skills such as scientific forms of noticing and associated observational practices.

A crucial step in designing this online learning platform is characterizing observational expertise in entomology in order to know what observational practices need to be supported. To inform this effort, we developed a novel visual representation of expert processes depicting how various forms of scientific knowledge and visual practices are put into action to make an accurate identification. We hypothesize that a visually informative representation of observational expertise is a productive way to elucidate key strategies for observational fluency and highlight the varied use of scientific inscriptions and resources that need to be supported and incorporated into the design of online learning tools and systems.

Methods

We conducted contextual inquiry think-aloud interviews with eight experts in entomology, ranging from early career researchers to professional taxonomists with 20-30 years of experience in aquatic macroinvertebrate ID. When feasible, interviews were conducted at the experts' work sites to ensure access to the materials and tools they would typically use when conducting an ID. The researcher provided participants with three specimens to identify to the lowest taxonomic level they felt comfortable (typically genus), asking them to describe their process and prompting them with clarifying questions as necessary. Transcriptions were made from audio recordings, and videos and photographs of the working environment were taken.

Analysis and findings

We sought to characterize how scientific expertise and associated practices shape the ID process. We first coded and distilled a subset of the interviews into a step-by-step listing of the moves made during each ID. A *move* is defined as a significant action or recognizable step that drives the identification process toward naming the specimen at the order, family and genus level. We next created a matrix representation matching the information gathered during the ID process with the resources used to generate that information. We define *resources* as any tangible tool (e.g. microscope), external source (e.g. dichotomous key, Internet search), or observational practice (e.g. manipulating specimens or lighting to optimize viewing). These initial representations helped clarify aspects of expert practice but were not yet a graphically succinct externalization of expertise that could be used to inform platform design. We therefore created a new representation, which we call Shared Externalization of Expertise (SEE) because of its potential for facilitating communication across stakeholders.

The SEE diagram (Figure 1a) uses an up-down metaphor frequently invoked in taxonomic identification that refers to progressive taxon levels as "lower," e.g. "taking it down to genus" and displays steps taken in the identification process as descending. If the taxonomist were using the same strategy (e.g. directly matching the characters listed in a couplet to features of the specimen) throughout the ID, the diagram would
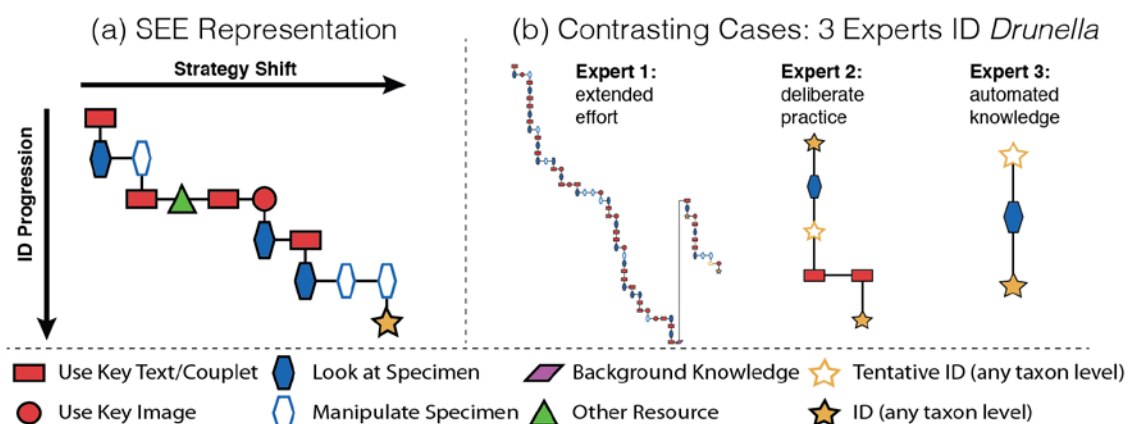
Figure 1. An example SEE diagram (a), and diagrams of moves by three experts identifying *Drunella* (b).

form a straight line down. However, experts tend to use multiple strategies during the identification process to make a judgment (e.g. consulting an additional text or image if the initial resource is insufficient), and these strategy shifts are displayed as horizontal movements along the x-axis.

Such horizontal moves are manifestations of expertise. In a complex activity like taxonomic ID, knowing how to navigate uncertainties is crucial for success, yet non-experts facing uncertainty are less likely to have the resources and knowledge to work around difficulties (i.e. shift strategies). SEE diagrams show how experts strategically address uncertainties, for example in our study as several subjects were asked to separately identify the same specimen (Figure 1b). Expert 1 had difficulty confirming characters and had to adjust after initially going down the wrong path in the key. By contrast, Expert 2 easily confirmed diagnostic characters and quickly navigated the key, and Expert 3 confirmed the ID by looking for known diagnostic characters without the aid of any text. Experts 2 and 3 didn't demonstrate uncertainty with this specimen, while Expert 1 struggled yet was still able to work around challenges. Our digital tool is not meant to transform novices into Expert 3, but to support them in persevering through a process like Expert 1's by providing appropriate resources and support.

Discussion

Expert taxonomists have extensive resources for identification, including their own knowledge and experience, a variety of keys and guides, access to informed colleagues, and an understanding of the "tricks" for recognizing diagnostic characters. Amateur citizen scientists have a much more limited toolbox, meaning that when their primary resource (e.g. a regional key) doesn't contain sufficient guidance, they have few places to turn for help. Our platform, macroinvertebrates.org, is designed as a visual guide to supplement the wide variety of primary ID resources already in use by citizen science groups and to support multiple audiences ranging from novice volunteers to trainers. Our key challenge is not to present all the entomological knowledge our users *could* need, but to present the right information in a way users can strategically access it.

The process of creating these representations has informed multiple aspects of our ongoing design based learning research. Certain strategy shifts recurred across multiple SEE diagrams, indicating their value to experts and suggesting they should be prioritized in our design. These diagrammatic representations have also been used in design meetings to evaluate navigation, interaction, and interface design choices in the expansion and redesign our platform. The representations of expert practice have served to concretize the open-ended design space from the general need to support volunteers into specific actionable scaffolds and information design solutions we can provide to our users to make it easier for them to learn to see with an expert eye.

References

Nerbonne, J. F., & Vondracek, B. (2003). Volunteer macroinvertebrate monitoring: assessing training needs through examining error and bias in untrained volunteers. *Journal of the North American Benthological Society*, *22*(1), 152-163.

Snyder, J. (2017, February). Vernacular Visualization Practices in a Citizen Science Project. In *CSCW* (pp. 2097-2111).

Acknowledgments

Design Based Research Approaches Towards Enhancing Social Learning Practices in MOOC Platforms

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Abstract: The MOOC context challenges social learning theory to perform at scale, and in an informal setting, but platforms may not have functionality which affords this. This study examines an intervention engineered into the social learning environment intended to increase this performance: The Comment Discovery Tool. Results from the initial iteration of this tool suggest positive impact, but further work is suggested to iterate in line with the stigmergic design paradigm.

Introduction

MOOCs are online courses which typically a thousand or more learners will enrol. Kizilcec et al. demonstrates that contribution in forums is strongly linked with 'completing' learners. and suggests that platform designers features promoting pro-social behaviour (Kizilcec, Piech, & Schneider, 2013). Other studies (e.g. Brinton et al., 2014) conclude that discussion features are not fit for purpose.

Tubman, Oztok, & Benachour (2016), discovered that conversations in the FutureLearn MOOC platform consistently decrease dramatically after the first reply, regardless of course size or subject matter suggesting that sociomaterial factors (i.e. the actual interactions afforded by the platform) are important.

Another design paradigm for social e-learning environments is based on the principle of 'stigmergy', or "communication through signs left in the environment" (Dron, 2006; Elliott, 2016).

This paper understands social learning in a MOOC context as a collection of miscellaneous conversations that together make up the learning space and focusses specifically on the material 'affordances' which mediate these interactions. MOOCs by their nature do not have the privilege of high tutor to student ratios, so it is important that platforms are developed with peer supported, self-directed learning at their heart.

Theoretical framework

Laurillard's 'conversational framework' builds on Vygotskian ideas that learning is emergent through the interactions between tutors, learners, and peers. It is through structured conversations and guided practice that conceptions and misconceptions emerge (Laurillard, 2002).

In smaller group activities there is greater potential for consensus about the shared objects of inquiry, which creates a fertile space for learning through participation. Lapadat (2006) argues that written participation achieves good learning experiences, however positive outcomes only occur when expectations are set in terms of the quality and quantity of contribution.

The MOOC scaffolds a 'networked individualism' (Castells, 2001). Participants must discover conversations which interest them through their mediated interactions of the online environment.

The challenge for platform designers, therefore, is to create an environment where learners are able to co-ordinate social participation in such a way as to avoid the pitfalls of densely packed, noisy discussion areas, and allow for collaborative activity within the system as a whole to be emergent, accessible, and scalable, in line with the 'stigmergic' design paradigm.

We have designed a tool which affords new interactions and propose to use a design based research approach to appraise it. We propose a taxonomy of 'conversation types' based on unique participants in a conversation, a social dimension based on turn taking and also the length attribute of a conversation to measure the efficacy of our intervention. These act as a proxy for diversity and collaboration which is important in a sociocultural analysis.

Chua et al. propose a taxonomy of comments based on the affordances of the FutureLearn platform. Each comment on the platform can only be one of 5 categories (initial, lone, first reply, further reply, initiator reply) (Chua, Tagg, Sharples, & Rienties, 2017). Our research extends these categories onto the whole conversation and breaks the initiator replies into 'first' and 'further', in order to place focus on 'going further' in a conversation. There are only 9 possible types of conversation according to the material affordances of the platform, but we suggest simplifying this into 4 broad categories to identify conversation with a greater potential for collaborative activity, and to act as a heuristic measure for the efficacy of the intervention (Lone, Q&A (1

post > 1 reply), Limited Social (initiator returns but nothing 'further'), Extended Social (anything with further replies).

The length attribute represents how likely the conversation is to have evidence of collaborative activity. It is hypothesised that a proportion of 'Lone' posts do not receive replies because they become lost.

This paper analyses the first iteration of a platform design intervention: an interactive 'word cloud' called 'Comment Discovery Tool' (CDT). The tool functions by visualising all the comments into a 'word cloud'. The comments are listed in full at the bottom of the cloud, and a link to each comment is presented, so learners then have the ability to contribute to that conversation.

Results

10,515 conversations were analysed. An ANOVA analysis showed that the unique learners variable was significant, $F(1, 10513)=116.47$, $p=0.00$, and also that the conversation length variable was significant, $F(1, 10513)=87.82$, $p=0.00$. Cohen's d scores were also calculated for a measurement of impact, and generated a score of 0.21 for unique learners, 0.18 for conversation length. This suggests the CDT has had a modest impact in its first iteration. The breakdowns of conversations by type demonstrate that the run with the CDT has a larger proportion of the heuristic groupings associated with higher levels of social constructivist learning: extended social conversation, conversations with more members, and fewer lone conversations. It can be tentatively concluded that the CDT is creating a modest increase in social interactions and contributions.

Discussion

The intervention does appear to have an impact on the social dimensions of the course. It is important to note that data should be collected from more MOOCs before concluding that the platform intervention has consistent impact across the board.

Some users suggested that some words in the CDT were not very meaningful, so didn't add value to the activity. An interesting development in MOOC pedagogy could be to encourage learners to hashtag their comments and generate a smaller corpus of themed words. It is hypothesised that learners would feel a greater sense of ownership over the MOOC if they had the means to enrich these datasets and visualisations.

Conclusion

The challenges for social learning online are not new, but they are 'flipped' in the MOOC context. In MOOCs, the challenge is to 'train' contributions so the buds of collaboration do not shade each other out, and that they are openly visible to all learners. We believe that visualising participation into meaningful and interactive units, according to learner preference, something new can be added to the pedagogy of scale.

References

Brinton, C. G., Chiang, M., Jain, S., Lam, H., Liu, Z., & Wong, F. M. F. (2014). Learning about Social Learning in MOOCs: From Statistical Analysis to Generative Model. *IEEE Transactions on Learning Technologies*, 7(4), 346–359. https://doi.org/10.1109/TLT.2014.2337900

Chua, S. M., Tagg, C., Sharples, M., & Rienties, B. (2017). Discussion Analytics: Identifying Conversations and Social Learners in FutureLearn MOOCs.

Dron, J. (2006). The way of the termite: a theoretically grounded approach to the design of e-learning environments. *International Journal of Web Based Communities*, 2(1), 3. https://doi.org/10.1504/IJWBC.2006.008611

Elliott, M. (2016). Stigmergic collaboration: A framework for understanding and designing mass collaboration. In *Mass collaboration and education* (pp. 65–84). Springer.

Kizilcec, R. F., Piech, C., & Schneider, E. (2013). Deconstructing disengagement: analyzing learner subpopulations in massive open online courses. In *Proceedings of the third international conference on learning analytics and knowledge* (pp. 170–179). ACM.

Lapadat, J. C. (2006). Written Interaction: A Key Component in Online Learning. *Journal of Computer-Mediated Communication*, 7(4), 0–0. https://doi.org/10.1111/j.1083-6101.2002.tb00158.x

Laurillard, D. (2002). *Rethinking University Teaching: A Conversational Framework for the Effective Use of Learning Technologies*.

Tubman, P., Oztok, M., & Benachour, P. (2016). Being social or social learning: A sociocultural analysis of the FutureLearn MOOC platform. Presented at the The 16th IEEE International Conference on Advanced Learning Technologies, Austin, Texas: IEEE.

Problematic Instruments:
Technology, Legitimization, and Citizen Science

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Abstract: At the intersection of science and society lies citizen scientists, and they are tasked with being part of the broader public as well as performing scientific legitimacy. This study aims to explore how citizen scientists interact with technology and legitimacy. The study site consists of a canoeing citizen science organization. The author conducted participant observation and collected video data. Results show that much of the anxiety related to legitimacy is deferred to their scientific instruments.

Introduction

Many citizen science programs aim to increase the public's engagement and understanding of science. However, citizen scientists exist in a liminal space between "ordinary folk" and privileged scientists (Irwin, 1995). In defending their claims, these citizen scientists will use the same empirical evidence and techniques that traditional scientists do. Yet, these citizen scientists have considerably less power than the traditional scientist despite mimicking their techniques. How then do citizen scientists handle problems of scientific legitimacy?

This research project aims to explore how the River Team (a pseudonym) handles issues of scientific legitimacy. The River Team consists of a group of water quality citizen scientists affiliated with a large Tier 1 university in the United States. Members of the River Team are provided water quality probes and instruments (Figure 1a) with a routinized protocol (Figure 1b) for "taking science" or collecting water quality data. This paper focuses on how River Team members' handles questions of scientific legitimacy centered on "taking science" and using the water quality instruments.

Theoretical framework

I take an interactionist stance (Jordan & Henderson, 1995) towards understanding how the River Team collects water quality data. I assume that the object of activity, talk, artifacts, and cultural norms are all crucial for interpretation. I particularly focus on the human-technology interactions and discourse between River Team members and water quality instrument probes. Imbuing technology with anthropomorphic properties as well as negotiating with them through talk provides technology with a sense of human-like agency, as previously seen in Actor Network Theory (Latour, 2005) and posthuman or more-than-human frameworks (Snaza et al., 2014).

In understanding scientific legitimacy, I turn towards sociologist Gieryn (1999) and his framework of boundary-work, which suggests that traditional scientists prescribe discursive and material boundaries that draw the line between authentic science and non-science. The boundary between scientists and non-scientists has often been shifted and continues to shift when convenient, even though there has been much effort to make school science (Roth, 2012) and citizen science (Dickinson, Zuckerberg, & Bonter, 2010) closer to "authentic science."

Methods

I have conducted a multi-year ethnographic participant observation (Wolcott, 1999) study of the River Team. Using wearable cameras or GoPros, I and a few members of the team recorded instances when we stopped on and alongside the river to collect water quality data. I watched and logged all the video data related to water quality data collection between Spring 2016 and Spring 2018. I then coded for emergent cases (Becker, 2014) related to how River Team members made sense of the water quality data in terms of scientific legitimacy with the water quality instrument probes. A case based approach (Luker, 2008) was used to compare cases of when team members felt the instrument probes were effectively legitimizing or de-legitimizing their scientific practice.

Results and discussion

Case analysis of video data suggests that River Team members felt both legitimized and de-legitimized by their usage of water quality instrument probes. Most cases however centered around team members feeling de-legitimized by the instruments. Team members would often focus on the instrument probe not working, not being accurate, and felt that the instrument was ill or sick.

For example, on a routine data collection protocol alongside the San Marcos River in Texas, Catherine and Henry (pseudonyms) are discussing the pH instrument probe. The pH, or the logarithmic concentration of Hydrogen ions, instrument probe reads a range from 1 to 14, and the pH value of water typically falls between 6

and 8. The pH probe Henry is working with reads a value of 2.5 (10:00). Catherine comments that "Jerry, [the name of the pH probe], is just gonna have to sit this trip out" (10:30). Eventually Catherine comes to Henry to help troubleshoot the probe (11:00) (Figure 1c). Catherine concludes that "the reality of the probe is that its insides has gone bad. It is dementia probe" (11:26). However, Henry keeps trying to get a better reading and says, "come on baby.." to it (11:36). Eventually Henry gives up and moves on to a different probe which also fails, and Catherine later comments how "she hates science, it gets so hard" (23:50).
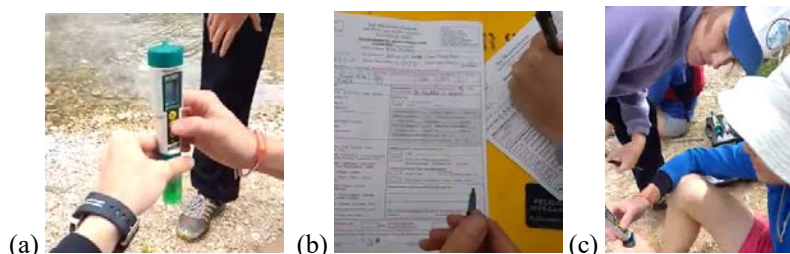
Figure 1. (a) pH instrument probe. (b) Water quality monitoring sheets. (c) Catherine and Henry troubleshooting.

We see here how the instruments are giving spurious and incorrect water quality values. However, these cases and type of talk regarding the faulty nature of the instruments continues throughout semesters, even if the instruments give more reliable readings. This suggests that some of the illegitimacy attributed to citizen science is deferred by its members to the scientific instruments they use. The stigma citizen scientists face as non-scientists is redirected to their scientific instruments, and their scientific instruments are often to blame for their less than ideal scientist status.

To remedy the problematic instruments, in Fall 2017, the River Team spent around $1000 on new instrument probes to improve their ability to take water quality data. Yet, they find many problems and errors with utilizing the new probes and again begin attributing problems with probes. This also reflects the tendencies of the River Team members to give anthropomorphic or human-like attributes to the instrument probes. Probes can go bad or have dementia or need encouragement. The instrument probes are given agentic and human-like properties in some hope that they will legitimize the River Team's scientific practice.

Seriously considering the role of human-technology interactions for human's legitimacy in scientific or other practices opens a discussion of how human-technology interactions can enable or disable certain groups of people. In this study, I explored how a citizen science team's interaction with technology left them feeling de-legitimized and drawn outside the boundary of science. Future work will explore how other interactions may enable feeling or legitimacy or illegitimacy.

References

Becker, H. S. (2014). What about Mozart? What about murder? Reasoning from cases. University of Chicago Press.

Dickinson, J. L., Zuckerberg, B., & Bonter, D. N. (2010). Citizen science as an ecological research tool: challenges and benefits. *Annual review of ecology, evolution, and systematics*, *41*, 149-172.

Gieryn, T. F. (1999). Cultural boundaries of science: Credibility on the line. University of Chicago Press.

Irwin, A. (1995). *Citizen science: A study of people, expertise and sustainable development*. Psychology Press.

Jordan, B., & Henderson, A. (1995). Interaction analysis: Foundations and practice. *The Journal of the Learning Sciences*, *4*(1), 39-103.

Latour, B. (2005). *Reassembling the social: An introduction to actor-network-theory*. Oxford University Press.

Luker, K. (2008). *Salsa dancing into the social sciences*. Harvard University Press.

Roth, W. M. (2012). *Authentic school science: Knowing and learning in open-inquiry science laboratories* (Vol. 1). Springer Science & Business Media.

Snaza, N., Appelbaum, P., Bayne, S., Carlson, D., Morris, M., Rotas, N., ... & Weaver, J. (2014). Toward a Posthumanist Education. *Journal of Curriculum Theorizing*, 30(2), 39.

Wolcott, H. F. (1999). *Ethnography: A way of seeing*. Rowman Altamira.

Acknowledgments

Don't Just Do It, Explain It: A 5th Grade Worked Examples Curriculum Supports Transfer to Algebra Content

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Abstract: 5th graders (*n*=527) were randomly assigned to self-explain worked examples (WE) or solve problems during a yearlong study. WE students learned more algebra skills when given algebra worked examples on an end-of-year transfer measure. Comparing attempts, conceptual, and mechanical correctness by condition, results demonstrated that the condition difference in accuracy was attributable to better understanding of conceptual ideas in the WE condition, not to greater willingness to try or fewer mechanical errors.

A mathematics curriculum using worked examples

Previous research has shown that using worked examples in an algebra curriculum supports student learning (Booth et al., 2015). This curriculum translates learning sciences principles into practice, drawing on ideas from the worked example principle (Sweller, 1999), the importance of using *incorrect* worked examples (e.g. Siegler, 2002), and the role of self-explanation prompts (e.g., Chi, Leeuw, Chiu, & LaVancher, 1994).

In the current investigation, we explore the effectiveness of using a worked example curriculum for teaching 5th grade mathematics. We extend previous research by measuring whether learning 5th grade mathematics with worked examples supports transfer to a new content area (algebra) using items designed to measure students' Preparation for Future Learning (PFL; Bransford & Schwartz, 1999).

Method

Fifth grade students (*n*=527) in 32 classrooms (19 teachers) across the Midwestern US participated in a yearlong randomized control trial. Students completed 69 assignments covering multi-digit numbers, place value, decimals, basic operations with fractions, multiplying and dividing fractions, geometry and volume, and ordered pairs. To maintain ecological validity, teachers chose when and how to incorporate the problems into the curriculum; the main stipulation was that the problems be used during class time instead of as homework.

Students were assigned to either a Worked Examples (WE) or Control condition. Students in the business-as usual Control condition solved problems for each arithmetic content area. In contrast, the WE condition received correct and incorrect worked examples and targeted prompts to self-explain features of the examples. After each example, WE students solved an isomorphic problem. Both conditions worked with the same problems; WE students self-explained worked examples of half and solved half whereas students in the Control condition solved all of the problems.

At the start of the year, students completed a pretest consisting of standardized test items measuring knowledge of 4th grade math concepts and skills plus research-based measures of student explanation, error anticipation, and flexibility. At the end of the year, students completed several measures, the results of which are reported elsewhere. Here, we analyze a PFL transfer measure. In this measure, students received learning resources (worked examples involving solving algebraic equations) and were asked to solve isomorphic problems. The algebra content was not addressed in the 5th grade curriculum; problems were designed to measure whether students could interpret worked examples and solve problems about new content.

Results

Average scores on the algebra transfer measure were 27.2% correct (SD = 3.53) for the WE condition and 19.7% correct (SD = 3.16) for the Control condition. Even controlling for pretest, students in the WE condition performed significantly better than Control ($F(1, 524) = 7.16$, $p = .008$, $\eta^2 = .013$). Though performance was relatively low, likely because this was a more challenging math topic for this age group, the significant condition difference suggests that learning from worked examples helped students learn in a new content area.

To further understand this condition difference, we investigated whether students' errors resulted from leaving the problem blank or making a conceptual error, a mechanical error, or both. Conceptual errors included mistakes that indicated misconceptions about the mathematical concepts tested, such as order of operations and performing equivalent operations on both sides of the equals sign, whereas mechanical errors included miscopying numbers (e.g. *13* vs. *31*) or simple arithmetic errors (e.g. *2+3=6*). This analysis, visualized in Figure 1, allowed us to address three possible mechanisms for the condition difference in accuracy.
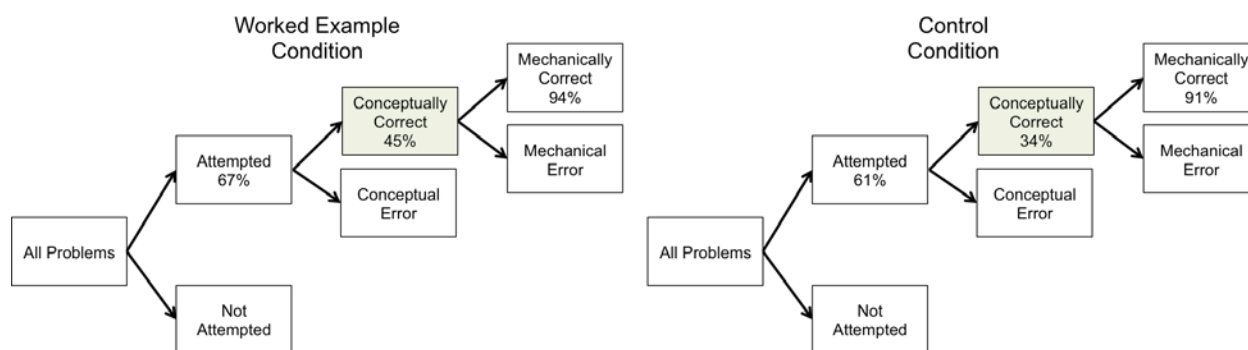
Figure 1. Likelihood of students attempting and correctly solving the algebra problems on the PFL transfer measure by condition. The highlighted level indicates a difference in conceptual understanding.

Attempts

One potential hypothesis is that students in the WE condition were more likely to attempt the problems because of their yearlong experience with worked examples. To answer this, we compared the percent of problems that students attempted: 67% in the WE condition vs. 64% in the Control condition. There was not a significant condition difference in the likelihood to attempt the problem (χ^2=1.67, p=.20); the condition difference in accuracy does not stem from a difference in the conditions' willingness to try.

Conceptual correctness

Alternatively, the condition difference in accuracy may result from a difference in students' ability to transfer their conceptual understanding, recognize the deep structure in the worked example, and apply it to the new problems. We compared the amount of conceptually correct problems as a percent of the attempted problems by group. In the WE condition, students were conceptually correct on 45% of their attempts as compared to 34% in Control. This was significantly different by condition (χ^2=10.76, p<.01); students in the WE condition were better able to understand concepts presented in the transfer resources and less likely to make conceptual errors.

Mechanical correctness

A final mechanism for the difference in accuracy could lie in students' attention to surface features. Of the problems that students got conceptually correct, did one condition make more mechanical errors? Mechanical correctness was high: 94% in the WE condition and 91% in Control. There was no significant condition difference (χ^2=1.33, p=.25); learning from worked examples did not lead to fewer mechanical errors.

Implications

This study extends previous translational research on worked examples to an elementary classroom setting and includes new error analyses to understand the mechanism though which worked examples can promote learning. Our results demonstrate that learning 5th grade mathematics from worked examples leads to greater learning in a new algebra content area. Importantly, this difference can be attributed to a deeper understanding of conceptual ideas among the WE students rather than an increased willingness to try solving the problems or a greater attention to surface feature mechanical details. These findings offer insight into the importance of carefully designing instructional materials that support learning and enable students to learn in future tasks.

References

Booth, J.L., Oyer, M.H., Paré-Blagoev, E.J., Elliot, A.J., Barbieri, C., Augustine, A., & Koedinger, K.R. (2015). Learning algebra by example in real-world classrooms. *Journal of Research on Educational Effectiveness*, *8*(4), 530-551.

Bransford, J.D., & Schwartz, D.L. (1999). Chapter 3: Rethinking transfer: A simple proposal with multiple implications. *Review of Research in Education, 24*(1), 61-100.

Chi, M.T., Leeuw, N., Chiu, M.H., & LaVancher, C. (1994). Eliciting self-explanations improves understanding. *Cognitive Science, 18*(3), 439-477.

Siegler, R.S. (2002). Microgenetic studies of self-explanation. *Microdevelopment: Transition processes in development and learning,* 31-58.

Sweller, J. (1999). Instructional design. In *Australian Educational Review.*

Multimodal Engineering Design Notebooks and Meta-Representational Competence

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Abstract: Research in mathematics and science education shows that elementary students develop more sophisticated disciplinary ideas and practices when teachers provide explicit supports for discourse and representation. Extending this research to engineering education, we describe how a multimodal design notebooking app influenced fifth graders' work during a collaborative design challenge. Unexpected meta-representational competence emerged as students constructed and critiqued external representations of their engineering design solutions in notebook entries as well as in more formal texts.

Introduction

Research in mathematics and science education has generated powerful strategies that help young learners participate in the Discourses that mediate individual and collective knowledge building in a particular discipline (McKlain & Cobb, 2001; Michaels & O'Connor, 2012). Compared to mathematics and science, in engineering education less is known about how to support discursive and representational practices during learning experiences in elementary classrooms. Although a growing number of organizations offer K-5 engineering curriculum materials, the field is still discovering how instructional supports such as talk moves and student notebooks help create learning environments where all elementary students can fully participate in engineering.

The overall goal of our research is to explore the influence of multimodal documentation technology on elementary students' engineering design discourse and decision-making. Adapting earlier work on digital science notebooks and design diaries (e.g., Puntambekar & Kolodner, 2005) to both elementary-school engineering and to modern computing tools, we developed a design notebooking iOS app to support students in documenting and reflecting on their engineering design ideas, tests, and decisions in disciplinary ways. This poster reports on an early teaching experiment with the notebooking app in which we found that students' meta-representational competence mediated the influence of the technology on their engineering thinking.

Theoretical approach

In this research we draw on decades of learning sciences research on knowledge-building communities where thinking is made visible in order to apprentice learners to ways of representing ideas in a particular discipline (Brown, Collins, & Duguid, 1989) and to enable idea improvement by others (Scardamalia & Bereiter, 1994). Within the discipline of engineering, knowledge-building involves making evidence-based arguments about the soundness of design decisions. Documentation and visualization tools aid professional engineering designers in doing this work (Aurigemma, 2013). Young engineering students may need specific scaffolds to document and visualize their engineering design work in particular ways at particular moments. In turn, the acts of documentation and visualization may help them engage in the challenging discourses of small-group engineering design (McFadden & Roehrig, 2018). The design notebooking app that we developed and used in this teaching experiment offers seven multimedia notebook page templates: Problem, Ideas, Test, Final Design, Feature, Exploration, and Issues. Each template combines brief prompts with blank photo, video, sketch, or text fields to highlight a different epistemic practice of engineering design. These templates draw on the idea that disciplinary work involves using the discipline's *epistemic forms* – ways of organizing knowledge – and playing its *epistemic games* – sets of rules, strategies, and moves made to populate a form (Collins & Ferguson, 1993).

Methodological approach

The data for this study come from a teaching experiment that three authors conducted with two teachers at an elementary school in a city in the eastern United States. In a fifth-grade classroom where students had not previously participated in engineering design, the first author and lead teacher co-taught a unit on the engineering of "stomp rockets," paper devices launched by air pressure. Over the course of ten days (60 minutes each day), students planned, built, tested, documented, and discussed the success and failure of small rockets made out of lightweight paper and plastic. Working in teams of three or four, they used the design notebooking app for documentation, and at the end of the unit they created formal posters with both texts and figures to

present design recommendations to another class of students. Before creating their own notebooks and posters, students analyzed several "mentor texts"– examples of completed digital design notebooks and design posters.

We utilized an interpretive case study approach and microethnographic analysis (Bloome et al., 2005) to explore the students' discursive and representational practices as they interacted with the notebooking app and created their design posters. Data sources included classroom field notes, digital and tangible student artifacts, video recordings, and transcripts of whole-class and team conversations. To characterize how fluently students created and critiqued different kinds of representations of their engineering designs, we turned to prior work investigating children's *meta-representational competence*, which is the ability to generate representations spontaneously, to judge the adequacy of such representations for a disciplinary task, and to notice differences between spontaneous representations and more canonical ones (diSessa, 2004).

Preliminary findings

As students captured their design work with the notebooking app and created posters to summarize their design recommendations, they displayed meta-representational competence frequently during whole-class discussions in two main ways. First, they intentionally generated new forms of representation to model aspects of rocket performance that photos or text alone could not show. For example, one student explained why she sketched wavy lines inside a wireframe drawing of her team's rocket: "See the squiggly in black? We drew that, since we couldn't get a clear picture of what it would look like on the inside of a rocket, so we decided to draw, estimate, what our picture would look like, so that squiggle in the hole is showing the air going into the hole, which would push the rocket up." Second, as the students judged the adequacy of their own and other teams' multimodal representations, they explicitly discussed the strengths and weaknesses of the notebooking technology for communicating about design ideas and results. In one whole-class discussion, several students talked about the value of being able to annotate and draw on top of photographs of design artifacts to draw attention to important features: "when we could take a picture and draw on top of the picture, it helped us with our ideas because we could get two ways to look at our ideas." In another design share-out, one student realized that his oral explanation of a rocket design failure was quite limited, and he asked for permission to project a video from his notebook on the classroom's projector screen because "it would help me explain my point."

References

Aurigemma, J., Chandrasekharan, S., Nersessian, N. J., & Newstetter, W. (2013). Turning experiments into objects: The cognitive processes involved in the design of a lab-on-a-chip device. *Journal of Engineering Education*, *102*(1), 117-140.

Bloome, D., Carter, S. P., Christian, B. M., Otto, S., & Shuart-Faris, N. (2005). A microethnographic approach to the discourse analysis of classroom language and literacy events. *Discourse analysis & the study of classroom language and literacy events—A microethnographic perspective*, 1-49.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher*, *18*(1), 32-42.

Collins, A., & Ferguson, W. (1993). Epistemic forms and epistemic games: Structures and strategies to guide inquiry. *Educational Psychologist*, *28*(1), 25-42.

diSessa, A. A. (2004). Metarepresentation: Native competence and targets for instruction. *Cognition and Instruction*, *22*(3), 293-331.

McClain, K., & Cobb, P. (2001). An analysis of development of sociomathematical norms in one first-grade classroom. *Journal for Research in Mathematics Education*, 236-26.

Michaels, S., & O'Connor, C. (2012). Talk science primer. *Cambridge, MA: TERC. Available online at http://inquiryproject.terc.edu/shared/pd/TalkScience Primer. pdf.*

Puntambekar, S., & Kolodner, J. L. (2005). Toward implementing distributed scaffolding: Helping students learn science from design. *Journal of Research in Science Teaching*, *42*(2), 185-217.

McFadden, J., & Roehrig, G. (2018). Engineering design in the elementary science classroom: supporting student discourse during an engineering design challenge. *International Journal of Technology and Design Education*.

Scardamalia, M., & Bereiter, C. (1994). Computer support for knowledge-building communities. *The Journal of the Learning Sciences*, *3*(3), 265-283.

Acknowledgments

A Geopositioning View of Teachers' Orchestration in Active Learning Classrooms: Following Teachers' Location Within the Classroom

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Abstract: In this study we report on a method to answer a simple yet fundamental question: How do teachers manage their space resources in active learning classrooms? Specifically, we document how a software, designed for physics education, might provide an alternative to documenting the physical position of the teacher as a function of time. This approach shows clear patterns can be produced, thereby revealing one dimension of the larger question of teacher orchestration.

A logical extension of active learning pedagogies (e.g., Chickering & Gamson, 1987) are active learning classrooms (e.g., the SCALE-UP & TEAL models). Just as the learning locus has shifted from teacher as sage on the stage to teacher facilitator supporting students' activity (King, 1993), the architecture of classrooms must also change. We define Active Learning Classrooms (ALCs) as technology-rich collaborative learning environments, which support students' learning experiences. These innovative spaces are intended to create a student-centered environment that encourages collaboration and communication among learners. Learning becomes distributed across the physical space because there is no definite "front" to the classroom: the teacher desk is often repositioned to the center of the room, if it exists at all, and rows of desks are replaced with group tables. As adapting to supporting students' needs drives the learning agenda, teachers no longer fully control what will happen in the classroom. Teachers must now manage feedback from multiple streams (visual, aural, oral, technological) and adaptively react adaptively. Such work can be characterized as *orchestration*, the real-time management of activity, along with the management of classroom resources (e.g., Dillenbourg & Jermann, 2010). As a research topic, orchestration has gaining much interest in the CSCL community (Dillenbourg, 2013). This moment-to-moment management of the constraints of the classroom ecosystem, coupled with the management of the learning, places greater demands on the teacher than traditional classrooms and traditional instruction. Physical space and layout are important orchestrational considerations (Dillenbourg & Jermann, 2010). Where the teacher is located, what the teacher can access does make a difference to the possible interactions and feedback to learners.

To date, eye trackers have provided a method to examine teacher orchestration (Prieto, Sharma & Dillenbourg, 2015). Arguably, that method comes with costs: financial, and, possible disruptiveness to the natural flow of the participants. This poster reports on an alternative, a post-hoc software, which also allows for the examination of one part of the orchestration puzzle: how the teacher moves in the learning space, as a function of time. We demonstrate the potential of the method by applying it to a case study of two classroom settings, each representing different architectural layouts that produces different movement and access patterns.

Methods

This exploration used data from a larger ethnographic study that collected classroom video data from two differently designed ALCs (classroom A & classroom B). Each classroom consisted of pod-like seating for groups of 6-7 students with group-dedicated interactive whiteboards. Classroom B, however, had a fixed central podium for the teacher, and each group table held three desktop monitors. The data selected were from two teachers, each early adopters of their respective ALCs. Collection of the video data followed a set protocol: two micro cameras (GO-PROs), one mounted on the front and another on the back walls of the classroom. An average of 12 sessions were video recorded for each teacher, the selected data is representative of the teacher.

Adapting Tracker software to follow the teacher's movement

Tracker software, is an open source video analysis and modeling tool designed to be used in physics education. In this case study, it is repurposed to locate the physical position of the teachers in the classrooms, determined as a function of time (every 5 seconds). The basic idea is quite simple: to determine a position vector relative to the

camera, all one needs is the angle and the distance from the camera. Perspective dictates that the further from the camera, the smaller the image on the camera sensor. To determine the relative size of the teacher's image, it is necessary to track two vertical points on the teacher in each frame. One point was the top of the teacher's head, and the other the teacher's waist. This, together with the angle on the video relative to the camera, gives a good indication of where the teacher is located in the room to within ~1m, after the necessary camera-specific calibration for each measure (angle and distance, and accounting for the absolute waist-head distance for a specific teacher) is made.

Results

Figures 1(a & b) show the results of the Tracker analysis (on 15 minute data segment) with the dot representing the physical position of the teacher every 5 seconds - connecting lines show the path. Interestingly, this visual representation allows us see differences between the two teacher's patterns of accessing the student groups - one aspect of orchestration. Figure 1a, shows the teacher is with each group, in a somewhat even distribution (density of dots); and, the path is varied but more often sticks to the perimeter, occasionally stopping between tables (see G4-G5 and G5-G6). By contrast, Figure 1b shows the teacher moves back and forth close to the central podium with one main move to G2 (based on the density of dots), compared to the other tables.

| Classroom A | Classroom B |
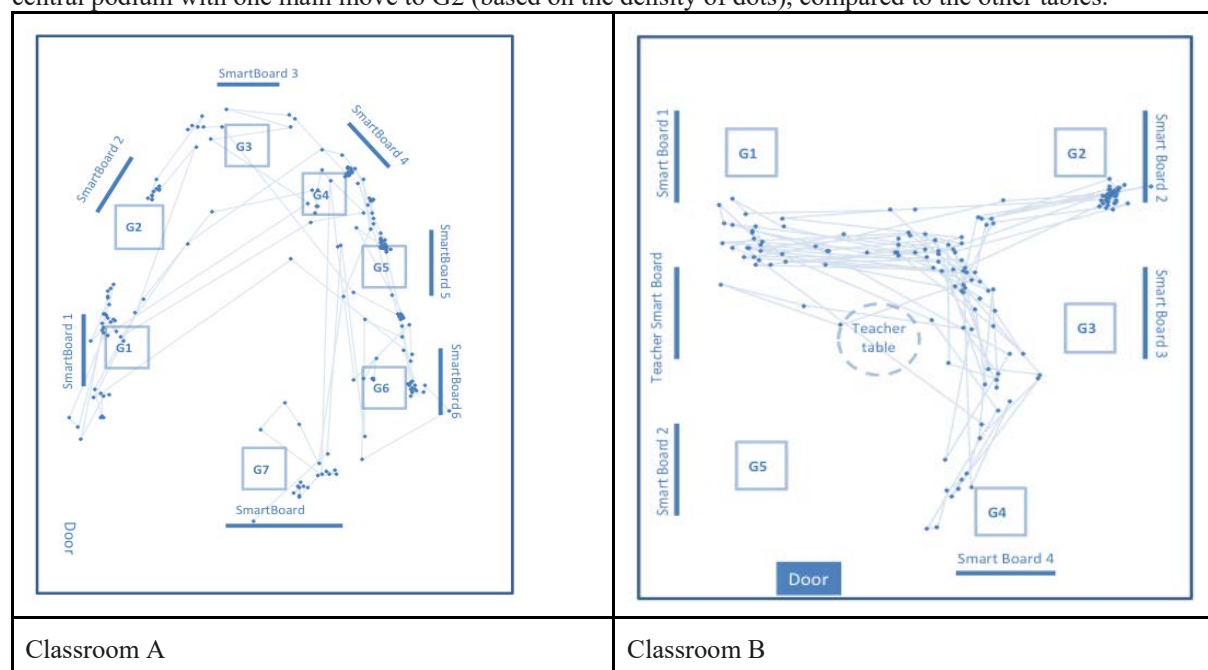
Figure 1. Tracking analysis of the teacher's physical location within classroom A and classroom B.

Discussion

Our aim was to explore the use of the Tracker software to help examine the movement of teachers within new learning spaces (ALCs), as part of the larger question about classroom orchestration. The results suggest that the visualization produced by the software can show differences between teacher movement, which can then be further analyzed and interpreted. We posit that this method holds potential for those doing this type of classroom research and interested in questions of classroom orchestration.

References

Chickering, A. W., & Gamson, Z. F. (1987). Seven principles for good practice in undergraduate education. *AAHE bulletin*, *3*, 7.

Dillenbourg, P. (2013). Design for classroom orchestration. *Computers & Education*, *69*, 485-492.

Dillenbourg, P., & Jermann, P. (2010). Technology for classroom orchestration. In *New science of learning* (pp. 525-552). Springer New York.

King, A. (1993). From sage on the stage to guide on the side. *College teaching*, *41*(1), 30-35.

Prieto, L. P., Sharma, K., & Dillenbourg, P. (2015). Studying teacher orchestration load in technology-enhanced classrooms. In *Design for Teaching and Learning in a Networked World* (pp. 268-281). Springer.

Domain-General Metacognitive Instruction Reduces Productive Learning Behaviors and Performance?

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Abstract: Metacognition is critical to self-regulated learning, but can a domain-general intervention improve college students' course performance? We compared an intervention teaching metacognitive knowledge and skills against one in which students read feature news articles related to course content. Students in the metacognitive condition performed *worse* on the final exam than students in the reading condition when controlling for prior metacognitive awareness. We discuss future directions for understanding how metacognitive interventions impact students' learning.

Major issues and significance

Metacognition, or the process of thinking about one's thoughts, strategies, and learning, plays a crucial role in self-regulated learning (Winne, 1995). Students must be able to recognize what they do not understand, plan and execute an appropriate course of action, and evaluate its effectiveness. Experiments testing interventions to promote metacognition have typically involved extensive, in-class training directed by researchers or instructors (Dignath & Buttner, 2008), which limits applicability outside the context of the study. Zepeda, Richey, Ronevich, and Nokes-Malach (2015) found that an intervention targeting declarative knowledge about metacognition and the application of metacognitive skills to course content improved middle school science students' motivation, conceptual physics knowledge, and course performance. Results raised questions about how the intervention affected students (e.g., were they studying more? making better use of resources?) and whether a similar intervention could help older students, who tend to be better but still flawed metacognitive thinkers (Metcalfe, Eich, & Castel, 2010).

The goals of the current work are threefold: First, we seek to test a metacognitive intervention among college students. Given that adults' metacognitive skills plateau, and that college students typically represent a selective group of high-performing students, it is not clear they will benefit from practicing metacognitive skills. Second, we aim to adapt prior research by creating a domain-general intervention. Most prior work has customized the intervention to incorporate problems or activities from the course in question. While this has often proven effective, it creates a barrier for teachers wishing to apply existing interventions in their classes. Third, we are collecting fine-grained data within a learning management system on students' course behaviors. This rich dataset will provide greater insights into the learning behaviors associated with levels of metacognition and the effects of a metacognitive intervention.

Methodology

Students were from a large, public university in the Midwest enrolled across five sections of two introductory-level educational psychology courses: one section of an intro-level course for non-majors taught by one instructor (64 enrolled) and four sections of an intro-level course for majors taught by two instructors (138 enrolled).

All students were asked to provide consent to analyze their course data; they were informed that they would be completing all course activities regardless of consent. Data from 27 students were removed from analyses because the students either did not provide consent, were enrolled in both courses, or participated in the pilot study conducted the previous semester in a different course. As a result, the final sample included 54 students in the first course and 128 students across four sections of the second course.

Both experimental and control materials consisted of self-guided, out-of-class activities, with students randomly assigned to the experimental or control condition at the individual level. The experimental materials focused on three critical metacognitive skills – planning, monitoring, and evaluation – and three types of metacognitive knowledge – personal, strategic, and conditional. We modeled the intervention materials after another metacognition intervention that improved learning and motivation among middle school students (Zepeda et al., 2015). To make the current materials domain general and broadly applicable across courses, students chose the assignments they wanted to target with each activity. The control condition received additional readings about course-relevant concepts from the popular press, along with a series of comprehension questions to ensure they were reading the materials. Readings were selected to be relevant to the course but to not directly review content that would be on any course assessments. For example, when learning about operant conditioning, students receive a reading about B.F. Skinner's pigeon-guided missile invention during World War II. The materials across

conditions were similar in length and style, so that any behavioral, motivational, or learning differences between the conditions could be attributed to the content of the intervention. Due to logistical constraints, students in the non-major course completed the intervention in eight segments, while students course for majors completed the intervention in four double segments.

Students received extra credit for completing surveys at the beginning of the semester and immediately before the final exam on which they self-reported their planning, monitoring, and evaluation (Metacognitive Awareness Inventory; Schraw & Dennison, 1994) and their academic procrastination (short form; Yockley, 2016) on six-point Likert scales. We also collected data on students' course behaviors within the online learning management system for each course, including how far ahead of deadlines students accessed major assignment instructions, how far ahead of deadlines students submitted work, how often students viewed their grades, and whether students accessed optional course resources. For the present submission, we focus on how far in advance of deadlines students submitted their intervention activities during the second half of the course. To examine the impact of the intervention on learning, we collected students' scores on the final course exams.

Results and conclusions

We conducted a series of one-way analyses of covariance (ANCOVAs) comparing students' post-intervention levels of planning, monitoring, evaluating, and procrastination across conditions, controlling for each corresponding pre-intervention variable. Results revealed no significant differences (Table 1). An ANCOVA of average submission times relative to deadlines that controlled for pre-intervention procrastination also revealed no condition effects (Table 1). An ANCOVA comparing students' final exam grades across conditions and controlling for pre-intervention levels of planning, monitoring, and evaluation indicated a small effect of condition, with students in the metacognitive condition performing *worse* on the final exam than students in the control condition (Table 1).

While students in the metacognitive condition did not differ from students in the control condition on levels of metacognitive awareness or procrastination did not differ, the intervention reduced their final exam performance. Further analyses of the rich behavioral data collected, along with the content of students' intervention responses, may provide greater clues regarding the reasons the metacognitive intervention reduced students' learning outcomes. Based on these results, a domain-general metacognitive intervention might not be beneficial in college classrooms, at least without a better understanding of the short- and long-term behavioral effects of the intervention. We will encourage discussion of this curious result and more details are to come with continued analyses.

Table 1: Preliminary results of ANCOVAs with adjusted marginal means

	F	p	η^2_p	Metacognitive condition M (SE)	Control condition M (SE)
1. Planning	0.01	.94	.00	4.12 (0.07)	4.12 (0.07)
2. Monitoring	0.00	.98	.00	4.11 (0.08)	4.11 (0.08)
3. Evaluating	0.90	.34	.005	4.05 (0.07)	4.15 (0.07)
4. Academic procrastination	0.66	.42	.004	4.13 (0.07)	4.12 (0.07)
1.15	0.68	.29	.025	23.64 (5.84)	32.38 (5.59)
6. Final exam	4.02	.047	.024	75.42 (1.43)	78.87 (1.48)

References

Dignath, C., & Büttner, G. (2008). Components of fostering self-regulated learning among students. A meta-analysis on intervention studies at primary and secondary school level. *Metacognition and Learning, 3*, 231–264.

Metcalfe, J., Eich, T. S., & Castel, A. D. (2010). Metacognition of agency across the lifespan. *Cognition, 116*(2), 267–282.

Schraw, G., & Dennison, R. S. (1994). Assessing metacognitive awareness. *Contemporary Educational Psychology, 19*, 460-475.

Winne, P. H. (1995). Inherent details in self-regulated learning. *Educational Psychologist, 30*, 173–187.

Yockey, R. D. (2016). Validation of the short form of the academic procrastination scale. *Psychological Reports, 118,* 171-179.

Zepeda, C. D., Richey, J. E., Ronevich, P., & Nokes-Malach, T. J. (2015). Direct instruction of metacognition benefits adolescent science learning, transfer, and motivation: an in-vivo study. *Journal of Educational Psychology, 107*(4), 954-970.

Exploring Ideological Becoming for Youth of Diverse Backgrounds: Documentary Practices as Internally Persuasive Discourse

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Abstract: This study explores how youth of diverse backgrounds grappled with varying civic perspectives in a documentary storytelling curriculum in a multicultural context. Our findings indicate that documentary making is a generative context for learning, where students critically examine the perspectives of their audience and interviewees against their own through dialogic addressing and responding, and in so doing generates new understandings.

Introduction

Given the enormous diversity that exists in our society today, the need intensifies for educators to create transformative environments that exploit the learning potential of encounter with differences within a multicultural framework. Much work has been invested in understanding the nature of these divides by examining in detail ethnic, cultural and social-class differences, and advocated a reconceptualization of the heterogeneity of human experiences and practices as fundamental to learning (Gutiérrez, 2008; Rosebery, Ogonowski, DiSchino, & Warren, 2010). However, these studies tend to focus on particular groups of learners rather than a diverse mix. Limited attention has been devoted to understanding the potential for learning from ideological differences in multicultural contexts, particularly how to support youths to deepen engagement with variegated views through intentional design and employment of tools and artifacts.

In this study, we look at how a class composed of youth from diverse populations grapple with contentious social issues in a documentary storytelling curriculum. The curriculum is informed by funds of knowledge (FoK) research (Moll, Amanti, Neff, & Gonzalez, 1992) and aims to bring in knowledge, experiences, and ideological resources from different spaces, especially spaces that are historically marginalized. These foci are reflected in our deliberate choice of documentary storytelling on issues such as immigration. Multimedia storytelling can promote the presence of resources, artifacts, knowledge and experiences from students' families and communities in the educational context (Honeyford, 2014). Socially oriented documentaries, in particular, have the potential to cultivate youth's civic understanding and engagement in ongoing societal conversations.

We find Bakhtinian ideas of dialogism and internally persuasive discourse (IPD) helpful in thinking about how the curriculum in general, and the documentary making process in particular, have the potential to create a space for deep engagement with ideological differences. Bakhtin (1981) asserts that one's ideologies develop when she comes into contact with available resources (discourses, practices, people, etc.) in her environment. A learning space rich with multiple perspectives can fuel learning as it affords plentiful opportunities to develop one's ideologies and expand understanding of the world. However, multiplicity of voices does not guarantee ideological growth. Particularly in terms of social controversies, much too often the engagement ends up with the monologism, where singularity of viewpoints, rather than dialogic meaning-making, dominates. In order for learning to take place, we must "struggle" (Bakhtin,1981) and dialogically test a diversity of related ideas in relation to our own. IPD is where such ideological struggle occurs through critical examination and dialogic addressing and responding, and in so doing generates new understandings and expands one's ideological horizons. In this study, we first seek to understand the complexity of the ideological environment of the class, given the heterogeneity of students' backgrounds and experiences, as well as our intentional design in accessing critical perspectives. We further hone in on one focal youth group's engagement with these perspectives as they produced *The Process,* a short documentary profiling the challenges that a Latino immigrant in their community experienced in obtaining legalization of residency.

Methods

The study emerged from a 10-week documentary storytelling project with a 12th grade social studies class located in an urban school district. Thirty students of diverse racial and ethnic affiliations, from different immigrant populations as well as nonimmigrant backgrounds, worked in teams to produce a short documentary on how immigration policy affected people in their community. Our data set includes field notes, video recordings, and student work. We also conducted interviews with each student group at the end of curriculum, which involved watching students' documentaries together, stopping after each cut and discussing students' choices. In order to identify the array of perspectives that emerged in the process, we used a hybrid approach of

inductive and deductive coding to analyze transcribed class sessions by turns. Then, we analyzed the focal group's interview in conjunction with the multimodal transcription of their video, focusing, as informed by the theoretical frame of IPD, on: 1. Production choices, where they explicate how and why certain elements are included; 2. References to class discourses, where they refer to particular perspectives raised in class; and 3. References to experiential resources, where they refer to personal experiences or those in their community, and the knowledge gained from these experiences.

Preliminary findings and discussion

The class conversations were rich in diversity and comprehensiveness of discourses, ranging across humanist, reciprocity, legal, and resource security perspectives, as students were afforded both opportunities to express their ideas drawing on their FoKs and to be exposed to multiple social voices of the world. Nonetheless, competing positions emerged along restrictive versus non-restrictive stances toward immigration, and few substantial relationships between elements of divergent discourses were established. During the documentary production process, on the other hand, the focal group not only engaged with all the above major perspectives that emerged in the class, but further extended and/or complicated these viewpoints through drawing on the testimonies of their interviewees and/or their own experiential resources, while also responding to the ideological conflicts in class by problematizing the opposing claims posed by their peers. More fundamentally, they restructured the relationships between the restrictive and the non-restrictive stances towards immigration through extending their humanist stance to address the theme of legalization.

Our analysis reveals the ways in which documentary making affords the opportunities of critical examination and dialogic engagement—through dialoguing externally with their interviewees and with their audience, and internally with themselves. As documentary filmmakers develop their ideas, they have to consider the audiences' viewpoints to craft an effective message. In our case, the focal group set out to inform their audience (mainly their classmates) of immigrants' struggles given the ideological conflicts in class. As they were constructing their documentary narratives, they referenced opposing viewpoints raised in class and consciously formulated responses to their peers. Using concrete testimonies from their interviewees, they problematized the definition and responsibility of illegality, repositioned them as people of resilience, which enabled deeper discussion within the legal and the resource security perspectives. The interactional space between the filmmakers and their interviewees is also dialogic. While filmmakers might preplan who they will interview, they must recognize and examine their interviewee' viewpoints in relation to their own as they bring their perspective to bear on what their interview subjects have told them. Though the focal youths' stance aligned with their interviewees, through dialogizing with them, the students got to see how a familiar idea (e.g., struggles of undocumented immigrants) unfolded in different contexts, and created new understanding by connecting, juxtaposing or contrasting these experiences and viewpoints. Voices of their audience and interviewees, through the IPD supported by documentary practices, become part of the focal students' consciousness and shape the lens through which they come to understand the issue of immigration.

Conclusion

These early findings suggest that documentary making is a generative context for ideological development as it supports the creation of an IPD. In this space, students critically examine the perspectives of their audience and interviewees against their own through dialogic addressing and responding. Building on previous research that underscores heterogeneity as fundamental to learning, this study further points to ways in which we can, through deliberate design and employment of tools and artifacts, foster youths' productive engagement with differences in a multicultural context.

References

Bakhtin, M. (1981). *The dialogical imagination: Four essays* (C. Emerson & M. Holquist, Trans). Austin, TX: University of Texas Press.

Gutiérrez, K. D. (2008). Developing a sociocritical literacy in the third space. *Reading Research Quarterly, 43*(2), 148-164.

Honeyford, M.A. (2014). From Aquí and Allá : Symbolic convergence in the multimodal literacy practices of adolescent immigrant students. *Journal of Literacy Research, 46*(2), 194–233.

Moll, L. C., Amanti, C., Neff, D. & Gonzalez, N. (1992). Funds of knowledge for teaching: Using a qualitative approach to connect homes and classrooms. *Theory into practice, 31*(2), 132–141.

Rosebery, A. S., Ogonowski, M., DiSchino, M., & Warren, B. (2010). "The coat traps all your body heat": Heterogeneity as fundamental to learning. *Journal of the Learning Sciences, 19,* 322–357.

From Computational Thinking to Computational Action: Understanding Changes in Computational Identity through App Inventor and the Internet of Things

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Abstract: This paper advocates for a shift from teaching and assessing computational thinking towards one of computational action, which instead emphasizes learners' ability to develop computational artifacts that can impact their daily lives. We also discuss the importance of developing computational identity and digital empowerment as central to computational action. In order to understand how to support the development of computational identities and digital empowerment, we examined a group of students (ages 15-19) engaged in a 5-week summer camp that combined MIT's App Inventor and the Internet of Things (IoT). Results showed that participants significantly improved their ability to use IoT for meaningful impact in their worlds, and to develop IoT solutions to common problems in their everyday lives.

Introduction

In education, there has been a groundswell of research attempting to understand what it means for learners to "think computationally" (NAS, 2010). For many researchers, computational thinking has an epistemological goal, focusing on learners' understanding of the nuanced elements of computation, including type checking, aliasing, modularization, loops, parallelism, operators, and data handling (NAS, 2010). Focusing on the means of computing, rather than the process and ends, is one of the most persistent challenges of math and science education (Flegg et al., 2012), and risks reducing computing to something that feels irrelevant to learners' daily lives. In response, we argue that there is a need to move beyond computational thinking as the goal of computing education, to a perspective of *computational action*. Computational action emphasizes learners' ability to develop computational artifacts that impact their own lives and communities. By providing low-barrier means for students to design and implement solutions to personally relevant problems, we can help them develop their computational identities (i.e., being capable of creating meaningful change in their lives using computation and recognizing their place in the larger computing community) and their sense of digital empowerment (i.e., opportunities to put that identity into action) (Tissenbaum, Sheldon, Soep, Lee, 2017). With the growing ubiquity of mobile technologies, we have a unique opportunity to address this challenge by moving computation off of the computer and into their daily lives. Going one step further, the proliferation of the Internet of Things (IoT) has embedded computation into everyday objects that connect with each other, and opens up new opportunities for people to computationally connect with their surroundings.

This paper describes one strand of research that seeks to understand how a summer camp that combined blocks-based mobile app development using MIT's App Inventor (appinventor.mit.edu) with Arduino-Based IoT devices promoted students' computational action. To this end, two research questions drove this work: 1) How did the summer camp change students' perceptions of their role with smartphones and IoT?; 2) How did the camp support students' ability to develop computational solutions to personally relevant problems?

Below, we discuss the theoretical background for this work, the computational tools used, the structure of the summer camp, our findings from pre- post-surveys, and implications for computational action.

Methods

Participants and setting

This study took place over five two-hour sessions as part of a summer camp with an organization that aims to support underrepresented youth (mainly K-12 students) to develop STEM literacy. In total, 23 students took part in the camp, composed of 12 female and 11 male students. The participants ranged in age from 14 to 19 (mean age 15.9). The sessions were held at an East Coast university as part of the camp's regular activities. Members of the research team served as instructors for each of the five sessions.

Intervention design

This study employed a design-based approach that built upon previous iterations of an App Inventor + IoT camp. In the first session of the summer camp, participants were introduced to the App Inventor authoring environment

and were given two introductory tutorials. In the second session, they were introduced to the IoT functionality of App Inventor. Next, the participants were split up into groups of two or three, and each group was given another IoT + App Inventor element to learn. In session three, students were placed into groups of three to four to collaboratively pinpoint a challenge in their everyday lives and then design a solution using IoT + App Inventor. The students were given the entire fourth and half of the fifth session to work on their. During the fifth session, the students presented their work to the rest of the camp, as well as a larger audience of academics and technologists.

Data collection
For the purposes of this study, we focused on three questions, each of which was on the pre- and post-surveys: 1) "How could the way you use smartphones impact your life?"; 2) "How could the way you use the Internet of Things impact your life?"; and 3) "How might you develop a system in your home that helps you monitor and take care of your pet(s)?" To assess changes in participants' thinking, we developed a set of rubrics to score the three pre-post survey questions. The rubrics for Questions 1 and 2 aimed to understand changes in students' development of computational identities and digital empowerment. The third question aimed to assess changes in students' ability to engage in basic design thinking around a problem using IoT. Interrater reliability was established between the lead researcher and another researcher well versed in the platform and domain.

Findings and discussion
For the first question (use of smartphone in their lives), changes were not significant between the pre-test (M=1.24, SD=0.83) and post-test (M=1.41, SD=0.94); t(16)=-0.58, p = 0.283. For the second question (use of Internet of Things), changes were significant between the pre-test (M=0.82, SD=0.88) and post-test (M=1.71, SD=0.96); t(16)=-2.75, p = .0049. The significant change in scores on Q2 revealed that participants developed more nuance in their understanding of the role that IoT can play in their world. More importantly, it also revealed an improved awareness of participants' ability to use IoT to solve problems in their lives. While changes in Q1 (use of smartphones) were not significant, the overall results showed positive change from pre- (M=1.24) to post-survey (M.1.41). This may be influenced by students already having strongly entrenched notions of what a smartphone can do in their daily lives, as compared to IoT. For the third question (develop a system to monitor and take care of your pet), changes were significant at between the pre- (M=1.17, SD=1.015) and post-surveys (M=1.88, SD=1.219); t(16)= -1.84, p = .0379. These gains seem to indicate that the enacted curriculum helped students to develop approaches for articulating computational solutions to everyday problems. When we examined the participants' answers individually, 8 of the 17 respondents got a perfect score on Q3 in the post-test, as compared to only 3 in the pre-test. In many cases, students transitioned from vague descriptions ("I could create a system that would feed my animals and clean out their cages daily") in their pre-test answers, to more detailed and actionable solutions ("You can use a light sensor to sense if the light in a room turns too dark, sync your phone and be able to turn on the lights for them if you aren't home").

The findings above indicate several interesting aspects about the enacted curriculum and its focus on computational action. The overall shift in students' perceptions of their own roles as producers, rather than consumers of digital technologies is encouraging. This is particularly true in the context of students who are traditionally underrepresented in computing and STEM disciplines (Pinkard et al., 2017). The results of this study, especially regarding the change in the participants' perceptions of the role of the Internet of Things and their ability to create with it, lay important groundwork for supporting students in the development of their computational identities. The results of the third question show how curricula that engage students in authentic opportunities to construct personally meaningful computational artifacts can help students to articulate more complex and complete computational solutions to other everyday problems.

References
Flegg, J., Mallet, D., & Lupton, M. (2012). Students' perceptions of the relevance of mathematics in engineering. *Intl. Journal of Mathematical Education in Science and Technology*, *43*(6), 717-732.
National Academies of Science. (2010). Report of a workshop on the scope and nature of computational thinking. Washington DC: National Academies Press.
Pinkard, N., Erete, S., Martin, C. K., & McKinney de Royston, M. (2017). Digital Youth Divas: Exploring Narrative-Driven Curriculum to Spark Middle School Girls' Interest in Computational Activities. *Journal of the Learning Sciences*, (just-accepted).
Tissenbaum, M., Sheldon, J., Seop, L., Lee, C., (2017, April). Critical Computational Empowerment: Engaging Youth as Shapers of the Digital Future. *IEEE Global Engineering Education Conference*, Greece.

Scientists Expand Professional Vision Through Outreach With People Underrepresented in Science

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Abstract: Scientists have commitments to impact the public's perceptions of science. How do they learn how to accomplish successful outreach in different communities? The research examined a multi-faceted engagement program between scientists and communities underrepresented in science. Research examined the practices forged, finding that scientists evolved their professional vision to adapt practices such as developing reciprocity of perspectives, building from empathy, adapting language, and changing teaching practices.

Introduction

Many in society could benefit from interactions with scientists, yet they have little or no access. While formal and informal science institutions do a great amount of science engagement, science experiences remain out of reach for many. They include people who have little or no access to science in their daily lives such as the elderly, those incarcerated, the homebound, and those who are unable to access science facilities. Access can be limited by physical distance and social barriers, such as for refugees and those from communities underserved by educating institutions. Yet, interactions with scientists show positive outcomes.

The STEM Ambassador Program (STEMAP) is a public engagement project that integrates features of three informal science education models: Research Ambassador Program (Nadkarni & Stasch, 2013), Portal to the Public (Storksdieck et al., 2017), and Design Thinking (Goldman, 2017). These models combine, aiming to facilitate multi-level connections between the scientific community and the public. Participating scientists undergo training and continued support for accessing and understanding communities and for tailoring science engagements. Scientists participate to foster curiosity, generate excitement, make the case for science to the public, and improve their outreach skills. We also see them add skills in translation and adaptation as they tailor public engagements to the needs and interests of specific communities. Forty scientists at an R1 university in the United States, from doctoral students to Associate Professors, were in the program in 2016 and 2017, completing 84 events for 1600 pople at venues such as jails and senior centers.

Methods

Research focused on how, if at all, scientists' identities and professional vision were expanded. Professional vision entails the "socially organized ways of seeing and understanding events that are answerable to the distinctive interests of a particular social group" (Goodwin, 1994, p. 606). Through training in and uptake of practices related to public engagement in STEM, scientists experienced opportunities to understand the objects of their professional practice in expanded terms, with implications for the conception and enactment of their identities as scientists. We illustrate and discuss several cases (Stake, 1995; Yin, 1989) developed from data collected on a subset of 17 scientists. The case studies analyzed scientists' responses on pre and post surveys and interviews, field notes from observations of their community engagements, and evaluations from community participants in events. Coding of interviews proceeded from open coding to a more refined set of codes. Codes focused on identity addressed evaluations of self-change (e.g., becoming more empathic or improving as a science communicator) and new ways of thinking (about, for example, public engagement or their future careers and research endeavors). Surveys in year two of the project addressed identity by asking participants to rate a number of practices according to the extent to which they enact them, how important they think they are, and how confident they are to enact them. Example practices included "Seek out opportunities for public engagement experiences with people or communities who may not engage actively in STEM" and "Make public engagement in STEM part of your research projects or the classes you teach." In these ways, our approach to identity included not only one's ideas about oneself, but also connection to practices and social relations (Nasir & Cooks, 2009).

Results and significance

Through case studies we saw scientists expand their professional vision while making connections to new communities. They found ways to adapt their inscriptions, share science topics and practices, and translate their

work for understanding, without "dummying down", while relating to the concerns of the people they engaged. For example, one scientist met with the head of university facilities to propose an engagement. She then designed the interaction to learn how the electricians conceptualize circuitry and use terminology to solve problems in their work. In a lunch meeting with over 20 staff in facilities, she asked questions and there was much discussion about how cancer cells and electrical circuits work. This was a mutually beneficial border-crossing engagement made possible through efforts to understand across communities of practice. Another scientist who met with senior citizens showed examples of how the study of deadly poisionous snails leads to new diabetes drugs. This engagement was designed based on the direct concerns of seniors. Results indicate that no versions of professional vision shifts were alike, yet archetypes of adapting professional practices were revealed as scientists foregrounded certain aspects of their work in community settings. The case studies revealed defining adapted practices that scientists took as they transacted science beyond their labs and peer publications and with people in a variety of community settings (see Table 1).

Table 1: Practicess of scientists emerged showing professional vision adaptations

Vision Expansion	Definition	Example
Reciprocity	Both scientist and community members advance their learning	Scientist meets with electrical systems operators to learn terms & whether circuits work like cancer cells
Empathy	Scientist develops empathy insights about the needs and abilities of people for learning science	Scientist visits youth treatment center to observe and talks with gatekeepers before planning
Citizen Science	Scientist establishes ways for people to contribute to data	Website can take entries of species seen by hikers in local foothills
Multimodal Communicator	Scientist sheds reliance on lectures, creates hands-on/interactive activities	Scientist brings beautiful shells of deadly snails to presentation
Collaborative Consociates	Scientists team with colleagues to meet the needs of a community, even when off-topic	Three scientists team up to support garden science at local jail
Adaptive Expertise	Scientist uses local and context cues with flexibility *en passant*	Scientist finds fossils to examine while on a hike with children
Teaching	Scientist plans to incorporate program approaches and ideals in courses they teach	New faculty will incorporate outreach while teaching

The archetypes of practices in scientist expansion and adaptation of their professional visions are informative for those who work to increase public engagement. The scientists expressed the importance of bringing science to the larger underrepresented public as a professional goal, even when it meant crossing borders and the comfort of existing professional vision. With science becoming a national debate rather than a given national priority, the ability for scientists to help the public understand science through expanded vision may be crucial.

References

Goldman, S. (2017). Design thinking. In K. Peppler (Ed.), *The SAGE encyclopedia of out-of-school learning*. Los Angeles: Sage Publishing.
Goodwin, C. (1994). Professional vision. *American Anthropologist*, *96*(3), 606-633.
Nadkarni, N. M., & Stasch, A. E. (2013). How broad are our impacts? An analysis of the National Science Foundation's Ecosystem Studies Program and the Broader Impacts Requirement. *Frontiers in Ecology and the Environment, 11*(1), 13-19.
Nasir, N. S., & Cooks, J. (2009). Becoming a hurdler: How learning settings afford identities. *Anthropology & Education Quarterly, 40*(1), 41–61.
Sherin, M. G., Russ, R. S., Sherin, B. L., & Colestock, A. (2008). Professional vision in action: An exploratory study. *Issues in Teacher Education*, *17*(2), 27.
Stake, R. (1995). *The art of case study research*. Illinois: SAGE Publications, Inc.
Storksdieck, M., Stylinski, C. & Canzoneri, N. (2017). *The Impact of Portal to the Public: Creating an infrastructure for engaging scientists in ISL*. Corvallis, OR: Oregon State University.
Yin, R. (1989). *Case study research: Design and methods*. New York: SAGE Publications Inc

"This Is for Boys. You Did It?": Agency Under Construction in a Girls-Only Design and Making Program

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Abstract: This study explores a summer program for high school girls in a girls-only space for design and making of physical objects using a combination of power tools and digital fabrication. The goal of the study is to understand how the program's design, practices and mentor-mentee interactions support girls' agency. We report themes which emerge in interviews with the girls illuminating the way girls view their participation in the program in relation to their lives and community.

Introduction

Over the past ten years, a growing number of youth informal learning spaces have been incorporating making and building into their programming. Making is an umbrella term that combines the long-standing culture of do-it-yourself, artistic exploration, and craftsmanship, together with newly accessible digital technologies and new ways for community building and information sharing (Martin, 2015). Since the beginning of the maker movement, researchers in the field of learning sciences have been interested in the learning that takes place through making, its potential to expand our views on learning and teaching, and the impact of making practices on specific educational concerns. Research in the field shows that incorporating making activities in learning spaces provides an avenue for engaging, interest-driven learning experiences that support youths' sense of agency and opportunities to impact their communities (Sheridan et al., 2014). At the same time, there is a growing body of literature that is concerned with issues of equity, and that is critical of the maker movement for being mostly dominated by the images, practices and work of middle-class, white men (Vossoughi et al., 2016). This criticism is joined by efforts in the field to design maker platforms that purposefully broaden access to making and, through making, to STEM and design practices for girls and youth from marginalized communities (Buechly, 2014; Barton et al., 2016).

This study explores a summer program for high school girls that took place at a girls-only space for design and making that uses a distinctive approach to give girls the opportunity to design and build large physical objects using a combination of power tools and digital fabrication. The program combines design work with discussions about gender issues like what it means to be a girl in our culture and in STEM fields. The goal of the study is to understand how the program's design, practices, and mentor-mentee interactions support girls' expression and sense of agency. We follow a sociocultural perspective on agency that pays attention to "the socioculturally mediated capacity to act," and therefore is sometimes referred to as mediated agency (Van Lier, 2008). Through this lens, agency is situated in a specific context, is constructed through action, and is not a static trait or tendency that someone has (Lasky, 2005). This perspective shifts the focus to the cultural tools and the ways they enable or constrain the possibilities for action (Holland et al., 1998). This perspective guides us in our analysis of how mentors and girls talk about themselves and their experiences, and in our observations of the physical work that takes place during the program.

Methods

The study took place at a girls-only space for design and making. The space accommodates different programs throughout the year and special programs during the summer. The program described in this study took place in two separate full-day, one-week sessions with twelve high school girls at each session (seven Hispanic, eight African American, three White, two Asian, four other). Data sources include video-recorded observations of program activities; semi-structured interviews with girls and mentors at the beginning and end of the program; program artifacts like documents and presentations prepared by mentors; written material produced during the design process (annotated sketches, journals, etc.); photographs of projects in process and finished; and field notes. We are currently in the process of analyzing the data. At this stage we are analyzing the pre and post girls interviews. After transcribing each of the interviews, we first read each transcript to get a sense of the girls' stories as a whole. Transcripts are coded in an iterative process of inductive and deductive coding (Valanides, 2010), ending up with emergent themes. In addition, we code for agency using Konopasky and Sheridan's (2016) linguistic agency toolkit. We plan to similarly analyze the mentors' pre and post interviews. The final stage of our analysis will examine how agency is co-constructed during work interactions, paying attention to both discourse and gestures.

Preliminary findings

Preliminary coding of girls pre and post interviews has raised themes of exploration, caring and support, inclusive environments and dealing with stereotypes. These themes illuminate how girls see their participation in the program in relation to their lives and their community. To illustrate these themes using the girls' words, we provide here several quotations from one of the girls, Avishag. Avishag is a senior in high school who lives with her mom in a small rural town. When she described her town, she said: "In my town, it's the White people and the Mexicans. The White people don't really like to talk to the Mexicans, so it's kind of like, so there's not really... they don't really blend". Not all girls came from small towns - the majority actually came from the inner city - but other girls described similar social situations in their daily lives.

Exploration: Girls spoke about the program as a place to meet and work with like-minded girls, and an opportunity to try different ways of being. When Avishag summarized her experience, she said: "It made me feel like there's more than that. There's more than the little town where I live, there's more of what the stereotypes are there. You can come out here and be someone else and learn better skills, and it's not just you staying up there and doing whatever everybody else does."

Caring and Support: Several of the girls described a teacher in their school who cares about them and supported their program application process. In Avishag's case, it was her elective design class teacher: "Mr. Carlson, which is a person that first introduced me and motivated me to do this... He just really believes that I have a lot of potential. He's always telling me about opportunities. He always wants me to explore and travel. So this was a good opportunity to do that." Some girls described their mom or a friend of the family as the person who introduced them to the program and encouraged them to participate.

Inclusive environment & Dealing with stereotypes: When girls spoke about the fact that this is a girls-only space, they usually compared their experience to the way their family and community associate gender with maker practices. Avishag described the difference between her feelings in the program to how she sometimes feels in the design class in her school: "You don't feel intimidated by the guys, because the guys are the ones that are supposed to be doing this stuff. So you feel like you want to do it more because you know that it's for girls. It just makes you feel like you know you could do it. It empowers you to try to do it more." When she spoke about showing her friends and family her welding project, she said "I think they're going to be surprised that I did well, and that it looks good. It's like, only my first or second time welding. My mom's going to be really surprised. Like, 'This is for boys. You did it?'"

Conclusions and implications

As we continue our data analysis, we will focus on aspects of the program design and design work interactions that foster the interview themes of a caring feeling and an inclusive environment. We will also look at the way girls talk about themselves in relation to STEM, while tracking what led to this talk. We expect that the findings of this research will contribute to the body of literature on equity and making with an emphasis on girls' learning through making, and will have implications for maker settings promoting girls' agency.

References

Barton, A. C., Tan, E., & Greenberg, D. (2016). The makerspace movement: Sites of possibilities for equitable opportunities to engage underrepresented youth in STEM. Teachers College Record.

Beuchley, L. (2014).Thinking about making. Speech presented at Eyeo Festiva

Holland, D., Lachicotte, W., Skinner, D., & Cain, C. (1998). Agency and identity in cultural worlds.

Konopasky, A. W., & Sheridan, K. M. (2016). Towards a diagnostic toolkit for the language of agency. Mind, Culture, and Activity, 23(2), 108-123

Lasky, S. (2005). A sociocultural approach to understanding teacher identity, agency and professional vulnerability in a context of secondary school reform. Teaching and teacher education, 21(8), 899-916.

Martin, L. (2015). The promise of the maker movement for education. Journal of Pre-College Engineering Education Research (J-PEER), 5(1), 4.

Sheridan, K., Halverson, E. R., Litts, B., Brahms, L., Jacobs-Priebe, L., & Owens, T. (2014). Learning in the making: A comparative case study of three makerspaces. Harvard Educational Review, 84(4), 505-531.

Van Lier, L. (2008). Agency in the classroom. Sociocultural theory and the teaching of second languages.163-186.

Vossoughi, S., Hooper, P. K., & Escudé, M. (2016). Making through the lens of culture and power: Toward transformative visions for educational equity. Harvard Educational Review, 86(2), 206-232

Design-Activity-Sequence: A Case Study and Polyphonic Analysis of Learning in a Digital Design Thinking Workshop

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Abstract: In this case study, we report on the outcomes of a one-day workshop on design thinking attended by participants from the Computer-Supported Collaborative Learning conference in Philadelphia in 2017. We highlight the interactions between the workshop design, structured as a design thinking process around the design of a digital environment for design thinking, and the diverse backgrounds and interests of its participants. Data from in-workshop reflections and post-workshop interviews were analyzed using a novel set of analytical approaches, a combination the facilitators made by possible by welcoming participants as co-researchers.

Keywords: Design thinking, polyphony, design learning

Designing and running the workshop

We present here some results of the experience had by facilitators and participants in a design thinking workshop held before the Computer-Supported Collaborative Learning conference in Philadelphia in 2017. In structuring the workshop, the facilitators drew on some of the multiple cognitive and procedural strategies that are interwoven in designerly ways of knowing. Each stage of the design thinking process - framing, ideation, prototyping, deploying, and iteration - was structured as a step in the workshop schedule, and each stage was closed by the participants reflecting on their experiences. After the workshop, the facilitators interviewed each participant using a semi-structured interview protocol, and subsequently invited them to join as research partners in the project described here.

Methodological approaches

The collaborative analysis of data from the one-day workshop combined insights from the analytical methods used by the different team members: design case, case study, thematic analysis, and polyphony.

Design case (Howard & Myers, 2011): The ideation stage of the design thinking process takes participants through divergent thinking (idea generation) and convergent thinking (pattern recognition, synthesis, and integration of ideas). Solutions are individually generated and then categorized, synthesized, and integrated by the group, leading to the selection of a target solution. For this workshop, the ill-structured problem of the design case was translating this process from a physical to a digital setting. The design move to use all stages of the design thinking process did create some difficulties, including blurring where the boundary of the problem was set. Similarly, the design decision of ensuring that the participants experienced the affordances of physical tools was made at the expense of using the affordances of digital media that would be a necessary part of a virtual environment solution.

Case study methodology (Merriam & Tisdell, 2016): The experiences of workshop participants can be taken as one case, and, at the next level, the phases of the design thinking process present multiple cases.

Thematic analysis: Transcripts of the interviews and the reflections were entered into the Dedoose qualitative data analysis software (www.dedoose.com/). Three members of the research team each coded all the written data. The codebook and the work of other coders was available to the whole team.

Polyphony analysis: Built on natural language processing, an analysis of the polyphony of discourse was used on the interviews only. Collaborating groups sometimes display a kind of spontaneous choreography (Trausan-Matu, 2013) in their interactions, including convergent and divergent inter-animation patterns (Trausan-Matu, Stahl, & Sarmiento, 2007). The interactions of the members of the group consist in individual and group knowledge construction cycles (Stahl, 2006) and this socially built discourse can be considered as containing several parallel threads (voices) in a discourse, where a voice is a group of one to three words that appear semantically connected in the text. These voices demonstrate divergent/convergent inter-animations in moving towards a shared goal (Trausan-Matu, Stahl, & Sarmiento, 2007).

Findings

Each of the methodologies highlight different aspects of the participants' responses to the workshop and their findings illustrate different implications for replicating or adapting the workshop on digital design thinking for other groups.

Thematic coding analysis showed the ties of the design thinking process to group dynamics, identity, and distributed cognition. The cycles of divergent and convergent thinking were linked with the affordances of a physical environment (silent individual and group processes) and with productive struggle. Each interviewee recognized the diversity of the group's backgrounds, along with the challenges and the benefits of group diversity in enhancing the design thinking process and developing better solutions. The analysis confirms the caution that Boon, Chappin, & Perenboom (2014, p. 59) draw from the literature that team members should be different, but not too different.

Polyphonic analysis highlighted divergent and convergent cycles between the "voices". The most prominent voices, labelled "think, design, thing" and "think, idea, design", were woven throughout the interviews, along with voices on participation ("talk, communicate, express"; "participate, introduce, enter").

Participant reflections and interviews also indicated the importance of the *tools used* in the design thinking process. Tools are important supports first for knowledge discovery and then for communicating and persuading others in the design team. Focusing in on the imagined learning environment, both analyses highlighted in different ways the participants' conceptions of a multi-part, configurable space, and their assessments of the costs and benefits of physical and virtual environments, including the quality of communication in each environment, and the emotional liberty that an online design thinking space might support.

Implications

Knowledge production, according to Barry, Born, & Weszkalnys (2008), happens through the dialogue of ideas as much as through their synthesis, and our analysis of this design thinking workshop bear this out. Diversity can provoke dialogue, and we therefore encourage the organizers of future workshops to seek out the opportunities that diversity provides; to recruit participants from different backgrounds, languages, disciplines and motivations and connect them through a design thinking process which uses digital tools to build a digital design thinking environment. Diversity can also power the balance between convergence and divergence in a project design (Boon et al., 2014).Despite the special analytical challenges that collaborative design presents (Kapur, Voiklis, & Kinzer, 2011; Strijbos & Fischer, 2007), the divergence-convergence cycle emerged in this workshop as an anchor for a group whose members were new to each other and new to design thinking. Representing and analyzing the divergence-convergence cycle over time was enhanced by combining qualitative and design perspectives with newer analytical models, methods, and tools such as computer systems based on polyphony (Trausan-Matu, Dascalu, & Rebedea, 2014).

References

Barry, A., Born, G., & Weszkalnys, G. (2008). Logics of interdisciplinarity. *Economy and Society*, *37*(1), 20–49.

Boon, W. P. C., Chappin, M. M. H., & Perenboom, J. (2014). Balancing divergence and convergence in transdisciplinary research teams. *Environmental Science & Policy*, *40*, 57–68. Retrieved from http://www.sciencedirect.com/science/article/pii/S1462901114000690

Howard, C. D., & Myers, R. (2011). Writing and rewriting the instructional design case: A view from two sides. *International Journal of Designs for Learning*, *2*(1), 40–55.

Kapur, M., Voiklis, J., & Kinzer, C. K. (2011). A complexity-grounded model for the emergence of convergence in CSCL groups. In S. Puntambekar, G. Erkens, & C. E. Hmelo-Silver (Eds.), *Analysing interactions in CSCL: methods, approaches and issues* (pp. 3–23).

Merriam, S. B., & Tisdell, E. J. (2016). *Qualitative research: a guide to design and implementation* (4th ed.). San Francisco, CA: Jossey-Bass.

Stahl, G. (2006). *Group cognition: computer support for buildings collaborative knowledge*. Cambridge, Mass.: MIT Press.

Strijbos, J.-W., & Fischer, F. (2007). Methodological challenges for collaborative learning research. *Learning and Instruction*, *17*(4), 389–393. https://doi.org/10.1016/j.learninstruc.2007.03.004

Trausan-Matu, S. (2013). Collaborative and differential utterances, pivotal moments, and polyphony. In D. D. Suthers, K. Lund, C. P. Rose, C. Teplovs, & N. Law (Eds.), *Productive Multivocality in the Analysis of Group Interactions* (pp. 123–139). Bosston, MA: Springer US.

Trausan-Matu, S., Dascalu, M., & Rebedea, T. (2014). PolyCAFe-automatic support for the polyphonic analysis of CSCL chats. *International Journal of Computer-Supported Collaborative Learning*, *9*(2), 127–156.

Trausan-Matu, S., Stahl, G., & Sarmiento, J. (2007). Supporting polyphonic collaborative learning. *E-Service Journal, Indiana University Press*, 58–74.

LGBT+ in STEM: The Transgender Experience

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Abstract: It has been widely reported that youth are more accepting of LGBT+ identities, and an increasing number of colleges and universities allow students to use gender-neutral pronouns. Yet, *research* on how inclusive STEM educational cultures are of sexual identity and gender fluidity is *meager*. In this poster, we present interview results on the lived experiences of transgender undergraduates in physics, mathematics, and computer science at institutions that have achieved inclusion by gender and race.

According to a Human Rights Campaign survey, 75 percent of LGBT+ youth report that most of their peers have no problem with their LGBT+ identity, yet 4 in 10 say the community in which they live is not accepting (HRC, 2012). Yet research in LGBT+ experiences across Science, Technology, Engineering, and Mathematics (STEM) disciplines describes of the *lack* of belonging (The American Physical Society (APS), 2016; Stout and Wright, 2016); which also characterizes the experience of women of color in these fields (Johnson et al, 2017; Leslie et al, 2015; Moss-Racusin et al, 2012; Ong, Smith, and Ko, 2017). In this poster, we explore the experiences undergraduate trans students have in physics, mathematics and computer science, and whether institutions that are more inclusive for women of color in these disciplines are also inclusive for trans students.

Theoretical framework

To frame our research, we apply Patricia Hill Collins' Domains of Power, comprising the interpersonal, the cultural, the disciplinary and the cultural (Collins, 2009). In comparison to one co-author's previous writing on science identity for women of color in STEM (Carlone and Johnson, 2007; Johnson et al, 2011), Collins' model frames these experiences as setting features rather than internal individual experiences (Johnson, in preparation).

In the **interpersonal domain**, where power is expressed between individuals, transgender physicists feel exclusion and isolation, as well as pressures to perform heteronormativity (APS, 2016). This aligns with findings for women of color whose interactions with peers and professors were characterized, "regardless of their actual abilities as measured by exam performances, grade point averages, and research mentor evaluations, … perceived nearly consistent messages--with some rare exceptions--that because they lack the standard appearance of a scientist, they also lack the intellectual competence associated with such an appearance" (Ong, 2005). This struggle with whether their bodies fit in STEM, and resultant performative impacts, is common to the experiences of women of color and trans students.

In the **cultural domain**, "where a group's values are conveyed (or contested)," power determines what it means to be a good scientist. Such beliefs lead to differential outcomes for job applicants who vary only by their identities (Moss-Racusin et al, 2012), with decisions interpreted as individual choices rather than cultural influences. Such beliefs are reified into rules and policy in the **disciplinary domain**, or when power is distributed via large social structures, like state and federal law, or the unintended consequences of clashing practices in the **structural domain**, we see "uneven", "lacking", or "discriminatory" policies, including those involving health care and bathroom access (Ackerman et al, 2012).

When analysed from this framework, the failure of these marginalized students to thrive rests not on lack of interest or ability, but on the need to face extra obstacles above and beyond the challenges all students face due to the difficulties of the science itself.

Data and methods

The research featured in this poster is part of a project entitled ***Centering Women of Color in STEM: Identifying and Scaling Up What Helps Women of Color Thrive*** (CWCS), which explores physics, mathematics and computer science educational settings to find the features that allow all kinds of students to thrive and learn, despite how profoundly non-representative these disciplines are for most women of color. Our interdisciplinary team is made up of a physicist, an anthropologist, 2 physics undergraduates, and a chemistry undergraduate.

CWCS applies the broad definition of gender articulated by the Athena SWAN criteria, which includes a consideration of transgender identity. To identify what the departments under study do to create environments

in which women of color thrive, we are conducting case studies that comprise student and staff interviews, observations of classrooms, and ethnographic field notes (e.g., community spaces, meetings, conferences, collaborative spaces). In additional to making a specific appeal to trans students in each department we are studying, we are working to build relationships with the campus organizations that support trans students. Our goal is to create as full a picture of the trans experience in context as possible.

Interviews are semi-structured, open-ended, hourlong, audio-recorded and transcribed. Participants were asked a broad set of questions about their academic background and interests, a challenging time and how they overcame it, factors that promote their success, advice for institutions, and advice for people like themselves. CWCS uses narrative analysis for coding and analysis, combining systematic methods and multiple researchers, to triangulate our understandings of the lived experiences of transgender students.

Findings

At ICLS 2018, we will present findings from our interviews with transgender undergraduates at three very different institutions (a small liberal arts college, a large research university, and an enormous open-enrollment university), whose commonality is that they have created environments in which women of color thrive in physics, mathematics, and computer science.

Our findings will be presented in the actual voices of our interview participants, with the expectations that poster visitors will have the opportunity to consider how they can increase inclusion for transgender STEM students at their home institutions. These conversations will identify ways in which physics, mathematics, and computer science settings can be extended to a wider diversity of learners.

References

Ackerman, N, Atherton, T, Deconinck, W, Falk, M, Garmon, S, Henry, E, and Long, E. (2012). *Gender and Sexual Diversity Issues in Physics: The Audience Speaks*. arXiv: 1206.4112.

APS. (2016). *LGBT Climate in Physics: Building an Inclusive Community*. College Park: American Physical Society.

Carlone, H. and Johnson, A. (2007). Understanding the science experiences of successful women of color: Science identity as an analytic lens. *Journal of Research in Science Teaching, 44*(8), 1187-1218.

Collins, P H. (2009). *Another Kind of Public Education: Race, Schools, the Media, and Democratic Possibilities*: Beacon Press.

Human Rights Campaign. (2012). *Growing Up LGBT in America: HRC Youth Survey Report: Key Findings*. Washington, DC: Human Rights Campaign.

Johnson, A. C. (In preparation).

Johnson, A, Ong, M, Ko, L, Smith, J, and Hodari, A. (2017). Common challenges faced by women of color in physics, and actions faculty can take to minimize those challenges. *The Physics Teacher*, 55, 356-360.

Johnson, A, Brown, J, Carlone, H, and Cuevas, A. (2011). Authoring identity amidst the treacherous terrain of science: A multiracial feminist examination of the journeys of three women of color in science. *Journal of Research in Science Teaching, 48*(4), 339-366.

Leslie, S-J, Cimpian, A, Meyer, M, and Freeland, E. (2015). Expectations of brilliance underlie gender distributions across academic disciplines. *Science*, 347(6219), 262-265.

Moss-Racusin, CA, Dovidio, JF, Brescoll, VL, Graham, MJ, and Handelsman, J. (2012). Science faculty's subtle gender biases favor male students. *Proceedings of the National Academy of Sciences*, 109(41), 16474-16479.

Ong, M. (2005). Body projects of young women of color in physics: Intersections of gender, race, and science. *Social problems, 52*(4), 593-617.

Ong, M, Smith, J, and Ko, L. (2017). Counterspaces for women of color in STEM higher education: Marginal and central spaces for persistence and success. *Journal of Research in Science Teaching*, 54, 1-40.

Stout, J. G., & Wright, H. M. (2016, May/June). Lesbian, Gay, Bisexual, Transgender, and Queer Students' Sense of Belonging in Computing. *Computing in Science & Engineering*, pp. 24-30.

Acknowledgements

Turning to Experience Negative Signs as Operations

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Abstract: Conceiving of negative sign notation as an operation is crucial for algebra. Thus, this study compared student learning with two integer models to explore how physical motions influenced conceptions of this notation. Preliminary results with 70 fifth-grade students suggested that physically turning the opposite direction better represented this notation as an opposite operation than moving objects with a chip model (p=0.001). These findings contribute to mounting evidence that how humans physically move influences learning.

Introduction

Internationally, it is well known that middle and high school students find operations with negative numbers difficult. Although research has studied representations of number, such as number lines (e.g., Siegler, 2016), such representations are just one part of a model. I define models as the patterns of physical motions and words used with particular representations that are intended to foster learning. Multiple integer models, such as chip and number line models are used in classrooms (van de Walle, et al., 2010). Comparisons of how specific models support or interfere with learning aspects of integer operations, however, are just beginning (Nurnberger-Haag, In Press; Tsang, Blair, Bofferding, & Schwartz, 2015). A crucial aspect of integer understanding that is difficult for students is to think of the symbol "-" as an operation that means "take the opposite of" (Ryan & Williams, 2007; Vlassis, 2008). Although this may seem a narrow research focus, consider that most equations in algebra and calculus require students to coordinate a negative sign as an operation (e.g., –(-2x – 4) or –X, "the opposite of X") as well as part of the structure of a number (e.g., -5; Vlassis, 2008).

Drawing on embodied cognition that how humans move influences how they think (e.g., Antle, 2011; Barsalou, 2008), this study tested a prediction that different models would differentially influence understanding of integer notation. Students who use the walk-it-off number line model physically "turn the opposite direction" for subtraction and negative signs (Nurnberger-Haag, 2007). For example, students stand next to the point -5 on a large number line, turn the opposite direction twice (once for the subtraction sign and once for the negative sign of -2) and walk two, resulting in an answer of -3. Students who use a chip model take away objects to subtract (e.g., students act out -5 - -2 with five white chips then remove two, resulting in -3). Thus, this report addressed the question: Do students who use a "turn the opposite" meaning of the "-" symbol learned with the walk-it-off model interpret a negative sign as an operation better than students who used a chip model.

Method

In a larger study eight classes at a fifth and a sixth-grade site were randomly assigned to learn with either a chip or number line model (Nurnberger-Haag, In Press). The chip model used black and white chips to represent positive and negative numbers respectively. The walk-it-off number line model emphasized the "-" symbol as meaning "turn the opposite direction" (unlike traditional number line models that treat subtraction as backward motion; Nurnberger-Haag, 2007). The researcher instructed all classes in eight parallel lessons differing only due to model. During instruction students only learned to add, subtract, multiply and divide negative numbers and represent opposite numbers (not operations) using the assigned model. To eliminate the possibility that students who memorized notational patterns would be indistinguishable from those who understood the meaning of the negative sign as an operator, opposite operations was assessed as a transfer construct (i.e., students were not taught these types of problems during instruction).

After five phases of piloting with 388 students, a written open-response scenario was finalized to elicit whether students could conceive of the "-" notation as an operation. An abridged description of the item is that "(negative number)" was presented in blue font and "–(negative number)" in green to elicit students to describe how the quantities differed. Post and delayed posttests of the three fifth-grade classes are reported (n=70 students), because no fifth-graders correctly answered at pretest. These responses were coded in terms of whether students offered a non-negative solution, and then integer model groups were compared with a chi-square analysis. Using embodied cognition, qualitative analyses are being conducted to provide insights about the ways and reasons students' physical motions on a number line or ways they moved objects related to their conception of the symbol "-".

Results

Given the difficulty of the construct, it was expected that few students would successfully answer this transfer item. Overall 7% transferred at posttest and 11% did so on the delayed posttest. Although 1.7 times as many students learned with a chip (n=44) than number line model (n=26), just 2% of students who used chips provided a non-negative solution whereas 15% of students who used the walk-it-off model did so. The chip student who was successful at posttest, regressed at delayed post, so 0% (0/40) of students who had used chips answered correctly at delayed posttest. In contrast, 27% (7/26) of students who learned with the walk-it-off model explained that the solution would be non-negative. A chi-square analysis using Fisher's exact test confirmed this difference was statistically significant (p=0.001) at delayed posttest. At posttest, the significance was close to threshold, but did not meet it (p=0.06). On the poster, student drawings and explanations will show how walk-it-off students used physical motions, arrows, and words like "turn opposite" to reason through this task that was beyond their instructional experience in contrast to students who moved chips and did not express these conceptions of negative signs.

Conclusions

By delayed posttest more than one-fourth of students who learned with the walk-it-off model could conceive of –(negative number) as a positive number, whereas no students who used a chip model did. Although the eighth-grade students in Vlassis' (2008) study had difficulty conceiving of the "-" symbol as an operation and even sometimes confused it with a subtraction sign, a substantial number (for a transfer item) of the fifth-grade students in this study were able to apply their experiences of adding, subtracting, multiplying, and dividing negative numbers to also conceive of the operation "opposite of" without explicit instruction on those problem types. This preliminary analysis suggests that physically turning the opposite direction on a number line in combination with related language "turn the opposite direction" better supports students to extend the meaning of the "-" symbol to an operation than the symbol meanings students act out with a chip model. This finding is consistent with other studies of cognition and learning which found that how humans move to represent ideas matters (Antle, 2011; Nurnberger-Haag, In Press), but extends this to how learners apply their physically constructed understanding to make sense of new ideas. More embodied cognition research is needed to study how each model supports or thwarts the complex meanings students need to develop about integers. Next steps include investigating students who learned with multiple integer models, disentangling effects of the representation from physical motions, and uncovering relationships between the effects of physical motions and the language used to describe them. These future studies could contribute to understanding how human movement relates to cognition and learning.

References

Antle, A. N. (2011). Balancing justice: Comparing whole body and controller-based interaction for an abstract domain. *International Journal of Arts and Technology*, 6(4), 388-409.

Barsalou, L. W. (2008). Grounded cognition. *Annual Review of Psychology*, 59, 617-645.

Nurnberger-Haag, J. (In Press). Take it away or walk the other way? Finding positive solutions for integer subtraction. L. Bofferding and N. Wessman-Enzinger, Eds., *Exploring the Integer Addition and Subtraction Landscape: Perspectives on Integer Thinking*. Cham, Switzerland: Springer.

Nurnberger-Haag, J. (2007). Integers made easy: Just walk it off! *Mathematics Teaching in the Middle School*, 13(2), 118-121.

Ryan, J., & Williams, J. (2007). *Children's Mathematics 4-15: Learning from Errors and Misconceptions.* Berkshire, England: Open University Press.

Siegler, R.S. (2016). Magnitude knowledge: The common core of numerical development. *Developmental Science,* 19(3), 341-361.

Tsang, J.M., Blair, K.P., Bofferding, L., & Schwartz, D.L. (2015). Learning to "see" less than nothing: Putting perceptual skills to work for learning numerical structure. *Cognition and Instruction*, 33, 154-197.

Van de Walle, J., Karp, K., & Bay-Williams, J. (2010). *Elementary and Middle School Mathematics: Teaching Developmentally* (7th ed.). New York: Allyn and Bacon.

Vlassis, J. (2008). The role of mathematical symbols in the development of number conceptualization: The case of the minus sign. *Philosophical Psychology*, 21(4), 555-570.

Acknowledgments

Authentic to Whom and What? The Role of Authenticity in Project-Based Learning in English Language Arts

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Abstract: Presents a framework for authenticity that informed co-design of a project-based 9th-grade English Language Arts course. A qualitative study examined ways teachers and students experienced authenticity. Three types of authenticity contributed to engagement and learning: being (1) authentic to self through opportunities for choice and agency; (2) authentic to others by addressing audiences through public performances and products; (3) providing opportunities to use authentic, genre-specific tools. Challenges to implementation—assessment and disciplinary norms— are discussed.

Keywords: Learning Environments, Literacy, English Language Arts, Project-Based Learning

Major issues

Project based learning (PBL) has a long history in US schooling (Dewey, 1938), but much of this work in recent years takes place in STEM contexts, developing practices around projects and inquiry, and connecting learning to real world challenges. Some school-based PBL takes place in history classrooms, but less has been studied about PBL in the English language arts classroom (ELA; Condliffe, 2016; a notable exception is Beach and Myers, 2001). Project based learning is intended to provide opportunities for teachers and their students to create learning spaces that are authentic and relevant. This study examines how 9th grade language arts teachers and students, during a design-based research project, encountered and experienced the issue of authenticity in PBL. Our research questions are: (1) What aspects of authenticity in ELA PBL do teachers take up and see as most meaningful? (2) How does authenticity relate to student perceptions and engagement with ELA PBL?

Theoretical approach

Our overall perspective on learning and human action draws on notions of mediated action and communities of practice. Our perspective on project-based learning is centered on the notion of "authentic making." As in most project-based approaches (e.g., Baines & DeBarger, 2017), we see a question or challenge driving and providing purpose and coherence to multi-week project work, where activities lead toward a culminating production, in the form of a concrete, complex artifact or performance. Three design criteria unpack the notion of authenticity applied to ELA PBL: *"Authentic to self"*, *"Authentic to others"*, and *"Authentic tools"*.

Authenticity criteria are based on prior work (Polman, 2012), where we noted three kinds of authenticity that learning environment designers across disciplinary contexts often attempt to achieve: encouraging "authentic personal agency", having "authentic community connections", and using "externally authentic cultural tools".

Context and methods

Eleven 9th grade teachers from five schools in two school districts in a United States Mountain West state participated over a two-year period (2015-16 and 2016-17) with a research and development team (including the authors) consisting of six university-based faculty members (in Schools of Education), one specialist on digital media and learning in ELA based at a community library, and six university-based doctoral students (in Schools of Education). The majority of the research and development team were former ELA teachers. Using a co-design model (Penuel, Roschelle, & Shechtman, 2007), the team of researchers and teachers developed and refined a year-long 9th grade English Language Arts course. The course is called "Compose Our World," and consists of four core projects that aim to make ELA emotionally and intellectually engaging for *all* students as they "compose" themselves, connect to wider communities, and become active world citizens. Additionally, all course materials are designed for local adaptation, so teachers can create experiences that are meaningful to their particular students, that adhere to specific standards, and that are engaging to teach. Teachers taught between one and four projects each year for two years. Teachers participated in a four day initial design institute, six two-hour sessions, and received individual support throughout the year.

Data sources on *teacher perceptions, student perceptions,* and *classroom enactments* including field notes, surveys, interviews, and artifacts such as teacher reflections, student work products, and emails were analyzed. Observations occurred 2-4 times monthly during enactment.

We used a design-based research model in which data analysis is conducted while teachers implement course materials, contributing to building local theories and informing subsequent instruction. We conducted ongoing and retrospective analysis, using qualitative research methods to code data, identify themes, and conduct procedures for trustworthiness. We combined etic and emic approaches to identify codes: starting with etic codes for the three broad senses of authenticity described above, and searching for emergent, emic senses where authenticity became salient to students and teachers.

Findings

Across classrooms, teachers and students pointed to authenticity as valuable. Teachers frequently referenced authenticity as valuable to student learning. In interviews and surveys, students consistently expressed feeling increased excitement and connection when projects offered choice and opportunities for real audiences.

Teachers enacted activities that students found to be authentic to self by providing opportunities for: choice, self-reflection, and connections to students' lives. Data analysis revealed that both teachers and students saw choice as key for developing feelings of ownership and agency during project enactment. Across the four projects, teachers provided students with opportunities to choose topics, groups, ways to structure class time, and means of self-expression. In interviews, students also expressed feeling most connected to projects when they felt that they had choice. A tension that arose was differences in interpretation of choice. While teachers and researchers assumed that students would recognize projects as authentic to self when they had freedom to choose topics and means of expression, students across classrooms voiced stronger feelings of ownership over and agency within projects when they were given the opportunity to determine how they *spent their time* to complete project goals and when they perceived that each step in learning and composing was not predetermined by the teacher.

Authenticity to others was emphasized by each of the 11 teachers. Analysis illustrated a significant shift from year one to year two in enactment of the projects and the ways students were encouraged to develop products for authentic audiences. Additionally, researchers recognized that while teacher interviews and survey responses emphasized authenticity to others as directly tied to audience for students' final product, students demonstrated higher levels of engagement in project goals from the moment they began considering their audience.

In each of the course project designs, students take on roles (e.g., investigative journalist or museum exhibit developer) that provide them with opportunities to create products that mirror those found in the world outside of the classroom. To create these products, students adopt the tools of the professionals they are emulating, while teachers help to create connections between these authentic tools and the English language arts skills taught in 9th grade. The themes that emerged from our data in this area were (1) the importance of capitalizing on student familiarity with literate practices using genre-specific tools, and also addressing teacher discomfort with unfamiliar tools, and (2) teachers' tensions around navigating the use of authentic tools while attending to the need to document learning through assessment and grading.

References

Baines, A., DeBarger, A. H., De Vivo, K., Warner, N., Brinkman, J. & Santos, S. (2017). *What is rigorous project-based learning?* San Rafael, CA: George Lucas Educational Foundation.

Beach, R., & Myers, J. (2001). *Inquiry-based English instruction: Engaging students in life and literature*. New York: Teachers College Press.

Condliffe, B., Visher, M. G., Bangser, M. R., Drohojowska, S., & Saco, L. (2016). *Project-based learning: A literature review*. New York, NY: MDRC.

Dewey, J. (1938/1950). *Experience and education*. New York: Macmillan.

Penuel, W. R., Roschelle, J., & Shechtman, N. (2007). Designing formative assessment with teachers: An analysis of the co-design process. *Research & Practice in Technology Enhanced Learning, 2*(1), 51-74.

Polman, J. L. (2012). Trajectories of participation and identification in learning communities involving disciplinary practices. In D. Yun Dai (Ed.), *Design research on learning and thinking in educational settings: Enhancing intellectual growth and functioning* (pp. 225–242). New York: Routledge.

Wenger, E. (1998). *Communities of practice: Learning, meaning, and identity*. New York: Cambridge Univ Press.

Acknowledgments

When Is It Safe Enough? Considering Diversity and Equity When Brokering Pre-Professional Opportunities to Youth of Color

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Abstract: This study conceptualizes "brokering pre-professional learning opportunities" as a practice that goes beyond facilitating access across settings to include concerns about when, exactly, an opportunity is "safe enough" as a fundamental question when connecting youth to opportunity. Utilizing a design-based research approach, we report results of an organizational 'vetting' routine used to assess companies being considered as work-placement sites for youth of color. Our findings confirm that characteristics of staff diversity and equity orientation of work-placement organizations can support or hinder positive learning outcomes. However, we also found that both strengths and limitations in terms of diversity and equity, in concert with other supportive factors, can be productive resources within the context of future goal setting for youth of color. We close with implications for researchers and designers interested in promoting equity-oriented cross-setting learning.

As learning scientists have theorized learning as a cross-setting phenomenon (Banks et al., 2007), the question of how to equitably support productive connections across settings has become a focal point for intervention design (Acholonu, Pinkard & Martin, 2015). One practice, that of brokering learning opportunities from one setting to another, has emerged as a key form of support for cross-setting learning pathways that sit within a larger framework of Connected Learning (Ching et al., 2016; Ito et al., 2013). However, the practice of brokering can easily be misunderstood as one that rests solely on an assumption that *access to new learning opportunities* is the only challenge to be addressed in order to support equitable learning pathways (Vossoughi, 2017). However, for non-dominant youth interested in various disciplinary pathways, opportunities brokered to them may themselves not be considered by youth or educators to be places that are productive, comfortable or 'safe.' Often, this can be connected to lack of representation of non-dominant groups in those industries and limits in terms of companies' orientations to equity and pro-social concerns within their organizational activities and business models.

This study is based in a research-practice partnership focused on developing brokering routines across learning settings within Hive NYC, a network of informal education organizations focused on digital learning. We report results from a design partnership with one organization, Scope of Work (SOW), which addressed issues of access to and transformation of creative industries in terms of under-represented youth. SOW's approach to brokering focused on not only considering issues of access, but also on assessing various characteristics related to diversity and equity of the settings they were 'brokering into' – the workplace sites they planned to match with their youth. Our cross-organization team co-designed and tested an organizational 'vetting' routine that could be used to assess the potential of a workplace to provide a positive early employment experience for youth of color. Because of SOW's organizational focus, all workplaces in the study were associated with creative sectors.

This analysis considers two factors the vetting routine focused on: *How were organizational characteristics of **staff diversity** and **equity orientation** consequential to positive early workplace experiences of non-dominant youth of color?* The pilot summer program, framed as a fellowship, involved five youth of color aged 16-21. Each was placed at a company in the creative sector including a high-end fashion brand, a hip-hop and electronic music record label, and three design and branding studios. This analysis utilizes data from three of the youth, including semi-structured interviews with the youth, with supervising employees at each of the work placement organizations as with SOW staff and, finally, observations of weekly activities SOW staff facilitated with the youth participants where youth discussed their week's work experiences.

Three findings emerged with regards to the role of staff diversity and equity orientations in organizations. Two were more straightforward and tracked with SOW's design conjectures that were indexed in the vetting tool about the consequentiality of the focal factors – that relative strengths and limitations in terms of diversity and equity orientations could contribute to positive and negative youth workplace experiences, respectively.

In the case of Mateo, an 18-year-old Dominican American, diverse leadership at his placement contributed to a positive orientation towards his work placement, to positive relationship development with staff, and to shifted conceptions related to diversity and business leadership. In talking about Rob, the company's CEO, he shared: "When I first started learning about business, I had this image of a CEO: In a corporate building, with a suit on, and you know, like bougie [short for 'bourgeois'], like 'don't talk to me you peasant!' [jokingly]. So then when I talk to [Rob]… he listens to rap music, I listen to rap music, he plays basketball, I play basketball. It's cool to see that you don't have to change, and be some type of robot to be successful."

Likewise, the experience of Sean, a 20-year-old African-American, provided additional confirmation of the importance of staff diversity. He shared that, for him, "there sure was not a culture fit" with staff at the record label he was placed at. He saw a lack of shared class background as hindering the formation of social bonds with staff through common interactions like 'water cooler' conversations; "If you can't relate, how are you going to jump into the conversation?".

The final case was the most notable, and unexpected, in terms of the ways that diversity and equity orientations of partner organizations played into youth's socio-political professional goal-setting. Eve, a 21-year-old identified as female, African-American and Puerto-Rican-American, was one of two women of color within an organization led by three white men with the rest of the staff made up of white cis-female interns. Her case highlighted distinct ways that *both* strengths around *as well as* weaknesses related to staff diversity in her workplace setting were utilized as a resource within her process of identifying what kind professional setting she wanted to be in in the future with regards to workplace diversity. Additionally, a perceived lack of equity orientation in the business model of the company Eve was placed in — a brand strategy firm called Signal that served corporate clients to promote their businesses —was leveraged as she affirmed and specified her plans around her professional future, plans that involved more explicit orientations to addressing issues of equity and celebration of black identity. She shared with us, in terms of these corporate clients, that "my voice and the work that I want to do is not for them. […] I want to be a part of something that's celebrating community... what it means to really be a human being, and a black human being, in America."

The final case of Eve led us to conclude that *both strengths and limitations of learning settings in terms of diversity and equity orientations, in concert with the support to understand such experiences from a critical and socio-political lens, can be productive resources within the context of future goal setting for youth of color.*

Within efforts to promote cross-setting learning for non-dominant youth, this study highlights the importance of broadening approaches to brokering from a purely access-orientation to include an equity-orientation concerned with the nature of the opportunities being organized for youth. In particular, in confirming conjectures that diversity and equity orientations of workplace environments can consequentially impact outcomes, it highlights the need for care and consideration when considering whether an opportunity is 'safe enough.' At the same time, findings show that limitations, along with strengths, can be productively utilized within youths' socio-political professional goal setting. The finding confirms existing research on the importance of sense-making supports set outside of work placement sites (Bronkhorst & Akkermen, 2016), of supporting youth to critically 'read' the dynamics at play within a work environment (Diemer & Blustein, 2006) and of extending critical youth development approaches into workplace learning settings (Ginwright & Cammarota, 2002). Given that reality, the answer to the question of "when is it safe enough?" likely depends, in some part, on what kinds of supports non-dominant youth have to engage with a worksite through critical and socio-political lenses.

References

Acholonu, U., Pinkard, N., & Martin, C. K. (June, 2015). *Locating opportunity gaps by mapping the computer science landscape in Chicago.* Presented at Digital Media and Learning Conference, Los Angeles, CA.

Bronkhorst, L.H., Akkerman, S.F. (2016). At the boundary of school: Continuity and discontinuity in learning across contexts, *Educational Research Review*, doi: 10.1016/ j.edurev.2016.04.001.

Ching, D., Santo, R., Hoadley, C., & Peppler, K. (2016). Not just a blip in someone's life: integrating brokering practices into out-of-school programming as a means of supporting youth futures. *On the Horizon*, *24(3).* pp. 296-312.

Diemer, M. A., & Blustein, D. L. (2006). Critical consciousness and career development among urban youth. *Journal of vocational behavior*, *68*(2), 220-232.

Ginwright, S., & Cammarota, J. (2002). New terrain in youth development: The promise of a social justice approach. *Social justice*, 29(4 (90), 82-95.

Ito, M., Gutiérrez, K., Livingstone, S., Penuel, B., Rhodes, J., Salen, K., ... & Watkins, S. C. (2013). *Connected learning: An agenda for research and design*. Digital Media and Learning Research Hub.

Vossoughi, S. (2017). Access and equity in out-of-school learning. In K. Peppler (Ed.), *Encyclopedia of Out-of-School Learning*. Thousand Oaks, CA: Sage Publications.

Projected Worlds:
How Informal Digital Learning Organizations Conceptualize Organizing Youth Futures

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Abstract: Understanding learning as an inherently value-laden and socio-political process is increasingly a concern of the Learning Sciences, and this focus forces us to confront fundamental questions relating to the purposes of learning and the multiplicity of possible and intended futures for learners implied by their learning environments. In this study, we utilize the framework of 'learning as the organization of social futures' – one that simultaneously foregrounds values and their expressions within learning activity – to understand orientations of informal digital learning organizations. The study focuses on three organizations, all part of a larger research-practice partnership. Utilizing staff interviews and organizational documentation, our findings show that the kinds of social futures valued by informal digital learning organizations varied in (1) how *specified* versus *open-ended* these futures were, (2) their focus on *access to existing social futures* vs *creation of alternative social realities* in order to allow new possible futures, (3) their relative focus on *individual* versus *collective* futures, with each of these dimensions having implications in terms of ways that pedagogies are designed within these organizations.

As Learning Scientists increasingly aim to conceptualize learning more explicitly through socio-political and historical frameworks (McWilliams & Penuel, 2016; PLWC, 2017), we must confront fundamental questions related to the purposes of learning, the underlying values that drive the design of learning environments, and the kinds of futures those environments imply for learners. In doing so, an understanding of learning as "the organizing of access to valued social futures" (O'Connor & Allen, 2010) helps us to simultaneously foreground both the value-based commitments of learning environments - what sorts of worlds they are implying, their *telos* - and the structural mechanisms and practices they employ to make those worlds possible for learners.

The following study uses this framework of organizing social futures to explore another area that has been a historical focus of the Learning Sciences - informal learning with technology, specifically within the context of informal out of school organizations (Santo, 2017a; Kafai et al., 2009). In doing so, we attempt to make more transparent the ways that such learning settings conceptualize their role and how technology plays a part in it. Given the relevance of informal learning environments within larger STEM and digital learning ecosystems (Acholonu, Pinkard & Martin, 2015; Ching et al., 2016), it is valuable to consider the roles they might play in supporting learning pathways across settings. In doing so, the study bridges two current areas of scholarship: studies exploring the place of ideological commitments and underlying value systems of learning environments, and studies that focus on cross-setting learning pathways and ecosystems. Our objective is to show how designed learning pathways are themselves always imbued with, and should intentionally contend with, commitments about which social futures are valued.

We focus on three informal learning organizations, all part of a larger research-practice partnership co-facilitated by the authors. All are community-based, located across urban centers in the United States and have self-identified as being engaged with digital learning in the context of their youth programs. All serve minoritized, low income communities and have explicit, though nuanced and distinct, commitments to equity. In order to understand these organizations' orientations towards valued social futures and the ways that technology relates to the organization of access to those futures, the research team engaged in 2 hour interviews with staff at each of the organizations which were augmented and triangulated with organizational documentation and participant observation.

Our findings show that the kinds of social futures valued by informal digital learning organizations varied in (1) how *specified* versus *open-ended* these futures were, (2) their focus on *access to existing social futures* vs *creation of alternative social realities*, and (3) relative focus on *individual* versus *collective* futures.

The first organization, LightLine, represented open-ended futures to be achieved through pedagogies and technologies associated with creative, collaborative 'making'. The executive director shared that he wanted to "eliminate all notions of an end point for a kid" and that "we don't believe that a kid's road to success is being the thing that is in demand right now. […] We want the kids to have their own opinions about what their road to

success is." The strategy to not focus on organizing towards any highly specified social future either in terms of academic, professional or civic engagement was indexed in the ways that they approached their pedagogy and the place of technologies within it. Students worked on what could be seen as somewhat idiosyncratic and even whimsical 'maker' projects, and the usage of technology in their pedagogy was determined largely based on its utility in supporting more generalist orientations to creativity and collaboration. LightLine's implied social futures were largely (1) *open-ended* in the sense that they were not linked to highly specified social world or discipline*, (2) had a relative focus on the social futures of *individuals* rather than collectives, though it implicitly saw collaborative activity as a feature of those futures and (3) generally did not address whether valued social futures involved participating in existing social structures or creating alternative social realities.

A second organization, TinkerSpace, is a community-based technology education organization based in mid-sized Northeastern city describes itself as a "maker space" and "tech center" serving non-dominant youth. Its conceptualization of valued social futures for its youth rests on an idea of "having an economically sustainable job or career and being a contributor back to your community." Their focus on technology career-readiness indexed a somewhat more specified *professional* future, but it's broad commitment to "being a contributor" indexed a more open-ended *civic* future. This more specified professional orientation was reflected in their approach to which technologies they taught their youth to use, framing these choices as being about balancing "applicability with accessibility", such as using the free, open source GIMP photo editor as opposed the more expensive but professional standard of Photoshop. Overall, their talk reflected a commitment to supporting individuals to access existing social futures currently out of reach.

Of the three, the final organization, Thrivewire, a computing education organization rooted in a high poverty area in a large northeastern city, shared the most highly specified conceptualization of social futures for its students. Their organization fused a strong pre-professional orientation and advanced technical computing skills training for individual non-dominant youth with a socio-political vision of "bootstrapping a technology ecosystem" in their region and of supporting alumni to "create their own economy", one that was seen as largely separate from the broader, white and upper middle class dominated technology sector and that would "beat them to market". In order to do so, it made choices about teaching with technology that were heavily driven by market trends and where it projected greatest areas of labor need would be. Thrivewire's conceptualization of social futures was highly-specified, and collectively-oriented towards creating an alternative social order.

Examining the projected futures that informal digital learning organizations imagine and aim to organize for their youth allows a deeper understanding of the kinds of underlying values that guide their work, ones that this study shows are far from unidimensional. Similarly, the analysis reveals diversity in the ways that such organizations think about the role of and decisions around technology as it relates to the organization of those futures. Within the context of the larger project of building cross-setting learning pathways and ecosystems, attending to such differences in orientation can help stakeholders involved in those efforts understand both what kind of roles informal digital learning organizations might play, and whether alignment of values among stakeholders exists. The framework may also provide tools for both reflection by educational organizations about the kinds of futures they want to support or by researchers interested in analyzing the commitments of learning environments they study or design.

References

Acholonu, U., Pinkard, N., & Martin, C. K. (June, 2015). *Locating Opportunity Gaps by Mapping the Computer Science Landscape in Chicago.* Presented at Digital Media and Learning Conference, Los Angeles, CA.

Bevan, B. (2016). STEM Learning Ecologies: Relevant, Responsive and Connected. *Connected Science Learning: Linking In-School and Out-of-School STEM Learning. 1(1).*

Ching, D., Santo, R., Hoadley, C., & Peppler, K. (2016). Not just a blip in someone's life: integrating brokering practices into out-of-school programming as a means of supporting youth futures. *On the Horizon*, *24(3)*. pp. 296-312.

Kafai, Y. B., Peppler, K. A., & Chapman, R. N. (2009). *The Computer Clubhouse: Constructionism and Creativity in Youth Communities. Technology, Education--Connections*. Teachers College Press. New York, NY.

McWilliams, J., & Penuel, W. R. (2016). Queer theory in the learning sciences. *Power and Privilege in the Learning Sciences: Critical and Sociocultural Theories of Learning*, 93.

Santo, R. (2017). *Working Open in the Hive: How Informal Education Organizations Learn, Collaborate and Innovate in Networks*. Doctoral Dissertation. Indiana University, Bloomington, IN.

The Politics of Learning Writing Collective (2017). The Learning Sciences in a New Era of US Nationalism. *Cognition and Instruction*, *35*(2), 91-102.

Social Reading: Field Study With an In-Home Learning Companion Robot

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Abstract: This study explores changes in childrens' (N = 12) responses to interacting with a learning companion robot for reading over time. Initial comparisons of pre- and post-interviews with the children revealed that social companionship, and situational interest were maintained after two weeks of in-home interaction.

Introduction

While the promise of interactive learning technologies has widely been demonstrated, little is known about how an interactive robot might play a role in the development of interest for an activity. Social interactions between humans have been found to positively influence interest and learning in a task (Sansone & Thoman, 2005), and prior research in human-computer interaction has found children to readily interact with robots in social ways (Tung, 2016). Since, robots have a more dramatic social impact compared to other learning technologies (Han, Jo, Park, & Kim, 2005), researchers have utilized the social ability of robots to improve educational outcomes, but little has been done to explore how interest in reading may be developed using social robots.

To further explore the use of a social robot to develop interest in reading, we used eight design features based on recommendations from interest-development (e.g. Renninger & Hidi, 2011) and human-robot-interaction (e.g. Mutlu, 2011) literatures to design *Minnie*, an in-home learning companion robot for upper elementary aged children (see Figure 1). In a pilot study, we tested the robot to explore families' perceptions about reading with the learning companion robot (Michaelis & Mutlu, 2017). We found that children described a very strong social companionship with Minnie, they felt the robot would help them improve their reading, and they described their experience in ways consistent with the development of interest.

A concern with any learning technology is that positive impressions of the technology may be due to initial excitement of working with a new technology. As this *novelty effect* wears off over time, researchers find reductions in interacting with a robot, including: after a week of learning English (Kanda et al., 2004), and steadily over five weeks of playing chess (Leite, et al., 2009). However, this is not always the case (cf. Hayashi et al., 2007), and the quality of the robot's functionality can overcome the negative impact of the novelty effect wearing off (Letie, Martinho, & Paiva, 2013). To assess how the novelty effect would impact interaction with our robot we conducted a two-week long follow up study, and present initial findings to address the question: How do childrens' experiences with interacting with a learning companion robot change over time?

Figure 1. The robot, Minnie, with augmented books (left), and interacting with a child (right).

Methods

Participants were children (N=12; *male* = 4) between the ages of 10 and 12 (*M* = 10.9), were described as *very disinterested* (n = 4), *somewhat interested* (n=4), and *very interested* (n=4) in a pre-study survey. During an initial visit with each family, children completed interviews and surveys, and were introduced the robot. The robot was then left in the child's home for two weeks, and children were asked to interact with the robot when they desired to. After two weeks, we returned to the home to conduct further interviews and surveys. In this poster, we report on pre- and post- comparisons of situational interest surveys and interviews.

The robot is designed to listen, while making eye contact and idle head movements, to children while they read books out-loud. Children were each given a set of 25 books with unique QR-type tags added every 3-5 pages. When these tags are scanned, the robot is programmed to respond with a specific comment written to

correspond to the story at that place. The robot adaptively sets, monitors, and encourages children to meet reading goals during each reading session. To select a new book, the robot offers three suggestions based on their ability, interests and reading habits, but the child is free to choose any book. Children are told they are entirely in charge of their reading sessions, and the amount of their reading has no impact on study completion. For a complete description of the robot development and interaction process see Michaelis & Mutlu (2017).

Results and discussion

We conducted situational interest surveys after the child's first interaction with the robot (pre) and after two weeks (pre), comprised of 5 Likert-style items on a scale of 1 (*strongly disagree*) to 7 (*strongly agree*), as a quantitative measure of each child's interest in working with Minnie. Scores were computed as an average of the five items on each survey and were found to be highly reliable for both pre ($\alpha = 0.93$) and post ($\alpha = 0.86$) surveys. Situational interest scores for the post-survey ($M = 5.16$) were not significantly different than pre-survey ($M = 5.44$; $t(11) = 0.92$, $p = 0.37$; $d = 0.26$). While the small sample size does not provide enough power to make generalizable statistical claims, it does indicate that there was some measurable decrease in situational interest over time. This decrease was not statistically significant, and of only a small effect size, and may be interpreted as an indication that situational interest was nearly the same after two weeks.

In our initial analysis of the interview data, we coded pre and post interviews for several factors, and report here on comparisons between two of the code categories, social companionship and positive affect, as a qualitative measure. During pre-interviews, we found that children described their experience similar to our findings from the previous study with Minnie. They felt a social companionship with the robot, and said that they liked "reading with somebody", that "it was more fun reading with her [Minnie] than just reading by myself", and that "it feels like she's one of my friends." These social sentiments were accompanied by strong positive affect, as children said they "loved Minnie", they were "excited" to work with her, and though she was "fun". The social companionship was often related to improving their reading and comprehension of the books, as one child said, "it's a partner that you can read with and almost seem like you can get more information."

These same sentiments have been echoed in our analysis of the post-interview data. Children continue to see the robot as a social companion and said "It is kind of fun because you have like someone to like read to so you're not - like you don't feel alone." They also describe their experience as "exciting" and "awesome". One common theme that has emerged in the post-interviews that was not strongly present in the pre-interviews was an additional attribution of emotions to the robot. After two weeks they may have felt that Minnie's reactions to the books showed an emotional response. One child told us, "I liked her because she had a lot of emotions about the books. She was scared when I was reading about The Magic Treehouse."

Conclusion

Prior work has indicated that children enjoy working with social robots, and their use can be effective for learning (Han et al. 2005). In this study, evidence from quantitative and qualitative sources suggest the sense of social companionship with a learning companion robot can be sustained over time. Understanding how children respond to a robot over time is important to inform the design of future learning technologies, and to understand the process of children's interaction with learning robots. Larger scale testing over a broader range of domains is needed to further explore these findings. We feel that our initial findings provide promising evidence that a social robot can successfully fulfill the role of a learning companion over time.

References

Han, J, Jo, M, Park, S., & Kim, S. (2005). The educational use of home robots for children. ROMAN 2005. 378.

Hayashi, K. et al., (2007). Humanoid robots as a passive-social medium - a field experiment at a train station, *International Conference on Human-Robot Interaction (HRI)*, Arlington, VA, 137-144.

Kanda, T., Hirano, T., Eaton, D., Ishiguro, H. (2004). Interactive Robots as social partners and peer tutors for children: a field trial. *Human Computer Interaction, 19*(1-2), 61-84.

Letie, I., Martinho, C. & Paiva, A. (2013). Social robots for long-term interaction: A survey. *International Journal of Social Robotics 5*, 291-308.

Michaelis, J.E. & Mutlu, B. (2017). Someone to read with. CHI 2017. Denver, CO.

Mutlu, B. (2011). Designing embodied cues for dialogue with robots. AI Magazine 32(4), 17–30.

Renninger, K.A., & Hidi, S. (2011). Revisiting the conceptualization, measurement, and generation of interest. Educational Psychologist 46(3), 168–184.

Sansone, C. & Thoman, D.B. (2005). Interest as the missing motivator in self-regulation. Eu. Psych. 103(3), 175–186.

Tung, F-W., (2016). Child perception of humanoid robot appearance and behavior. Int. J. HCI 32(6), 493–502.

Engaging Teachers in Discussions Around Temporality Measures from Analytics to Inform Knowledge Building Discourse

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Abstract: This study examined the use of learning analytics designs to support teacher understanding of knowledge building discourse. In this study, learning analytics are designed to help teachers shift their focus on idea-centric knowledge building discourse, i.e. one that weigh students' questions and ideas on the potential for authentic inquiry and improvability. We present teachers' weekly meeting at which a group of teachers interpreted two sets of markers in students' online discussion using Knowledge Forum®. They are (i) keywords as content markers and (ii) Knowledge Building scaffold support as epistemic markers. We hope to inform the use of temporal measures of the learning analytics to surface invisible indicators to teachers that allowed them to understand students' discourse from the stance of improvability and reflect on how to improve the idea-centric discourse among students.

Introduction

This study is based on a series of research effort to develop a practical frame of 'learning analytics intervention' for teachers. This "Learning analytics intervention" for teachers -has been defined as the frame to guide teachers in the designing and enacting classroom activities and interaction with data from analytics tools, data, and reports (Wise, 2014; Wise & Chuy, 2011). There is huge potential in the use of learning analytics by teachers for professional development has not been well investigated and merit research attention.

In many Singapore classrooms, the spectrum of student-centred inquiry-based practice is so large that it is not surprising that many of the students do not get to experience important cognitive activities such as exploring dissonance; negotiating meaning; co-constructing learning. In many classroom discussions, we observed from the knowledge building project, promising questions and ideas that students raised in class is often "killed" before the class truly benefit from it. These promising ideas are either assessed as 'out of syllabus' or missed by the teacher having to navigate the many questions posted by students. In the long run, students may never get to develop adequate competencies to lead or navigate a productive and creative discourse in work-place. This study on using learning analytics to engage teacher in understanding the tenets of idea-centric discourse by making use of learning analytics to help teachers (i) identify discourse markers such as pivotal question or pivotal information and (ii) surface invisible indicators that are closely aligned to 21st century competencies (Chen & Resendes, 2014). This 'evidence' of learning would provide the confidence to teachers in moving their class towards improvable discourse.

Method

This poster describes the learning analytics designs based on Knowledge Forum work and a set of teacher discussion recording their interpretation of the different visualizations created by the analytics about their classroom practice. The intervention is to help teachers notice important but invisible indicators through examining the visualization of students' discourse recorded on Knowledge Forum. The three sets of visualisation generated by learning analytics that we think would serve to surface these important but invisible indicators are:

(a) Content as learning markers: Three sets of keyword maps, each set provdes a different level granularity of analysis to the teachers. The first is a composite visualisation of 2 related word-map (Fig. 1A) churned out by learning analytics. The green wordmap that display main keywords most frequently used by the students and a yellow word-map that provides a higher granulairty showing words are used by students even if it is only once. The visualisation includes the bold words and the text boxes are added in to allow teachers to read the details of the notes connected in the analytics. The other two are wordmaps of the keywords of the same topic from two other sources, the curriculum document and a corpus of scientific articles.

(b) Pattern of centrality of keywords in the discourse, which we colloquially termed it as 'live of a word' in the online discussion database (Fig. 3). It provides teachers an overview of the kind of words collectively used by the students.

(c) Epistemic markers: graph of different types of scaffold supports students adopted in their discourse.

(d) Students' interaction: pattern of centrality of students and their ideas in the database, which we termed as "live of a student" in the online discourse database as indicator of students' contribution to the discourse.
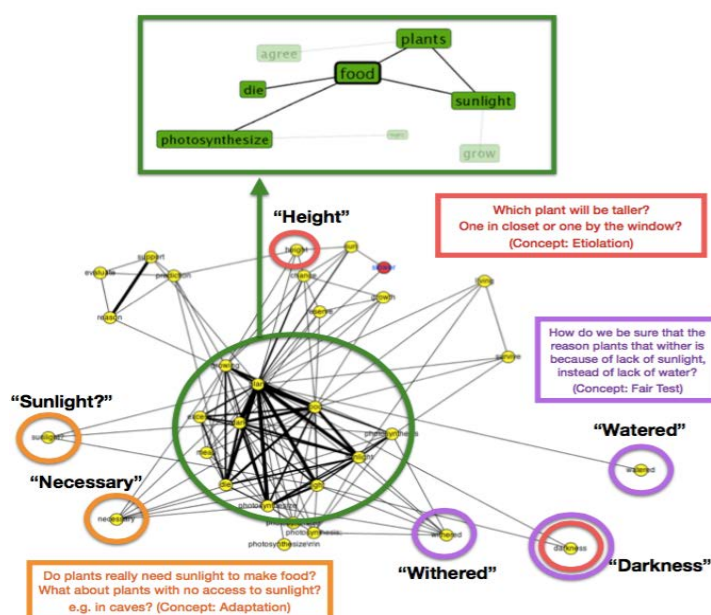
Figure 1. Two sets of related word-map generated from *students' discourse*.

Analysis and discussion

The team engaged in discussion around analysis every three months. This discussion was attended by 4 teachers including (teacher A) who conducted the lessons. The meeting lasted 1.5 hours. In these discussions, the teacher made sense of these data from learning analytics in relation to the 'seized' and 'missed' opportunities in their practice, in the following three areas:

(i) Developing concepts and content: Do the keyword maps reveal to them students' ideas and questions that they did not notice in class? What do they see from the comparison across different sets of keyword maps?

(ii) Competencies of scientific thinking and literacies: Anything that surprised the teachers in the way the analytics report to them how students think through and inquire about the problems?

(iii) Class' dynamics: Anything about the students leading the conversation or the pattern of reading and be-read network that surprises them?

From the discourse, the visualization seemed to have supported the teachers in reflecting on the missed opportunity of not using some of the very interesting questions from his students when he saw the wordmap from his students' discourse. He also reflected on the lack of depth in the students' word-map when he compared it across the curriculum and of the scientific literature wordmaps, triangulated with the data from scaffold trackers. He shared that maybe he should have more time for the students to dwell deeper in their discussion. The teachers were pleasantly surprised with this visualization of the centrality measures of the concept and content words used by students. He agreed that these conceptual words may be more important than students just regurgitation content words. This indicates a possibility of translating the evidence of epistemic markers to influence teachers' practical moves.

References

Wise, A. F. (2014, March). Designing pedagogical interventions to support student use of learning analytics. In Proceedings of the Fourth Intl Conference on Learning Analytics and Knowledge (pp. 203-211). ACM.

Wise, A. F., & Chiu, M. M. (2011). Analyzing temporal patterns of knowledge construction in a role-based online discussion. International Journal of Computer-Supported Collaborative Learning, 6(3), 445-470.

Chen, B., & Resendes, M. (2014, March). Uncovering what matters: Analyzing transitional relations among contribution types in knowledge-building discourse. In Proceedings of the Fourth International Conference on Learning Analytics and Knowledge (pp. 226-230). ACM.

Constructing Entities in Scientific Models

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Abstract: Science education research on modeling has often overlooked the prevalence of theoretical objects in scientific models. The phenomena being modeled are often not observable (e.g., what causes a ball to move), but theoretical (e.g., what causes kinetic energy to increase); similarly, objects responsible for those phenomena are often not tangible, but theoretical. Supporting students modeling requires support for developing theoretical objects that populate models, and embodied representations may uniquely support the construction of theoretical objects.

Introduction

When one billiard ball strikes another—the first one stopping and the second rolling away—it seems intuitive that the first ball had something that was transferred to the second ball in this interaction. In a model of this interaction, a physicist would say that the first ball had *kinetic energy*, and that *work* transferred that energy from the first ball to the second.

A hallmark of engagement in scientific inquiry is students' pursuit of such coherent, mechanistic models of natural phenomena (Hammer & Van Zee, 2006). An articulation of the construct of *mechanistic* by Russ et al. (2008, p. 512) emphasizes the importance of identifying entities ("the things that play roles in producing the phenomenon"), their properties, and their organization such that they can be said to causally produce the phenomenon being modeled. However, the entities and phenomena that populate most scientific models are not physical objects that are readily noticed, categorized and employed in causal stories, but theoretical objects. In the example above, *energy—a* non-physical object—is positioned as an entity that is transferred by a similarly non-physical entity. Other examples include "*entropy* causes *solubility to rise*," "*genes* cause *transcriptional interference*," and "*topological defects* cause *phase winding*." The construction and shared understanding of such entities represents a significant scientific achievement. Entities in scientific models are not so much physical objects that are readily *identified* as they are theoretical objects that are carefully *constructed* as a significant accomplishment in the development of scientific models.

In this poster, we describe a pedagogical embodied activity used to model energy in systems, Energy Theater (Scherr, et al, 2013). Drawing on video data from students as they engage in this activity, we demonstrate how the embodied nature of the activity supports students in constructing new theoretical entities as part of an iterative process of generating mechanistic models of phenomena. We highlight that such construction of theoretical entities by students is a significant part of modeling. More broadly, this work suggests that explicitly embodied activities may be uniquely powerful in supporting students in such causal, mechanistic reasoning because of the ways in which embodiment supports the construction of entities – a process called nominalization. Finally, we argue that such nominalization supports students not only in using the construct of energy to model phenomena, but in recognizing energy itself as a phenomenon to be modeled.

Background

Below, we begin with a brief overview of nominalization and mechanism, the connections between nominalization and embodiment, and then describe Energy Theater. In our poster, we provide transcripts and related data from classrooms in which high school and university level students use Energy Theater as they construct scientific models.

Nominalization and mechanism

A feature of academic language in general, and scientific language in particular, is the prevalence of *nominalization*, in which "any element or group of elements is made to function as a nominal group in the clause" (Halliday & Matthiessen, 2004, p. 41). For example, if we rephrase *decide* as making a *decision*, "decide" has shifted from a verb to a noun – a nominal group in a clause. Nouns have affordances, as they become objects, and then categories of objects, to reason about and with.

The word "mechanism"—suggesting the interacting parts of a machine—underscores the importance of nominalization in science: we construct nominal groups and then treat them as objects, as if such objects can have a causal - even mechanical - influence on events. Reasoning mechanistically in science, then, usually entails a process of nominalization as we construct theoretical entities; those entities populate our models, and

are responsible - causally - for phenomena. Below we will consider how explicit embodiment when modeling phenomena can support students in developing those entities, thus supporting mechanistic reasoning.

Embodied cognition and embodied learning activities

Embodied theories of cognition take the perspective that knowledge representations are fundamentally connected with sensorimotor experiences. Our concepts are largely communicated via metaphors to experiences, such as the saying "there's trouble coming down the road" as if trouble were an object traveling in space. When dealing with abstractions, embodied metaphor is natural, unconscious and pervasive (Lakoff, 1993) and instruction can take advantage of this by engineering experiences that promote certain metaphors.

We anticipate that an explicit embodiment will support students not only in reasoning mechanistically, but in constructing "entities" responsible for phenomena. In science education, for example, students have been successful in understanding new topics with causal mechanisms where the mechanisms account for objects that cause local changes (White, 1993). We now turn to an explicitly embodied learning activity, Energy Theater.

Energy Theater

Energy Theater (ET) is an embodied modeling activity aiming to support learners in understanding energy flows, transfers, and transformations, using a substance model of energy. In this activity, regions of the floor signify objects, and people (students) denote units of energy that move from region to region to represent the flow of energy, and by signaling their form of energy to represent transformations from one form of energy to another (Daane, et al., 2014). Prior research on ET has shown that this activity promotes the disambiguation of matter and energy, distinguishing among energy processes, and representing energy as a conserved. It is not surprising that this embodied activity supports students in using "energy" as a theoretical entity in their models; as we will argue, below, the representation also supports students in constructing other theoretical entities.

Contribution and focus

Our contribution is, first, recognition that defining phenomena to be modeled, and then constructing the entities that populate those models, represent a nontrivial part of scientific modeling. We also argue that employing an explicit embodiment activity when modeling phenomena can support students in developing theoretical entities to populate their model, thus supporting mechanistic reasoning. Our approach is to focus on two settings in which groups of learners are engaged in an embodied modeling activity; in each, their activities promote the development of theoretical objects in a mechanistic model. In the first example in our poster, we demonstrate how this embodied activity supports students in developing a mechanistic model of energy itself. In the latter two examples, we show how using an embodied activity to model physical phenomena leads to the construction of novel theoretical entities in the model (e.g. "regulation," "input," and "output"). These cases illustrate two ways in which the embodiment in ET supports the development of theoretical entities.

References

Daane, A. R., Wells, L., & Scherr, R. E. (2014). Energy theater. *The Physics Teacher*, *52*(5), 291-294.

Halliday, M.A.K., & Matthiessen, C. M. I. M. (2004). *An introduction to functional grammar*. London: Arnold.

Hammer, D., & van Zee, E. (2006). *Seeing the science in children's thinking: Case studies of student inquiry in physical science*. Heinemann Educational Books.

Lakoff, G. (1993). The contemporary theory of metaphor. In Ortony, A. (Eds.,) Metaphor and Thought (2nd edition), Cambridge England; New York, NY, USA: Cambridge University Press.

Russ, R. S., Scherr, R. E., Hammer, D., & Mikeska, J. (2008). Recognizing mechanistic reasoning in student scientific inquiry: A framework for discourse analysis developed from philosophy of science. *Science Education*, *92*(3), 499-525.

Scherr, R. E., Close, H. G., Close, E. W., Flood, V. J., McKagan, S. B., Robertson, A. D., ... & Vokos, S. (2013). Negotiating energy dynamics through embodied action in a materially structured environment. *Physical Review Special Topics-Physics Education Research*, *9*(2), 020105.

White, B. Y. (1993). Intermediate causal models: A missing link for successful science education? In R. Glaser (Ed.), *Advances in Instructional Psychology, Vol. 4* (pp. 177-252).

Acknowledgments

Using Example-based PF Conditions to Investigate Preparatory Effects of Problem-solving Prior to Instruction

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Abstract: Research on the effectiveness of Productive Failure has demonstrated that prompting students to solve a problem before they get instruction about the canonical solution, aids their learning compared to getting instruction first, even if they generate incomplete or erroneous solutions. However, it is still unclear how failing to solve a problem prior to instruction prepares students for learning. In two studies, we used example-based conditions to investigate preparatory effects of problem-solving prior to instruction.

Introduction

One theoretical explanation for the beneficial effects of the Productive Failure (PF) approach highlights developing an awareness of knowledge gaps as an essential preparatory mechanism of the initial problem-solving phase in PF (Loibl & Rummel, 2014). When students produce erroneous solutions prior to instruction, they may become aware of the flaws of their solution attempts during the problem-solving process. This could then make them more receptive to the subsequent instruction. As was shown by Loibl and Rummel (2014), students learn more from the instruction after the initial PF problem-solving phase, if the instruction uses erroneous student ideas as a starting point for explaining the canonical solution. This finding supports the notion that students first need to become aware of the shortcomings of their knowledge in order for instruction to successfully overcome those. The awareness of knowledge gaps may be established at the outset of instruction (Loibl & Rummel, 2014) or before, through experiences of failure during the initial problem-solving phase of PF. Research has not yet established the link between students' awareness of knowledge gaps during the initial problem-solving phase and their learning from the subsequent instruction. This lack of empirical evidence can be explained by the high diversity of students' problem-solving attempts. When students solve a problem prior to instruction, they generate a different quantity and quality of solutions. Examining the impact of the awareness of knowledge gaps is thus challenging, because the solution number and quality may affect to what extent students can become aware of their knowledge gaps. For instance, if a student only generates one or two solutions there might be fewer opportunities for becoming aware of solution limitations (and thus of associated knowledge gaps), than if he/she generates a higher number of solutions. In order to examine the impact of knowledge gap awareness on learning from PF, the number and quality of student solutions need to be experimentally controlled. A promising methodological approach to handle this challenge could be to use example-based PF conditions. In an example-based PF condition, students observe solutions created by other PF students without generating own solutions. This allows to control for the number and quality problem-solving attempts students are faced with in the initial phase of PF (i.e. prior to instruction). Furthermore, example-based conditions can be varied to test additional hypotheses: one relevant question is whether students gain a higher awareness of knowledge gaps and thus benefit more from the subsequent instruction when they a) observe the entire problem-solving process of the model PF student, who is becoming aware of his/her knowledge gaps ($EX_{process}$), or b) whether it is sufficient for them to learn from the final solutions of the model PF student ($EX_{solution}$). One limitation of example-based PF conditions could be that observing a failing student in developing awareness of knowledge gaps has a lower impact on student learning, than experiencing one's own failure. However, Kapur (2014) found that observing solutions created by other students also prepares students for the subsequent instruction. Although the observing students gained less from the instruction than students who experienced own failure, the example-based condition outperformed a direct-instruction condition, which is the usual control condition for PF. When the examples do not only include the final solution, but the process of attempting to solve the problem, benefits of observing PF might be stronger.

Methods

In two studies at secondary schools in Germany, we implemented example-based PF conditions to investigate whether students need to become aware of their knowledge gaps prior to instruction. Study 1 had a quasi-experimental design with four conditions (PF, two example-based PF conditions, direct Instruction; $N = 75$; $M_{age} = 16.08$, $SD = 1.87$). Study 2 had an experimental design with three conditions (PF, two example-based PF conditions; $N = 177$; $M_{age} = 16.06$, $SD = .76$). In this paper, we zoom in on the two example-based PF conditions. In Study 1, the students in the PF-condition produced solutions on tablet-PCs while thinking aloud. By recording

this process (video and audio recordings), we created the content for our example-based PF conditions. Only the audio recordings include process information about the PF student's awareness of knowledge gaps. In one example-based PF condition ($EX_{process}$), students' observed the full process of how a PF student generated solutions (video) and what the PF model said while thinking aloud (audio), whereas in the other example-based PF condition ($EX_{solution}$), the students only viewed the final solutions of a PF-student (picture). After studying the PF examples, the students of both conditions received an instruction about the canonical solution, followed by a knowledge post-test (conceptual and procedural knowledge). We hypothesized that the $EX_{process}$ condition, in which students have access to the model's knowledge gap awareness (displayed by the processes), leads to better conceptual knowledge than displaying only the final solutions to students ($EX_{solution}$).

Results

Although students of the $EX_{process}$ condition descriptively outperformed the $EX_{solution}$ condition in both studies (see *Table 1*), Mann-Whitney U tests revealed no significant differences for conceptual knowledge in Study 1 (U = 110.5, p = .371), or study 2 (U = 1433.0, p = .074).

Table 1: Descriptive statistics for post-test scores on knowledge (Study 1 & Study 2)

Study 1		Conceptual & Procedural (max. 12 points)	Conceptual (max. 7 points)	Procedural (max. 5 points)
Condition	N	MEAN (SD)	MEAN (SD)	MEAN (SD)
$EX_{process}$	15	6.03 (2.47)	2.43 (1.62)	3.60 (1.56)
$EX_{solution}$	18	5.61 (2.46)	1.94 (1.55)	3.67 (1.50)
TOTAL	33	5.80 (2.44)	2.17 (1.58)	3.64 (1.51)
Study 2				
$EX_{process}$	57	5.50 (3.11)	2.99 (1.48)	2.51 (1.99)
$EX_{solution}$	62	4.94 (3.21)	2.52 (1.78)	2.42 (1.92)
TOTAL	119	5.21 (3.16)	2.74 (1.65)	2.46 (1.95)

Additional analyses revealed, that students' (self-reported) awareness of knowledge gaps after studying the PF examples did not significantly differ among the $EX_{process}$ (M = 2.07; SD = .99) and the $EX_{solution}$ condition (M = 2.15; SD = .91) as revealed by a T-Test (t(117) = -.476, p = .635). Looking at each condition separately, we found a significant correlation between students' perceived competence and their conceptual knowledge for $EX_{process}$ (rs = .417, p < .01), but not for $EX_{solution}$ (rs = -.037, p = .780). Therefore, students in the $EX_{process}$ condition seem to assess their competence more accurately according to their post-test performance.

Discussion

Contrary to our hypotheses, the results of both studies do not support the assumption that displaying process information prepares $EX_{process}$ students more effectively for instruction than observing only the outcome of PF. Furthermore, the two example-based PF conditions did not differ in their self-reported awareness of knowledge gaps. As shown by Loibl and Rummel (2014), contrasting incorrect student ideas with the canonical solution showed much stronger effects on learning than problem solving first, and being instructed afterwards, but without using incorrect student ideas during this instruction. Because $EX_{process}$ as well as $EX_{solution}$ obtained an instruction with contrasting incorrect student ideas, it may be sufficient to only provide solutions in the first place to aid learning. However, we found differences regarding the perceived competence among students in the in the two example-based PF conditions, which hint at beneficial effects of observing process information. Our analyses revealed that only if students have access to the entire problem-solving process ($EX_{process}$), the perceived competence positively correlated with students' performance on the post-test. Students who had access to the entire problem-solving process therefore seem to assess their learning more accurately according to their post-test performance, which at least partially supports the assumption that being aware of knowledge gaps prepares students for the subsequent instruction.

References

Kapur, M. (2014). Productive Failure in Learning Math. *Cognitive Science, 38*, 1008-1022.

Loibl, K., & Rummel, N. (2014). Knowing what you don't know makes failure productive. *Learning and Instruction 34,* 74-85.

Student Perceptions of Object-based Learning With Digitized Museum Materials During Classroom Science Instruction

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Abstract: Digitization initiatives at modern museums have created unprecedented opportunities to use online collections objects in classrooms. A key question is whether digitized objects can engage students and promote perceptions of scientific authenticity. Students' perceptions were gathered via embedded surveys immediately following online investigations with digitized museum objects. Responses showed strong engagement and positive perceptions of authenticity (e.g., feeling like a scientist) with bimodal patterns for negative boredom and confusion.

Keywords: Object-based learning, student engagement, museum objects, digital models, middle school

Introduction

A significant critique of classroom learning has been that it is "decontextualized from direct experiences with objects" (Dierking, 2002, p. 4). Research on learning in museums generally has shown positive impact of objects on learner engagement and satisfying user experiences (Schwan, Grajal, & Lewalter, 2014). Because real objects have inherent motivation, expectations, and interest (Dierking, 2002), object-based learning may have strong potential for engaging students in classroom instruction. Some research has shown that bringing physical museum objects into a classroom environment can increase student engagement (Wyner, Koch, Gano, & Silvernail, 2010), but authentic objects from museums can be difficult to acquire for K-12 use. Modern advances in digital imaging have greatly increased opportunities for object-based research and learning in classrooms via digitized museum objects, but little is known about how digitized objects are perceived by students during classroom instruction. The current research examined students' perceptions of a set of online, inquiry-based research investigations that used digitized museum objects.

Method

Participants

Data was analyzed for 617 unique session IDs (about 1234 students working in pairs) from 34 teacher accounts for investigation 1 and 411 unique session IDs (about 822 students) linked to 37 teacher accounts for investigation 2.

Materials and Procedure

Classrooms used Research Quest (www.researchquest.org) investigations 1 and 2. Investigation 1 used 3D models of authentic museum objects (i.e., dinosaur fossils) to identify the type and species of three mystery fossils. Investigation 2 used digital museum materials (e.g., an interactive quarry map) to explore why so many animals died in one location. Surveys consisted of nine, Likert-type items modeled after rapid feedback "mini surveys" employed by Penuel and colleagues (Penuel, Van Horne, Severance, Quigley, & Sumner, 2016). Two items targeted positive emotions (confidence, excitement); two items addressed negative emotions (boredom, confusion); one item assessed perceived authenticity (feeling like a scientist); four items gauged self-reported critical thinking processes. Student surveys were embedded at the end of each online Research Quest investigation and were completed by a collaborative pair for each computer logged into a teacher account. Survey responses were anonymous and logged according to a random session ID that could not be linked with individual students but were linked to teacher accounts.

Results

Positive emotions and critical thinking processes showed strong patterns of agreement, with response frequencies growing from slightly agree to strongly agree. Following each investigation, between 58% and 68% of students indicated some level of agreement with positive emotions (min = 58%, max = 68.2%), with strongly agree being the most frequently selected response (see Figure 1).
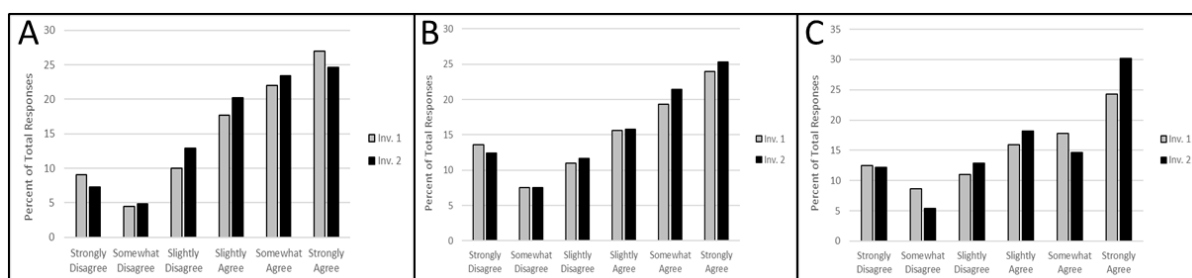
Figure 1. Response frequencies for positive emotion items: confident (1a), excited (1b), feeling like a scientist (1c).

As seen in Figure 2, frequencies of student responses to negative emotion items were largely bimodal. For the item "Today in science class, I felt bored" (Figure 2a), the largest percentage of students chose "strongly disagree" (Inv 1: 24.6%; Inv. 2: 23.8%), but the next most common response was "strongly agree" (Inv. 1: 20.9%; Inv. 2: 21.4%). Confusion showed a similar but less divergent pattern (Figure 2b); the largest percentage of students strongly disagreed (Inv. 1: 24.6%; Inv. 2: 23.6%), with "slightly agree" the second most common response (Inv. 1: 17.2%; Inv. 2: 19.5%).
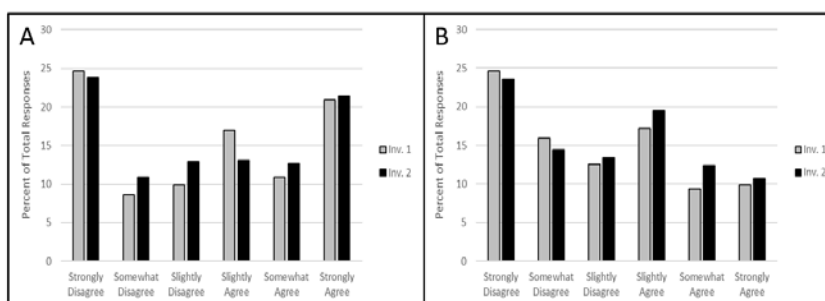
Figure 2. Response frequencies for negative emotion items: bored (2a), confused (2b).

Conclusions

Overall, students who used digitized museum objects and materials for scientific investigations were highly engaged by the digitized materials, responded positively to the perceived authenticity of the investigations, and reported strong engagement in critical thinking processes. A majority of student collaborative pairs reported feeling confident, excited, and like a scientist when working with digitized objects. Thus, efforts to increase object-based learning opportunities in classrooms may benefit from using digitized museum collections. However, results were not uniformly positive. Items gauging boredom and confusion showed bimodal responses. This may indicate the need for more personalized scaffolds to customize investigation objects and adapt instructional features. Future research is needed to better understand when and how to engage all students in object-based investigations using authentic, digitized objects. Additional research on Research Quest is using educational data mining with logged interactions to predict moment-by-moment student engagement and learning needs.

References

Dierking, L. D. (2002). The role of context in children's learning from objects and experiences. In S. G. Paris (Ed.), *Perspectives on object-centered learning in museums* (pp. 3-18). Mahwah, NJ: Lawrence Erlbaum.

Penuel, W. R., Van Horne, K., Severance, S., Quigley, D., & Sumner, T. (2016). Students' repsonses to curriculuar activities as an indicator of coherence in project-based science. In C.-K. Looi, J. Polman, U. Cress & P. Peimann (Eds.), *Transforming Learning, Empowering Learners: The International Conference of the Learning Sciences (ICLS) 2016, Volume 2* (Vol. 2, pp. 855-858). Singapore: ISLS.

Schwan, S., Grajal, A., & Lewalter, D. (2014). Understanding and engagement in places of science experience: Science museums, science centers, zoos, and aquariums. *Educational Psychologist, 49*(2), 70-85.

Wyner, Y., Koch, J., Gano, S., & Silvernail, D. (2010). *Using museum resources to develop environmental science modules that link daily human behavior to ecological principles.* Paper presented at the 2010 Annual Meeting of the American Educational Research Association, Denver, CO.

Introducing Bifocal Modeling Framework in Elementary School Learning Science Using Concrete Modeling Tools

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Abstract: In this study, we implemented a Bifocal modeling unit on diffusion with physical models instead of computational models, using two different tools: 1. Paper modeling, 2. Modeling with micro-robot toy. We worked with 5th grade students for a period of 5 hours. After running experiments, students developed physical models and then interacted with a virtual model. Using either tool, students significantly improved their conceptual understanding of diffusion, but engaged differently in the modeling processes.

Introduction

Scientific models foremost serve to explain natural phenomena; they gain their meaning in juxtaposition with the real-world data (Duschl & Grandy, 2008). However, much of the research on model-based instruction has focused on the support of students in the construction and exploration of models as ends by themselves (VanLehn, 2013). Little work has focused on how to get students to *think with* models *about* natural phenomena, in order to explain observations, etc. This is the focus of the Bifocal Modeling Framework (BMF), which integrates real-world experimentation and computer modeling in the same representational space, enabling students to compare real-world data and virtual models explicitly and in real-time (Blikstein, 2012). While BMF can be effective for science learning (Blikstein, 2012; Fuhrmann et al., 2014), programming computational models remains challenging for students and teachers, and the practice impedes science learning (VanLehn, 2013). In this study, we explore alternative media for modeling, which do not require programming and entail only minimal logistical considerations. We implement a BMF unit on diffusion with 5th grade students, using two distinct modeling methods: "paper modeling" with pen and paper; and the "micro-robot model," which represents a tangible, agent-based model of diffusion. We focus on the following research questions: 1) How conducive is each tool in helping students develop a conceptual understanding of diffusion? 2) Do students using these different tools engage differently in the modeling activity?

Modeling tools

We selected the modeling tools based on two types of criteria: access, affordability, and types of cognitive engagement utilized during modeling. We ended up choosing two tools: 1) pen and paper; 2) Hexbugs. Hexbugs are off-the-shelf, toy micro-robots that exhibit random movements similar to the Brownian motion of molecules. In the paper-model condition, students had to draw an explanatory model using paper and colored pens. In the Hexbug model condition, students were given a limited set of objects to interact with (two boxes, a sticky mat, 25 hexbugs). The two tools differed in terms of medium (two-dimensional versus three-dimensional), temporal representation (static versus dynamic), and the degrees of freedom for conceptual decisions to be made: in the paper-model activity, students had to make decisions about all aspects of the model, whereas in the Hexbug model, many of these decisions were offloaded onto the model.

Methods and materials

The study was conducted with two 5th grade classes in a K-12 urban charter school (85% low-income, 68% ESL). The classes, both taught by the same science teacher, were randomly assigned to either condition (paper-model: 25 students; Hexbug: 28 students). The total Bifocal Modeling unit on diffusion took 5 hours across multiple days.. The unit started out with *physical experimentation*. Students followed an activity guide to design and run experiments to study the rate of diffusion, using blue food coloring, water of two different temperatures, thermometers and stopwatches. This was followed by *physical modeling*; students were prompted to design a model that would explain their physical experiment using materials of their corresponding modeling conditions (see previous section). The unit ended with the exploration of a *virtual model* of diffusion in NetLogo (Wilensky,1999) designed by the authors. Students had to compare the virtual model's behavior with that of their experiments, and use the model to explain their empirical observations. We applied a mixed-methods approach, utilizing several different data sources. We evaluated students' content knowledge with pre-, mid- and post-tests, which included multiple choice items (Blikstein, 2012). We analyzed the students' modeling processes based on video recordings of the physical modeling activities. We binned each video into 4 time sequences and coded each sequence according to the level of "Collaboration" (students working together), "Active" (students being

physically engaged), "Planning" (students reflecting discursively prior to action), "Focus on task" (students doing task-relevant work); each category was ranked on a scale of 0, 1 or 2.

Results

Students in both conditions significantly improved their conceptual understanding of diffusion, with a significant main effect of test phase (Figure 1), $F(2,86)=36.6$, $p<.001$ (repeated measures ANOVA on test scores, nested within student). We found no significant interaction between condition and phase overall, $F(2,86)=1.4$, $p=.3$. Looking at mid- and post-test only, we did find a marginally significant interaction effect, $F(1,43)=3.2$, $p=.08$. Students' learning gains from the physical modeling activity were similar for both conditions, but the Hexbug model condition had higher learning gains with the virtual model than the Paper model condition. Looking at the coding of learning processes (Figure 2), we find that most of the groups in the Hexbug model condition had higher rank-averages for "Collaboration" and "Active", but lower ones for "Planning" than the Paper model condition.
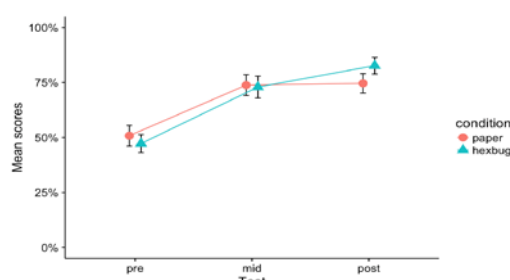
Figure 1. Proportional test scores by phase and condition.
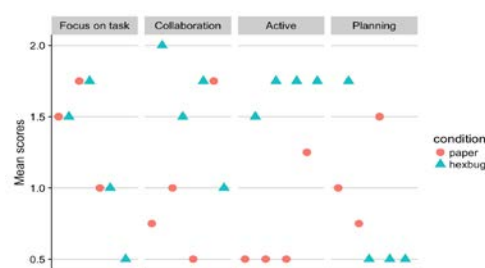
Figure 1. Avg. rank of each group per coding.

Discussion and conclusion

The two tools – Hexbug and Paper model – influenced student engagement and learning differently: the Hexbug model condition produced more learning from the virtual model during the last activity; the Paper model yielded more planning, but appeared less collaborative and active. We cannot make conclusive causal claims because of the many differences between the tools. One key distinction is that the Hexbug model was an interactive, analogous representation of the final virtual model. Another distinction is that the objects of inquiry are tangible in the Hexbug condition, while the paper-based representation is intangible. Further investigations are needed to examine how the tools influence student engagement in the modeling processes. However, we argue that the differences between the tools have complementary beneficial effects for learning; thus, the question is not necessarily which approach is the better to use, but rather how best to combine them. For example, the paper condition might be beneficial to elicit students' prior ideas about a phenomenon and make them explicit in the form of external representations. Tangible, interactive models like the Hexbug model provide another representation of the target phenomenon, which could help highlight key aspects that teachers want students to focus on.

References

Blikstein, P., Fuhrmann, T., Greene, D., & Salehi, S. (2012, June). Bifocal modeling: mixing real and virtual labs for advanced science learning. In Proceedings of the 11th International Conference on Interaction Design and Children(pp. 296-299). ACM.

Duschl, R. A., & Grandy, R. E. (2008). Reconsidering the character and role of inquiry in school science: Framing the debates. Teaching scientific inquiry: Recommendations for research and implementation, 1-37.

Fuhrmann, T., Salehi, S., & Blikstein, P. (2014). A Tale of Two Worlds: Using Bifocal Modeling to Find and Resolve "Discrepant Events" Between Physical Experiments and Virtual Models in Biology. In Proceedings of the International Conference of the Learning Sciences (ICLS 2014).

VanLehn, K. (2013). Model construction as a learning activity: A design space and review. Interactive Learning Environments, 21(4), 371-413.

Wilensky, U. (1999). NetLogo [computer software]. Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL.

Acknowledgments

Teaching and Learning Using Virtual Reality: Identifying and Examining Two Design Principles of Effective Instruction

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Abstract: Virtual Reality (VR) is perceived to have potential for improving student learning. This project examined two instructional design principles, based on the unique affordances of VR, that informed the creation of lessons tested in classrooms. All groups of students experienced learning gains. In only one of the lessons did VR students outperform the students in the non-VR conditions. These initial findings support the potential learning benefits of VR and the need for further research.

Introduction and background

Virtual reality (VR) is gaining traction as a commercially viable and exciting genre of games and entertainment. Anecdotally, using VR in classroom settings has the potential to foster student learning in new and innovative ways (Dede, 2009), although this assertion has been largely unexamined empirically. In this research affordances are defined as the properties of a technology that can be leveraged by designers, educators and other end-users to support learning process (Norman, 1999), building from the notion of offered by Gibson (1954) that affordances are characteristics of an environment that indicate possibilities for action. It is important to consider, for example, in what ways can the affordances of Virtual Reality, across the different types and extent of immersiveness, align well with teaching and learning goals in order to improve student outcomes? The study focused on 8th grade science lessons, given the abundance of prior research on science teaching and learning that could inform this project, and the availability of science content in the Expeditions library.

This exploratory project examined two design principles of instruction (which we call Instructional Design Principles; or IDPs) that were identified and further developed based on an analysis of the unique affordances of the virtual reality technology used in this study (namely its immersiveness and ability to show scale) and were then used to create two lessons, each implemented in the classroom with multiple VR-related conditions to investigate these principles. The two Instructional Design Principles tested in the classroom study presented here are: 1) Develop Narrative: immerse students in VR stories to engender learning, interest, and empathy; and 2) Create Scale: pair VR with real life experiences to support students' understanding of scale and proportion. The study examines the impacts of lessons designed based on these principles, using an off-the-shelf solution, *Google Expeditions*, that is widely available. The two lessons used in the study were Spirit: Life of a Robot (abbreviated hereafter as Spirit) and Ocean Acidification (abbreviated hereafter as OA).

Study design and methods

The study used quasi-experimental design, involving three conditions: 1) a VR condition (where students participated in an Expeditions lesson using the full Expeditions kit (phones and Cardboard VR viewers), 2) a phone-only condition (where student viewed the same Expedition content on only smartphones without the accompanying VR viewers i.e. using Expeditions in Magic Window mode, and 3) a panorama condition (where students participated in an Expeditions lesson with no technology, using paper printouts of the same photospheres or panoramas from the corresponding Expeditions virtual field trips). These conditions were selected in order to keep the content of the lessons as constant as possible across the conditions while isolating the affordances of one type of technology over another. Students took a pre-test and the same post-test to measure learning gains. Test items and coding schemes were designed using an Evidence-Centered Design (Mislevy & Haertel, 2006) approach to ensure their appropriateness. Each lesson took two 45-minute class periods or one longer 90-minute block period to complete.

The study participants included eight 8th grade teachers at six public middle schools in the San Francisco Bay Area. These eight teachers chose three of their classes to include in the study. Each of the three classes was assigned to one of the three study conditions so that each teacher taught one session of each of the three study conditions. A total of 24 classes (623 students) were involved in the study. Schools and teachers were recruited to enable matching teachers across lessons, to ensure there were as few differences among teachers of each lesson

as possible and to represent a set of classrooms that typically have fewer opportunities to integrate technology into their lessons (thus avoiding a typical research challenge of over-recruiting affluent schools) but included teachers with sufficient teaching expertise and personal comfort with technology so that these variables would not negatively impact implementation of lessons. Teachers were surveyed before and after and interviewed after the study to ascertain their attitudes and understandings about the use of VR in classrooms.

Findings

After teaching the Expeditions-based lessons (using the lesson plans developed for this study), most teachers reported that they envisioned a wider range of possible activities they could teach using VR. These impacts were similar for teachers independent of which lesson they taught. For example, before teaching the lesson, when asked how useful VR might be for various classroom activities, teachers most frequently identified activities where students argue a point of view, design their own problems to solve, link hands-on activities to concepts, and work individually in class. After the lesson, teachers most frequently identified activities where students argue a point of view, design their own problems to solve, make a product, and work in small groups in class.

Students' STEM content learning significantly increased during both lessons, across all conditions, as measured by pre and post tests scores and t-test comparisons (Spirit: n = 285, $p < 0.001$; OA: n = 294, $p < 0.0001$). In the Spirit lesson, students in the VR condition outperformed students in both the phone and panorama conditions on the post-test, as determined by an ANOVA ($p = 0.02$). In the OA lesson, learning gains were equivalent across all three conditions.

Discussion

While the field of education research is just beginning to understand how best to leverage VR for learning, our study's findings point to the potential of VR to transform classroom activities, impacting both teacher and student outcomes. Study teachers were positively impacted in their views and understanding of VR for the classroom after teaching only one Expeditions lesson. This is a significant finding, given the preponderance of research (e.g., Lawless & Pellegrino, 2007) that indicates that teachers often require significant professional development when implementing new technologies in their lessons. Additional analyses not reported here eliminated the possibility that teacher effects, time-in-VR, and differences among students at the beginning of the study explain the difference we see in students' learning in the *Spirit* lesson by condition. Although the effect of VR on learning in *Spirit* is small, the finding points to the importance of future systematic research studies to determine the ways that VR experiences can be designed and leveraged in instruction to maximize the impact of VR on learning. The documented difference in learning by condition after only one 90 minute lesson lends credence to the idea that VR could potentially have larger effects on student learning outcomes. Most importantly, this study provides an example of theoretically-informed investigation of affordances of VR technology, via the use of IDPs, to support classroom learning while demonstrating the need for future study.

Other important factors to examine in future studies must include the types of classroom activities included in the lesson to support learning, as well as the scope of the STEM content presented in the Expeditions tour. The efficacy of classroom activities accompanying VR and the scope and quality of content presented to students within the VR experience will need to be closely monitored in future studies of learning.

References

Dede, C. (2009). Immersive interfaces for engagement and learning. *Science*, *323*(5910), 66-69.
Gibson, J. J. (1954). The visual perception of objective motion and subjective movement. *Psychological Review, 61*, 304-314.
Lawless, K. A., & Pellegrino, J. W. (2007). Professional development in integrating technology into teaching and learning: Knowns, unknowns, and ways to pursue better questions and answers. *Review of Educational Research*, *77*(4), 575-614.
Mislevy, R. J., & Haertel, G. D. (2006). Implications of evidence-centered design for educational testing. *Educational Measurement: Issues and Practice*, *25*(4), 6-20.
Norman, D.A. (1999). Affordance, conventions, and design. *Interactions, 6*(3), 38-42.

Acknowledgments

Teacher's Re-design of Virtual Reality Based Curriculum in an Elementary Classroom

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Abstract: This is a qualitative study that explored teacher's use of VR contents in an elementary classroom using a case study approach. Based on the thematic analysis of written reflections, interview transcriptions, and field notes along with teacher-produced artifacts, I provided in-depth descriptions of the entire process of teacher's planning, implementing, evaluating, and revising lessons for using VR. The preliminary analysis revealed that a teacher developed his TPACK of using VR while re-designing VR-based curriculum.

Introduction

In technology-enhanced learning environments, teachers are often considered adopters of technology and executors of ready-made curricular materials. However, the teacher's active role in developing a technology-enhanced curriculum has become increasingly important because the meaningful transformation of learning with technology requires extensive teacher knowledge of technology, pedagogy, and content (TPACK) (Mishra & Koehler, 2009). While teachers' design of curriculum is not entirely new (Kirschner, 2015), bringing emerging technologies into classrooms demands teachers consider variables that have not been essential previously. Especially, the rapid development of virtual reality (VR) technologies has brought new possibilities to education and needs of teachers' professional development. However, research on the adoption of VR in real classroom settings is still immature, and little research has explored the process of curriculum design that involves VR and how teachers develop their understanding about the use of VR in classroom practices. The complex nature of designing curriculum using emerging technologies does not seem to have been well facilitated by traditional forms of one-time out-of-context professional development (Liu, 2013). Instead, teachers' curriculum design practice as a form of professional development has recently gained scholarly attention (Voogt et al., 2015). Despite this increased attention, there is scant empirical evidence that demonstrates how teachers develop their knowledge towards emerging technologies while designing technology-enhanced lessons. Therefore, in this study, I explored an experienced teacher's use of VR in an elementary classroom and tried to describe how the teacher developed TPACK while designing VR-based curriculum.

Methods

Context of study

In this study, I worked with one elementary teacher who worked in a private elementary school located in a metropolitan area in South Korea. Mr. Park was a 43 years old male teacher with 19 years of teaching experiences and was currently working on a doctoral degree. He was a homeroom teacher for 4th graders with 28 students (14 boys and 14 girls), that were divided into two groups of 14 students for a class. The teacher was the head of the research department at school and had extensive experiences of researching and designing curriculum incorporating various innovations. As part of the study, Mr. Park was introduced to Google Expeditions and suggested to incorporate it into his teaching. Google Expeditions is a mobile application that provides over 500 three-dimensional virtual field trips that can be downloaded on a mobile device and viewed with a low-cost VR headset.

Data collection and analysis

This study is a qualitative one-case case study that has a bounded system of teacher's work including lesson planning and teaching, and his interaction with me. Within this bounded system where the teacher designed two units of lessons, qualitative data was collected in forms of teachers' written reflections during planning, video recordings of teacher's classroom teaching and field notes, and follow-up semi-structured interviews after each teaching. Also, lesson materials that Dr. David created, such as PowerPoint presentation slides, and student activity sheets were also collected. All written reflections, interview transcriptions, and field notes were coded using a thematic analysis method and triangulated with data from other sources. The results extracted from the preliminary analysis was reorganized to present the teachers' development of TPACK.

Teacher's development of TPACK through re-designing VR curriculum

Preparing technologies and reorganizing a physical space

When designing the initial lesson, Mr. Park spent most of his time gathering information and researching about VR, and concerning technological aspect of using VR in his classroom. As he searched more about VR, he began to realize that the use of VR required specific technical specifications and entailed the students' physical movement and reactions to viewing the VR, which needed to be adequately addressed and accommodated. The technological knowledge he developed includes not only the knowledge about VR but also necessary physical setup for using VR in his classroom. Based on this knowledge, he reorganized the classroom setting to accommodate students' movement during VR experiences as well as prepared two extra chairs at the corner of the classroom for students to be able to take a rest when they feel uncomfortable. During the enactment, he continuously reflected on some problems emerged, such as Wi-Fi connection, battery shortage, etc. and addressed them in his second lesson. Instead of having 14 students using VR simultaneously, in the second VR lesson, seven students used VR at a time, and a couple of extra sets of devices were prepared. The classroom was also reorganized to have an ample open space in front of the classroom for seven students.

Modifying learning content for pedagogical use of VR

Another aspect of teacher knowledge developed was content knowledge with combining pedagogical and technological knowledge. During the design of the second lesson for Korean literacy, Mr. Park modified existing learning objectives and textbook contents to be better aligned with VR contents. While reviewing 'The use of information' in the Korean elementary curriculum, he realized that their Korean textbook only focused on traditional media, such as books, newspapers, internet search, and television as information sources. However, he developed his knowledge about a new medium during the design of this lesson and learned that VR is an emerging technology that can certainly bring a new type of information in education. Thus, he designed that particular week's lesson to include VR and how the information presented in VR is different than the one delivered by other media that students were already familiar with.

Pedagogical understanding of VR for instructional interventions and student activities

Based on his understanding of VR and resources available, Mr. Park devised instructional interventions and student activities that were implemented in teaching. During the design, he developed the understanding of the pedagogical aspect of using VR. Guided exploration was applied to maximize the purpose of VR experiences by utilizing the guide mode in the Google Expeditions that allowed students to experience the same content with the same sequence. On the second lesson, a compare/contrast group activity was designed for experiencing two different mediums as information sources.

Discussion

Throughout the instructional design process, the teacher was actively involved in curriculum re-design by modifying a space, content, and activities to incorporate VR. The process of modification was based on the design process that follows gathering information, diagnosing what is best for the learners, determining an effective course of instruction, enactment and evaluating the teaching (Kirschner, 2015), which again led to another cycle of the designing process. During the iterative processes of designing and redesigning lessons and activities responding to emerging learners' needs as well as constraints and affordances in educational contexts (Matuk et al., 2015), the teacher developed new TPACK around the use of VR in the elementary classroom.

Reference

Kirschner, P. A. (2015). Do we need teachers as designers of technology enhanced learning?. *Instructional Science, 43*(2), 309-322.

Koehler, M., & Mishra, P. (2009). What is technological pedagogical content knowledge (TPACK)?. *Contemporary issues in technology and teacher education, 9*(1), 60-70.

Liu, S. H. (2013). Teacher professional development for technology integration in a primary school learning community. *Technology, Pedagogy and Education, 22*(1), 37-54.

Matuk, C. F., Linn, M. C., & Eylon, B. S. (2015). Technology to support teachers using evidence from student work to customize technology-enhanced inquiry units. *Instructional Science, 43*(2), 229-257.

Voogt, J., Laferrière, T., Breuleux, A., Itow, R. C., Hickey, D. T., & McKenney, S. (2015). Collaborative design as a form of professional development. *Instructional Science, 43*(2), 259-282.

Studying the Interactions between Components of Self Regulated Learning in Open Ended Learning Environments

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Abstract: This paper investigates the interactions between learners' cognitive strategies and affective states; both important components of self-regulated learning (SRL) processes that influence student learning. We study cognitive-affective relationships in high versus low performing students as they worked on a model building task to teach their agent in Betty's Brain, an open-ended science learning environment. Our initial results allow for some interesting discussions, but they also emphasize the need for fine grained affective data to match up against cognitive states to determine how they influence performance or vice versa.

Introduction

Self regulated learning (SRL) involves the temporal deployment of cognitive, affective, metacognitive, and motivational processes (Azevedo et al., 2012). SRL processes are important for successful science learning, especially in open-ended learning environments (OELEs). Related work in this area show that affect can impact cognitive behaviors like decision-making, information processing, and reasoning (Forgas et al., 2006). Previous results highlight the importance of measuring and studying the interactions of affect with students' learning performance and behaviors. These findings help us understand that detecting and alleviating negative affect leads to better learning. This paper analyzes the interactions between components of SRL, primarily cognitive strategies and affective states, in the Betty's Brain OELE (Leelawong and Biswas, 2008).

Methods

We ran a study with 87 sixth-grade students in an urban public school in Nashville, TN, USA, who worked on modeling the causes and effects of climate change in Betty's Brain over four days. Students' interactions in Betty's Brain were logged. Two trained human observers (*Cohen's kappa, $\kappa > 0.8$*) collected data on students' affective states (*bored, confused, delight, engaged concentration, frustrated, other*), as well as their task behaviors (*on-task, off-task, on-task conversation, other*) following the Baker Rodrigo Ocumpaugh Monitoring Protocol (BROMP) for field observations (Ocumpaugh, Baker, & Rodrigo, 2015). We used differential sequence mining to identify frequent cognitive strategies that differed between high and low performing students (Kinnebrew et al., 2013). We then computed the differences in affect observed for high versus low performers, and thereby studied the relationships between cognitive strategies and on-task affective states.

Results and discussions

We applied the measure of students' in-system performance, their map scores (*median value* $= 11$), to divide all the students ($n = 87$) into *High* (Hi) and *Low* (Lo) performers. Students with a map score greater than 11 were labeled "Hi" ($n = 44$) and those with a map score less than 10 were labeled "Lo" ($n = 39$). Data for students at the median value ($n = 4$) was discarded to maintain the distinction between the two groups. Next, we ran a differential sequential pattern mining algorithm (Kinnebrew et al., 2013) to identify the differentially frequent cognitive patterns between Hi and Lo performers. Table 1 presents 3 frequent cognitive strategies sorted by the difference in the two groups' instance support values. The descriptors "-EFF/-INEFF" and "-SUP/-UNSUP" attached to causal link edit actions show whether the actions were *effective*/*ineffective* (led to an *increase*/*decrease* in the map score) and *supported*/*unsupported* (*related*/*unrelated* to previous actions), respectively.

Table 1: Differentially frequent patterns for High vs Low performing students

Pattern	*i*-Frequency Diff (Hi − Lo)	*s*-Frequent Group	*p* value
READ → LINKADD-EFF-SUP → QUIZ	2.1	Hi	< 0.001
QUIZ → READ	4.35	BOTH	< 0.001
READ → CONV-REQ	−0.47	Lo	0.02

We analyzed the data collected on affective states of the students by group (Hi and Lo performers). We found that the amount of time spent being bored was significantly higher for the Low performers ($p = 0.002$) when the learners were in on-task mode. On-task behavior was also naturally marked by significantly higher level of delight ($p = 0.015$) for the Hi group. Next, we studied the affective states during use of the cognitive strategies from Table 1 between Hi and Lo performing students. The results of these cognitive-affective interactions are illustrated in Figure 1.

Quiz→Read, a frequently used pattern by all students, was linked to delight or frustration for the Hi performers, versus boredom and confusion for the Lo performers. A possible interpretation of this result is that, seeing good quiz results or improvement in the results produces delight, whereas negative quiz results produce frustration in the Hi performers. Confusion and boredom in Lo performers can be attributed to not being able to analyze the quiz results to find the information to read. However, frustration in high performers caused by the lack of immediate success did not seem to affect their desire to persist (unlike the low performers who got bored and gave up). Instead, frustration seemed to be channeled into reading activities that helped them find the information that they needed to correct their maps, and, therefore, they got past their frustrated state.

Read→Conv-Req is a differentially frequent pattern for Low performers. It includes a period of reading resource pages, but not understanding the content (or finding the desired information), therefore, seeking help from the Mentor. This is good SRL behavior, however, the Lo group showed a lot of boredom during this period (implying their lack of success led them to disengage from productive work on system), while the Hi performers primarily displayed confusion or frustration (unable to understand content, therefore, confusion or frustration, but they seemed to follow up by seeking help in a productive way).

Read →LinkAdd-Eff-Sup→Quiz is differentially frequent in High performers. Here, the student read and converted the information they read into correct causal links, and then took a quiz to verify if their added link was correct. For Lo performers, who performed this strategy rarely, no affect state was recorded (hence, their affect states are not included in Figure 1). Hi performers displayed significant levels of delight during this period, indicating that they were happy because they updated the map correctly based on what they read in the resources, and the quiz results confirmed that they had added correct link(s).
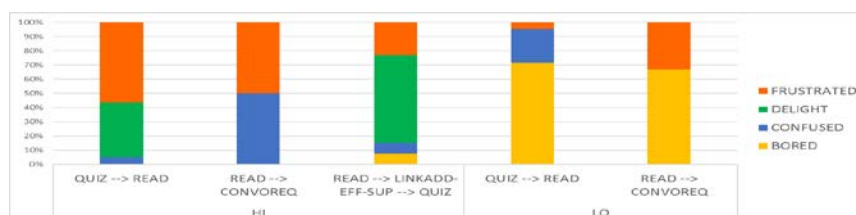
Figure 1. Hi vs Lo students - Emotions (on-task) for four different behavioral strategies.

Conclusions

The findings in this paper show that learners' affective states in an open-ended learning environment are linked to their cognitive strategies and performance in the system. As a broader research goal, we believe that establishing cause-effect relations between cognitive and affective processes will help us construct more complete models to gain an understanding of the relations between cognition, metacognition, and affect in SRL.

References

Azevedo, R., Behnagh, R. F., Duffy, M., Harley, J. M., Trevors, G. (2012). Metacognition and SRL in student-centered learning environments. *Theoretical foundations of learning environments*, Ch. 7.

Forgas, J., Wyland, C., & Lahan, S. (2006). Hearts and Minds: An Introduction to the Role of Affect in Social Cognition and Behavior. *Affect in Social Thinking and Behavior*, Psychology Press, 3-18.

Kinnebrew, J.S., Loretz, K.M., & Biswas, G. (2013). A Contextualized, Differential Sequence Mining Method to Derive Students' Learning Behavior Patterns. *Journal of Educational Data Mining*, 5(1), 190-219.

Leelawong, K., & Biswas, Gautam. (2008). Designing learning by teaching agents: the Betty's Brain system. International Journal of Artificial Intelligence in Education, 18(3), 181–208. IOS Press.

Ocumpaugh, J., Baker, R. S., & Rodrigo, M. M. T. (2015). Baker Rodrigo Ocumpaugh Monitoring Protocol (BROMP) 2.0 technical and training manual. Technical Report. New York, NY: Teachers College, Columbia University. Manila, Philippines: Ateneo Laboratory for the Learning Sciences.

Acknowledgments

Mentors in the Making: A Case Study of Heterogeneity in Meaning Making at a Public Library Makerspace

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The rise of public makerspaces in the US is seen as a way to democratize access to STEM fields, but many questions remain about how the maker movement can reach a diversity of youth in sustained ways. Adult mentors are a potential pivot: the expansiveness or narrowness of their conceptions of making and makers may shape the democratizing potential of makerspaces. This poster studies adult mentors at an award-winning public library makerspace working with racially and socioeconomically diverse teens. It asks *How do these mentors conceptualize their practice and the relationship between mentors, making, and (teen) makers?* Our findings contribute to broader efforts to establish makerspaces at public institutions that truly democratize access to powerful ideas and practices.

Data were generated over three months in 2017, in a study including participant observations, semi-structured interviews with mentors and makerspace leadership, and interviews with focal students. Here we focus on mentor interviews, exploring how they, as institutional agents and artists with expertise in varying domains (e.g., textile crafts, robotics, music production), conceptualize the relationship between mentors, makers, and making. We use Chevallard's (1985) didactical model to frame accounts of their conceptions (see Fig 1a). This model was originally proposed to analyze general elements of a mathematics learning environment - namely, teacher, student, and knowledge taught (Ben-Peretz, Moon & Brown, 2004); for our study this translates as a system with vertices for mentor, maker, and making, respectively. Chevallard's model is deceptively simple because the surrounding *context*, though not explicitly depicted, is as important as the elements themselves. That is, Chevallard argued that institutional and societal contexts matter significantly for how relationships between teacher, student, and content unfold, although scholars adopting the framework often neglect its dynamic aspects (see Schoenfeld, 2012). A sociocultural perspective on the didactical system highlights how mentors' conceptions are shaped by personal histories and by social, historical, and political contexts of schooling, the library, and the broader maker movement.

Figure 1a. The didactic triangle (Chevallard, 1985), left; and Figure 1b. our analytic refiguring, right

Findings

As Figure 1b suggests, we found that mentors engaged thoughtfully **about how heterogeneity was built into the design and enactment of the makerspace** in ways that indicated achievements along the mentor and making vertices. For our interviewees, **the "mentor" vertex** should be imagined as "exploded" to reflect the array of expertise that various mentors embodied. The makerspace's targeted hiring of artists strengthened its goal of heterogeneity in making while also allowing teens to experience the space as having a purpose apart from career readiness or technical training. Mentors represented an expansive definition of making, one that counters a dominant narrative in the US Maker Movement in which accomplished making practices often map to *technology-centered entrepreneurship*. In particular, the deliberate inclusion of spoken word and music artists indicates the makerspace's vital connections to a city actively reviving Black heritage music in the South. Images of making embodied in the mentors' expertise were also decoupled from the pursuit of economic return in the lives of minoritized teens. **The "making" vertex** of the didactic system should also be "exploded" into an array of vertices, reflecting the plurality of ways that "making" was defined in this setting - 3D printing, 3Doodlers, virtual reality play, music production, textile art and animation, to name a few. This plurality (greater than "making as robotics" but less than "making as all cultural practice"), resonated with the diversity of material resources in the setting and of expertise among the mentors. Teen makers could regularly choose among a range of activities on entering the space.

In counterpoint with these successes, **at the "maker" vertex**, many mentors expressed uncertainty or conflict. Some mentors seemed unsure about the importance of drawing new makers into the space. Relatedly,

mentors' perspectives differed on whether making was *a priori* a necessary good for all teens. These challenges both point to questions about the nature and flexibility of relationships with teen makers that mentors sought to promote. While mentors generally understood their work intrinsically to involve building relationships with teens, they described this in two ways. Some described maker-mentor relationships as grounded in shared histories and experiences, or social affinity (e.g., racial or linguistic similarities), mentioning the need for teens to see themselves physically represented among the mentors. Such affinity-based perspectives implicitly recognize the expansiveness of making as a cultural form for all racial, economic, and social communities. And while this runs productively counter to the Maker Movement as a cloistered space of straight, white, upper middle-class masculinity (see, e.g., Beuchley, 2013; Dawkins, 2011; Vossoughi, Hooper, & Escudé, 2016), our data suggest caution in relying on representational approaches to enact structural change: to refigure making in light of such broad participation means also creating the conditions for mentoring as an anti-bias practice. A second way mentors spoke of building mentor-maker relationships was *through* making. In the terms of the didactic model, rather than follow a direct connection of maker to mentor, this approach had mentors *meeting makers at the making vertex*, when shared social histories or affinities were elusive. However, a challenge naturally emerged here in conceptualizing teens who are not yet connecting with a making practice. Non-participation in the space or activities often led mentors to hypothesize about *kinds of teens*, in ways that revealed challenges they faced to bridge social distance. The need to support mentors in an ongoing project of developing and sustaining a sociopolitically and ideologically informed reflective practice (Philip, Gupta, Elby & Turpen, 2017; Zeichner & Liston, 2013) thus emerged as integral to the makerspace's larger efforts at broadening and sustaining participation in making among a diversity of makers.

Conclusion

The U.S. has seen a rapid rise in making and digital fabrication in education. The diffuse nature of where, how and when making occurs suggests limitless possibilities for it as a form of social creativity and innovation, and for who might identify as a maker. However, equitably institutionalizing such human activity is a nontrivial challenge (Halverson & Sheridan, 2014), and makers would benefit from the body of research on how to promote ambitious and equity-oriented practices. This includes continuing to expand epistemic heterogeneity in making, by promoting mentors who embody (professionally and personally) the expansiveness of making as a cultural form. Further still, supporting and organizing mentors' learning in relation to the sociopolitical context of their work (past and present) as a reflective practice (cf., Zeichner & Liston, 2013) may empower them to identify deficit ideologies of race, poverty or gender, which we know infiltrate science and engineering learning contexts (e.g., Philip, Gupta, Elby & Turpen, 2017), from subverting the otherwise democratizing power of the work they do. This emerging field of action, we argue, offers a consequential foothold for the learning sciences to "count" and to contribute to ways of rethinking learning in the digital age.

References

Buechley, L. (2013, October). Closing address. FabLearn Conference, Stanford University, Palo Alto, CA. Retrieved from http://edstream.stanford.edu/Video/Play/883b61dd951d4d3f90abeec65eead2911d

Ben-Peretz, M., Brown, S., & Moon, B. (Eds.). (2004). *Routledge international companion to education*. Routledge.

Chevallard, Y. (1985). La transposition didactique—Du savoir savant au savoir enseigné. Grenoble: La Pensée Sauvage.

Dawkins, N. (2011). Do-it-yourself: The precarious work and postfeminist politics of handmaking (in) Detroit. *Utopian Studies*, *22*(2), 261-284.

Halverson, E. R., & Sheridan, K. (2014). The maker movement in education. *Harvard Educational Review*, *84*(4), 495-504.

Philip, T. M., Gupta, A., Elby, A., & Turpen, C. (2017). Why Ideology Matters for Learning: A Case of Ideological Convergence in an Engineering Ethics Classroom Discussion on Drone Warfare. *Journal of the Learning Sciences*, 1-41..

Schoenfeld, A. H. (2012). Problematizing the didactic triangle. *ZDM*, *44*(5), 587-599.

Vossoughi, S., Hooper, P. K., & Escudé, M. (2016). Making through the lens of culture and power: Toward transformative visions for educational equity. *Harvard Educational Review, 86*(2), 206-232,307-309.

Zeichner, K. M., & Liston, D. P. (2013). *Reflective teaching: An introduction*. Routledge.

Acknowledgments

Exploring the Impact of Virtual Internships for Democratic and Media Education

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Abstract: This paper focuses on the design and effects of our pilot study of PurpleState, a Virtual Internship simulation. PurpleState utilizes the concepts of epistemic frames and communities of practice as models for learning in media and democratic education. PurpleState places students in the roles of interns at a strategic communications firm who are hired to develop a media campaign on a proposed fictitious state level "fracking" ban. Results of the study include significant effects on participants' knowledge of the issue, why it was controversial, the ability of participants to understand political media, and in their beliefs about being able to engage in civic action.

Introduction

This paper describes the design framework used to create PurpleState Solutions, a Virtual Internship simulation, and presents findings from a pilot study of the simulation with two classes of grade nine students. For PurpleState, we sought to provide students the opportunity to develop an understanding of the dynamic nature of media in politics and help them to develop the skills and knowledge to be both more critical of the political media they engage with *and* more skilled and confident in using media strategies to take political action. Through the use of the concepts of epistemic frames and epistemic games from learning sciences, as well as theories from political communications and existing civic education models, we present the virtual internship as a model that is more relevant and authentic for developing today's young citizens.

Theory and design frame**work**

The use of simulations in democratic education is far from new, but most are designed to be more engaging models for helping students learn standards-based curriculum, academic content, and skills (e.g., Parker, et al., 2011; Parker, et al., 2013). These simulations also often place students in roles of official power and at the national level, such as a Supreme Court Justice or member of Congress. As a result, students may not fully understand the dynamic nature of politics and the roles that other groups outside of the structures of elected office may have. The official curriculum also often lacks specific objectives related to critical media literacy in the context of politics, or media strategies for taking political action (Raphael, Bachen, Lynn, Baldwin-Philippi & McKee, 2010; Stoddard, 2014).

PurpleState was designed using the model of Virtual Internships developed by Shaffer (2006a, 2006b) that employs epistemic frames and communities of practice from professions as models of learning. The concept of epistemic frames provides a model with the potential to help students transfer their academic experiences to their role as citizens outside of school (Bagley & Shaffer, 2009; Shaffer, 2006a, 2006b). We use the epistemic game model and the epistemic frame of strategic communications consultants, whose firms assist candidates, political action committees, and special interest groups to develop and implement media and campaign strategies; this epistemic frame emphasizes expertise in the skills, knowledge, and values that can transfer to young peoples' actions as citizens outside of school.

Methods

Here we present findings from our third iteration of implementing PurpleState, with 43 grade nine students from central Wisconsin (USA). The participants engaged in the simulation over a three-week period (10 class hours) and we worked closely with the teacher to collaborate on helping all students be successful, including the two ESL students in the class and several students with special needs. This mixed methods study focuses in particular on measures related to the participants' knowledge of the issue, i.e., fracking, their understanding of why it is controversial, and in their ability to transfer the political media strategy to a related but different context. We also focused on adapting existing measures of self-efficacy for political engagement to better fit the current context of political engagement and the role of media. Data utilized here were generated as part of a pre-post questionnaire and student tasks in the simulation. See Stoddard & Chen (2018), also in this volume, for more on the development of these measures.

Results

We were particularly interested in how much students would learn from engaging in the controversial issue, framed as a proposed ban on fracking. We saw significant increases in open-ended items focused on participants' knowledge (Fracking Knowledge, p<.0001) of the issue and why it was controversial (Fracking Controversy, p=0.0002). They also had a significant increase in their ability to explain how they would apply political media strategy to a different but related context – illustrating transfer of the strategy that they had learned (Politician Advice, p=0.0002). These items measured students' abilities to use evidence and reasoning related to the issue, and for the question about why it is controversial, we were also looking to see if students could explain why it is controversial from both sides of the issue.

We also saw significant growth in participants' epistemic understanding of political messages and how they are structured to persuade in a Video Analysis task. This task asked participants to apply their epistemic understanding of political communications to a political advertisement that was part of an "Energy Voter" campaign funded by a petroleum industry lobbyist group. We saw significant changes in participants' abilities to identify the intended audience for the video (p=0.0045) and in their ability to identify the intended political message of the video (p<.0001). We did not see a significant change in their abilities to identify the specific persuasive technique being used (e.g., bandwagon, appeal to emotion).

Finally, given the intersection of political knowledge, skills, and beliefs being a predictor for future political engagement, we were also interested in the potential impact of participants' confidence to engage politically. We saw a significant increase in participants' self-efficacy for political engagement (p=0.0007), assessed using adapted instruments that have been validated in the past (alpha=0.79). Items in this scale include "Construct good arguments about political issues" and "Identify hidden political messages in advertising". As noted above, more information on the adaptation and development of this scale can be found in Stoddard and Chen (2018), elsewhere in this volume.

Conclusion and implications

In this paper we describe the design and results from our pilot study of the PurpleState virtual internship. The conceptual framework of epistemic frames developed here, when operationalized through epistemic games, has the potential to significantly change the nature of how we teach young people to be citizens, in addition to serving as a dynamic model for reaching academic and skills goals. PurpleState is designed to engage young people in collaborative practice, a better understanding of the nature of media and its function in society and politics, and provide opportunities to engage in relevant contemporary controversial issues.

There is evidence that epistemic games have great potential to develop student civic thinking and action by engaging students through virtual internships in authentic contexts and problems. The significant gains found in our study of participants' knowledge of the issue and why it is controversial, and in their increased self-efficacy for engaging politically and in particular using media to engage, illustrate the potential for this model. If our goal in civic education is having informed citizens who are confident in taking action, PurpleState illustrates one approach to working toward this goal. These games also have the potential to develop student skills in persuasive communications and media literacy over traditional academic work and assessments.

References

Bagley, E. and Shaffer, D.W. (2009). When people get in the way: promoting civic thinking through epistemic gameplay. *International Journal of Gaming and Computer-Mediated Simulations, 1*(1), 36-52.

Hess, D. (2009). *Controversy in the classroom: The democratic power of discussion.* New York, NY: Routledge.

Parker, W. C., Mosborg, S., Bransford, J. D., Vye, N. J., Wilkerson, J., & Abbott, R. (2011). Rethinking advanced high school coursework: Tackling the depth/breadth tension in the AP US Government and Politics course. *Journal of Curriculum Studies, 43*(4), 533–559.

Parker, W., Lo, J., Yeo, A. J., Valencia, S. W., Nguyen, D., Abbott, R. D., . . . Vye, N. J. (2013). Beyond breadth-speed-test: Toward deeper knowing and engagement in an Advanced Placement course. *American Educational Research Journal, 50*(6), 1424–1459.

Raphael, C., Bachen, C., Lynn, K. M., Baldwin-Philippi, J., & McKee, K. A. (2010). Games for civic learning: A conceptual framework and agenda for research and design. *Games and Culture, 5*(2), 199-235.

Shaffer, D. W. (2006a*). How computer games help children learn.* New York: Palgrave MacMillan.

Shaffer, D. W. (2006b). Epistemic frames for epistemic games. *Computers & education, 46*(3), 223-234.

Stoddard, J. (2014). The need for media education in democratic education. *Democracy & Education, 22*(1). Available online: http://democracyeducationjournal.org/home/vol22/iss1/4.

Conceptual Goals While Using a Simulation: Three Different Sources and Learning Outcomes

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Abstract: Although there is a broad research base demonstrating positive science learning outcomes from simulation use, less is known about the learning processes that may mediate these outcomes. This study investigated the source of conceptual goals that students pursued while using a simulation. Using a case study approach, we found that student goals were from three main sources: instructional materials, self, and instructor. Findings suggest that self-selected conceptual goals may result in more stable knowledge.

Introduction and theoretical framework

Although there is broad consensus that computer simulations are effective for promoting science learning outcomes, less is known about mediating learning processes (Rutten, van Joolingen, & van der Veen, 2012). Thus, this study investigates sources of conceptual goals that students pursue while using a simulation and their implications for learning outcomes. In addition, this study involves investigating student engagement in constructing explanations and modeling, which is timely and relevant because these are two practices that are emphasized in the Next Generation Science Standards (NGSS Lead States, 2013). This study addresses the following research question: *What are sources of the conceptual goals that students pursue while using a seasons simulation to model and construct explanations?*

This study is framed by a view of conceptions as dynamically emergent structures (Brown, 2014). In this view, there is unison of seemingly dichotomous perspectives on student conceptions as fragmentary and theory-like, and it suggests affordances of examining conceptions in multiple ways. Importantly, this view suggests that conceptions "are dynamically emergent from the interactions of conceptual resources" (Brown, 2014, p. 1473). This dynamic view of conceptions highlights the importance of closely examining the contexts in which conceptions are developed.

Method

This study was conducted from an interpretivist paradigm (which can be considered a subcategory of the qualitative research paradigm). Accordingly, this study used instrumental case-study methods (Stake, 1995) to investigate the research question. The data for this study come from video observations and interviews. Video recordings were made of one group of three middle-school students using a simulation intended to help them develop explanations for causes of the seasons. The video was combined with synchronized screen recordings, so it was possible to see what students were doing within the simulation. Video recordings of individual students giving explanations of the seasons after using the simulation were also included in the data set. The classroom teacher was asked to select students who had permission to be video recorded to work in groups. The study took place during normal classroom instruction of an eighth-grade astronomy unit in a public middle school located in the Midwestern United States. During the study, students used a novel learning environment called a gesture-augmented simulation. This type of simulation differs from conventional simulations in that it affords interaction using hand motions rather than a mouse or trackpad. While students were using the simulation, they were provided with a worksheet that indicated settings to select in the simulation windows to create various "setups." The worksheets also asked students to focus on specific aspects of the simulations such as depictions of the angle of light rays or spacing of light rays hitting a patch of ground.

Findings

Case analysis showed that there were three main sources for the conceptual goals that students pursued while using the simulation: (a) instructional materials, (b) self, and (c) instructor. Two of these categories are illustrated in the following sections.

Conceptual goals from instructional materials

In this episode, students used settings in the simulation that were listed on a worksheet, which asked students to focus on the angle of light rays.

> S2: June is when it's the most straight down [gestures to show steep angle of light rays], and

S1: Yeah.

S2: December's like the lowest [clicks and drags the earth in its orbit from June to December and then to March and back to December].

S3: Yeah. When you go back to March it gets higher, then it gets lower.

S1: Mmhmm.

In this episode students noticed the difference in the angle of the light rays between summer and winter for the selected city. All students in the group expressed agreement for the idea, and then they continued with the activity without further discussion of the underlying reasons for the difference in the angle of the light rays.

Conceptual goals from self

In this episode, one student in the group spontaneously changed settings in the simulation.

S2: [clicks to load an earth view in a third window that had previously been empty] Hey, that's cool. Look at that.

S1: Oh, whoa! Use your hand, use your hand now.

S2: No, I just want to watch it.

S1: No, I want to see. I wanna use my hand.

S2: We're the closest in June. Dang. We're the closest to the equator in June.

S3: We are?

S2: We're the closest to the equator in June.

S1: [uses gesture control to view simultaneous changing of light ray angle, orbit, and earth] That's so cool.

In this episode one student changed settings in the simulation to investigate an idea that seemed to come up spontaneously. When he loaded the "earth view" he mistakenly identified the line depicting the earth's orbit as the equator. After watching the simulation for a few moments, the student concluded that his city moves closer to the equator in summer and farther from the equator in winter. Another student in the group expressed surprise and interest in this idea ("We are?") while the other group member did not acknowledge the comment.

Conclusions

This study responds to a need to better understand learning processes when students use simulations by showing how students pursue conceptual goals from various sources. These results are important because they show that ideas that were generated from self-selected conceptual goals seemed to be more salient than ideas generated from other sources. Returning to a dynamically emergent perspective of conceptions (Brown, 2014), this may suggest that conceptions from self-selected goals may form stronger "attractor" states for students, and thus, those ideas may be the most salient ones used in explanations provided by the student. This raises new issues for practices such as modeling and explanation with regards to the extent to which learners converge on shared understanding of phenomena. Additional research is needed to further explore connections between the source of conceptual goals, as well as other aspects of learning processes, and student learning outcomes.

References

Brown, D. E. (2014). Students' conceptions as dynamically emergent structures. *Science & Education, 23*, 1463–1483.

NGSS Lead States. (2013). *Next Generation Science Standards: For states, by states*. Washington, DC: The National Academies Press.

Rutten, N., van Joolingen, W. R., & van der Veen, J. T. (2012). The learning effects of computer simulations in science education. *Computers & Education, 58*, 136–153.

Stake, R. E. (1995). *The art of case study research*. Thousand Oaks, CA: Sage.

Acknowledgments

Toward the Design of Scaffolds for In-the-World Situated Science Reflections Through Wearables

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Abstract: This paper presents a study with 38 elementary school-aged children using smartwatches in their everyday lives for reflections on 3 science topics. We analyzed the recordings retrieved to understand what and how children noticed their everyday experience to relate to science. Findings identify the types of noticing 'triggers', common faults in the science reflections, and the nature of the reflections. We discuss how our findings point to recommendations for the design of scaffolds to support situated reflective learning through smartwatches.

Introduction

The need to help students see the relevance or value of science in their everyday lives has long been a goal of both formal and informal education. Curriculum relevant to students' everyday lives may be a way to eventually develop individuals that will form a scientifically literate citizenry, but it is challenging for science teachers to connect formal science concepts taught in the classroom to everyday situations (Cajas, 1998, 1999). We argue that wearable technologies can potentially address the problem of personal relevance in formal science learning by having students reflect on how specific concepts are present in and can be applied to situations and objects that they are familiar with in everyday experience. Our research looks at how wearable devices may be used to enable students to have such situated reflections about science. Through qualitatively analyzing situated reflection recordings made by 38 elementary aged students, we aim to understand what kinds of scaffolds are needed to support students to produce effective science reflections in their day-to-day life.

Theoretical framework

Our research posits that the smartwatch has critical properties that can support out-of-school situated learning, especially in science. Situated learning posits the importance of the "integration of subject-matter knowledge and everyday knowledge…for children's conceptual development" (Hedegaard, 1998). Unlike desktop computers, smartwatches do not require the user to be tethered to a specific location, and when well-designed, may enable situated science reflections. Reflection entails purposeful thinking oriented toward a goal (Dewey, 1997). Moon's 'map of learning' (Moon, 2013) defines five stages of learning that range from the least to the most reflective: Stage 1 – 'taking notice of new information'; Stage 2 – 'Making sense'; Stage 3 – 'Making meaning'; Stage 4 – 'Working with meaning'; Stage 5 – 'Transformative learning'. Using this framework as a starting point, we break down the process of capturing a reflection with a smartwatch as consisting of at least three aspects:

1) Noticing, or being able to identify *what* could potentially relate to science in one's everyday environment – everyday life and everyday environments are noisy, unlike a classroom setting where the focus of attention is deemed to always be on the teacher and on the content to be learned;

2) Determining *how* the identified item interrelate with science – this is dependent upon recollection of the science concept at a specific moment and current level of understanding; and

3) *Deciding* to capture the reflection into the smartwatch – the user must first be motivated to initiate the capture, and second encode the reflection in a format suitable for capture.

Our goal is to understand what kinds of scaffolds need to be designed into a science reflection smartwatch app to support the first two processes. We addressed two research questions: i) What kinds of science reflections do elementary school-aged students capture using smartwatches?; and ii) What kinds of structures are needed to support children's situated reflections through smartwatches?.

Methods and Analysis

We conducted a study in which 38 participants used commercial smartwatches to capture reflections on the science topics of *friction*, *gravity*, and the *oxygen-carbon dioxide cycle* throughout their everyday lives. The study was done in two phases: i) 20 children (12 boys and 8 girls) aged 8 to 11 were invited to a lab to use the Samsung Gear Neo 2; and

Table 1: Summary table

	Friction	Gravity	O_2-CO_2 Cycle
Total no. of recordings	70	19	45
% of recordings that have noticing 'triggers'	77%	79%	71%
Average no. of principles per recording	1.57	1.28	2.90
% of recordings with at least one incorrect principle	41%	32%	48%

ii) 18 children (7 boys and 11 girls) aged 10 to 11 from a local elementary school science class used the ASUS Zenwatach 2. Both watches allowed for 48 hours of continuous use and voice recordings. Students were told to do recordings of whatever they thought could be related to the given science topic in their everyday life over two and half days. A total of 131 recordings were collected and transcribed. The first row of Table 1 shows the total number of recordings for each science topic.

Findings

Table 1 shows the % of recordings motivated by an aspect of the child's observation of the real world; the average number of science principles by topic; and the percentage of recordings with faulty principles by topic. We proposed earlier that situated science reflections involve at least three aspects: noticing science in the world, relating one's observation to science, and being motivated to capture reflections. Our analysis of the reflections led to: 3 categories of noticing science (observation, doing an activity, and engaging in an experiment); 3 categories of inaccuracy of reflections (wrong mental models, lack of knowledge, ambiguity or conflicts). E.g., in the following recording, the child attributed a wrong cause to the science concept: *"The friction of me writing with my pencil since the paper was a solid surface it would not move back."* The 'solidness' of the surface is not the reason why the paper did not slide back; and 4 types of reflection recorded (explanation, reason/cause and effect, use, and question-asking). Each category had sub-categories, shown in Figure 1 with percentages indicating prevalence.

Discussion and conclusion

This study showed that the approach of situated reflection through the smartwatch allows for the integration of science learning and personal relevance, whereas working through a set of application questions in class is far less powerful. Recordings were heavily skewed toward observing one's surroundings for the topic of $O^2 - CO^2$ cycle. For gravity, the emphasis was on observing a specific event, and for friction, reflections happened more while doing an activity. The ease of making situated reflections appears related to the type of content. Friction and gravity are both principles, while $O^2 - CO^2$ cycle is more of a representation. Faulty reflections were caused mostly by gaps in knowledge but over time we expect children to

Figure 1. Types of noticing 'triggers' (top' Types of inaccuracies (middle); Types of application (bottom).

learn more complex models of how the science concepts work. Problems with inaccuracies and lack of clarity in the recordings are more problematic because although the children demonstrated that they can recognize features from an everyday situation and relate them to science concepts, associations made were only general and students failed to retrieve precise factual information about the science concept. Moreover, while the recordings were tremendously rich in terms of application domains, a significant number of reflections tended to be descriptive. We suggest that smartwatch scaffolds are needed to: i) stimulate inquiry-based activities; ii) account for the type of science topic assigned; iii) identify patterns of faults in reflections to request review and recapture; and iv) convey factual information related to the science concept to motivate deeper level reflections.

References

Barnett, S. M., & Ceci, S. J. (2002). When and where do we apply what we learn?: A taxonomy for far transfer. *Psychological bulletin, 128*(4), 612.

Cajas, F. (1998). Using out-of-school experience in science lessons: an impossible task? *International Journal of Science Education, 20*(5), 623-625.

Cajas, F. (1999). Public understanding of science: Using technology to enhance school science in everyday life. *International Journal of Science Education, 21*(7), 765-773.

Dewey, J. (1997). *How we think*: Courier Corporation.

Hedegaard, M. (1998). Situated learning and cognition: Theoretical learning and cognition. *Mind, Culture, and Activity, 5*(2), 114-126.

Moon, J. A. (2013). *Reflection in learning and professional development: Theory and practice*: Routledge.

Room for Everyone? Identification Processes in Crafting

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Abstract: Studies attempting to address the relative absence of women and girls from the STEM pipeline often focus on deficits in the girls themselves, or—slightly less often—on the shortcomings of culture and context. This early-stage interview study starts instead from a positive space of persistence in the mathematical practices of textile crafting and examines the local negotiation of identification processes as compared with those in K-12 math classes.

Introduction

Despite significant gains in K-12 achievement, females[1] in the United States continue to be underrepresented in careers related to science, technology, engineering, and mathematics (STEM) (State of Girls and Women in STEM, 2016). While some studies that address this observation focus on individual traits such as "grit" or "persistence", other scholars seek to understand how women are systematically excluded from STEM-related spaces (e.g. institutions of higher education, tech companies). Such analyses have shown that gendered social processes contribute to women routinely being told, often tacitly, that they do not belong in these spaces (Seron et al., 2016). These analyses shift the onus for change from individual women to institutions, but they still document failure, starting culturally valued spaces and showing how they exclude the participation of women.

In response to these deficit analyses, we offer the counter example of textile craft. Even in the modern day such communities tend to be dominated by—though not exclusively available to—women; furthermore textile crafting practices themselves have been shown to involve mathematics (e.g. Hebb, 2003). These speaces therefore provide a context that potentially shares some similarities with STEM-related careers (i.e. doing math) while presumably avoiding the gendered practices that systematically exclude women.

Furthermore, analyses of these broader gendered social processes often rely on assumptions of cultural uniformity. This assumption is rejected by poststructuralist and intersectional perspectives, which emphasize an individual's position in multiple social streams. Thus, in an attempt to account for the heterogeneity of women's experiences, we start from an interactionist perspective and examine the process of identification more closely. Specifically, we take a view of identification as an interactional achievement (Cobb, Gresalfi, & Hodge, 2009), looking at how *personal identities*—the extent to which a person identifies, complies, or resists—develop in relation to prevailing *normative identities* in a given social context (Cobb, Gresalfi, & Hodge, 2011). Finally, though the theorized site of underrepresentation is in STEM careers, the process of identification with a discipline begins much earlier; thus, we contrast stories of crafting with stories of K-12 experiences.

The current study looks at the experiences of six women as reported in hour-long interviews. Beginning with the identification framework mentioned above, we explore the opportunities to participate in school mathematics and in craft that are described by our participants, and the extent to which individuals come to identify with, comply with, or reject such forms of participation.

Methods

The six interviews included in this analysis were identified as potentially representing a range of identification with mathematics (three answered "yes" to the question "Did you enjoy math in school?" and three answered "no") and are confined to knitting and crochet—two crafts that had overlapping practices. Semi-structured interviews were conducted by one of the first two authors over the phone, audio recorded, and later transcribed by a third party. Transcripts were reviewed by all three authors in four distinct phases of inductive coding.

Table 1: Case Comparisons

Participant	Lucinda	Olympia	Caroline[2]	Mica	Marlo	Paula
Math norms	logical, pattern-driven, sense of a single right answer	concept-driven, sense of mathematics as a constellation of connected topics	sensemaking, particularly to overcome dyscalculia	as a student—rote, repetitive; as a teacher—problem-solving, multiple pathways	solitary, black and white, confusing, anxiety-provoking	speed, natural ability, no clear path

Identification	full identification	full identification	rejected some aspects but identifies with the discipline	ambivalent	full rejection	rejected math, though identified with math-in-science
Crafting norms	seeing things fall into place; putting in the time; using judgment	process-focus; skilled iteration; flexibility	balance; flexibility; fuzziness; fluidity	goal-oriented; crafter as final authority; expertise takes time	many ways to engage; fluid movement between practices	process-oriented; lots of resources; expertise shows in product

Discussion

Across all six interviews, we find remarkable within-person consistency across the contexts of mathematics and crafting. It is not the case, for example, that each woman was performing in one way in math class and in a completely different way in her crafting community. Rather, in each case, the personal preferences that the women described as the basis for their identification, compliance, or rejection of the normative identity was consistent, whether for math or for craft. Participants brought something they felt personally committed to—be it a focus on process, a love of logic, or a deep need for deliberate sense-making—and that was measured against the local normative identity. As regards school mathematics, in two of the cases women rejected the local normative identity of mathematics, resulting in disidentification with mathematics as a discipline. In three cases, individuals identified with the practices of the class. In a final case, one woman was able to carve out her own space in which to identify with mathematics, despite embodying certain conflicts with the local normative identity. As regards crafting, by contrast, all participants were able to carve out their own spaces, without in any way making a less clear commitment to being a certain-kind-of-crafter. Rather, in this space, multiple identities were recognized and valued, and many women even moved fluidly between those practices, while still maintaining a commitment to a dominant preference. Thus we find, in crafting there is remarkable consistency across the normative identities available precisely because those identities are themselves heterogeneous, allowing for the legitimate participation of many different kinds of crafters.

Limitations and next steps

We acknowledge that this is a preliminary sketch. In particular, future work will compare these findings to the larger corpus. Most importantly, however, the specific contribution of gender—to say nothing of race or other identities—is itself undertheorized in this preliminary analysis, largely due to constraints of the data. We see this commitment to outline these higher-level norms as honoring the post-structuralist call to pay attention to within-group differences as a way of resisting dominant narratives of sex-based traits. Still, more work is needed to investigate and document how these identification processes intersect with the social construction of gender and other identities, both within and across these different settings.

Endnotes

(1) We follow Leyva (2017) in using the terms 'females' and 'males' to denote sex or sex categories, and 'women' or 'girls' and 'men' or 'boys' when denoting gender categories. Whilex we aim analytically to focus on notions of gender as a discursive social production, where statistics are based on sex-categorization we acknowledge such through diction.

(2) All names save this one are pseudonyms.

References

Cobb, P., Gresalfi, M., & Hodge, L. L. (2009). An interpretive scheme for analyzing the identities that students develop in mathematics classrooms. Journal for Research in Mathematics Education, 40-68.

Gresalfi, M. S., & Cobb, P. (2011). Negotiating identities for mathematics teaching in the context of professional development. *Journal for Research in Mathematics Education*, *42*(3), 270-304.

Hebb, K. (2003). The Mathematics of Quilting: A Quilter's Tacit Knowledge of Symmetry, Tiling and Group Theory. In Meeting Alhambra, ISAMA-BRIDGES Conference Proceedings (pp. 511-520). University of Granada.

Leyva, L. A. (2017). Unpacking the male superiority myth and masculinization of mathematics at the intersections: A review of research on gender in mathematics education. Journal for Research in Mathematics Education, 48(4), 397-433.

Seron, C., Silbey, S. S., Cech, E., & Rubineau, B. (2016). Persistence Is Cultural: Professional Socialization and the Reproduction of Sex Segregation. Work and Occupations, 43(2), 178-214.

State of Girls and Women in STEM. (2016). Retrieved April 24, 2017, from https://ngcproject.org/statistics.

Uncovering Students' Ecological Knowledge Resources

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Abstract: This paper reports a cognitive resource analysis of middle school students' understanding of energy flow and matter cycling in ecosystems. We discuss students' resources that we uncovered through our analyses, highlighting how those that emerged through analysis of the second cohort of students extend our previous work. Five major topic areas of cognitive resources were identified in one cohort and confirmed in a second.

Introduction

This project focused on the scientific domain of ecosystems, with a special interest in how students understand and think about the flow of energy and cycling of matter. We emphasized the role of prior knowledge in learning and accepted scientific inaccuracies as characteristic of students' initial phases of learning (Smith et al., 1994). Our Knowledge in Pieces (KiP) framework, representing a class of learning theories (Hammer, Elby, Scherr & Redish, 2005; diSessa, 1988; Clark & Linn, 2003), takes a fragmented approach to describing student knowledge. Students' possess knowledge fragments that some call phenomenological primitives (diSessa, 1988), resources (Hammer et al., 2005) or simply ideas (Clark & Linn, 2003).

In previous work, we explored how a KiP framework can be used to examine students' understandings in this domain (Minshew, Barber-Lester, Derry, & Anderson, 2017). In contrast to misconceptions literature, which suggests that learning is a process of replacing misconceptions with expert knowledge (Smith et al., 1994), a KiP perspective allows for the reorganization of resources. In other words, resources are not necessarily extinguished but reorganized when students learn scientific concepts. In this study, we extended a previous analysis (Minshew et al., 2017) to a second cohort of students. The research question was: 1) What resources related to flow of energy and cycling of matter in ecosystems do students in Cohort Two bring with them to the classroom and how do those resources compare to those exhibited by the students in Cohort One?

Research design

Participants were sixth graders (*n* = 208) at a rural STEM-focused middle school in the southeastern United States. Data was collected over two academic years, 2015-2016 (Cohort One) and 2016-2017 (Cohort Two). Our initial analysis (Minshew et al., 2017) based on data from Cohort One was extended by this analysis of data from Cohort Two. Each year a representative sample of 12 students were interviewed before engaging in the Compost Unit. In interviews students explained models they constructed representing their understandings about energy and matter in ecosystems. Interviews were analyzed qualitatively through successive steps of coding, creation of data matrices and summaries.

Results

Our analysis of Cohort Two students' interview data revealed that they had resources in the same major topic areas (*food chains, decomposers, waste, energy*, and *matter)* initially found in Cohort One, providing confirmatory evidence for resources identified in our initial analysis. Analysis of data from Cohort Two also revealed five specific resources that were not initially noted in our analysis of Cohort One. Table 1 provides an overview of both discovered and confirmed resources. Resources in Table 1 are organized by major topic area; columns on the right side indicate in which cohorts a resource was discovered (•), confirmed (☉) or absent (blank).

Conclusions and implications

Our study focused on the knowledge that students brought with them concerning energy flow and matter cycling in ecosystems. Analysis of students' interviews from a model-based assessment task uncovered resources in five major topic areas. These had been previously identified in Cohort One and confirmed by this analysis in Cohort Two. Students in Cohort Two expressed additional specific resources in the topic areas of *energy* and *matter*

which were not initially identified in Cohort One. However, a post-hoc analysis revealed that some of these were present in Cohort One.

The use of a KiP framework to examine student understanding is novel in the science domain of energy and matter in ecosystem. This resource-oriented view of student understanding pushes both researchers and educators to focus on the wealth of experiences that students bring with them to the science classroom. These resources are potentially powerful and important assets to be engaged in the pursuit of advancing scientific understanding.

Table 1: Identified resources related to flow of energy and cycling of matter for both Cohorts One & Two

Topic Area	Resource	Cohort 1	Cohort 2
Food Chains	There is a relationship between sun/sunlight and producers	•	⊙
	Animals eat other animals	•	⊙
	Animals eat plants	•	⊙
	Decomposers are a part of the food chain	•	⊙
Decomposers	Bacteria, worms, and mushrooms are decomposers	•	⊙
	Decomposers break things down	•	⊙
Waste	Animals and humans generate waste	•	⊙
	Some waste can be broken down and is connected to soil	•	⊙
Energy	The sun is central to energy	•	⊙
	Rain and clouds are connected to energy	•	⊙
	Organisms need energy	•	⊙
	Plants need energy to make their own food/perform photosynthesis		•
	Animals eat to get energy	⊙	•
	Electricity is connected to energy	•	
	Decomposers get energy from breaking down dead organisms or organic waste	⊙	•
	Energy flows through an ecosystem	⊙	•
Matter	Everything is matter/matter takes up space	•	⊙
	Matter exists in different states	•	⊙
	There is organic and inorganic matter	⊙	•

References

Clark, D., and Linn, M. (2003). Designing for Knowledge Integration: The Impact of Instructional Time. *The Journal of the Learning Sciences. 12(4),* 451-493.

diSessa, A. A. (1988). Knowledge in pieces. In G. Forman & P. B. Pufall (Eds.) *Constructivism in the Computer Age (pp. 49-70).* Hillsdale, NJ: Lawrence Erlbaum Associates.

Hammer, D., Elby, A., Scherr, R. E., & Redish, E. F. (2005). Resources, framing, and transfer. In J. P. Mestre (Ed.) *Transfer of Learning from a Modern Multidisciplinary Perspective (89-119).* Greenwich, CT: Information Age Publishing.

Minshew, L. M., Barber-Lester, K. J., Derry, S. J., & Anderson, J. L. (2017). Leveraging students' knowledge to adapt science curricular to local context. *Educational Technology & Society, 20(4),* 205-218.

Smith, J. P., diSessa, A. A. & Roschelle, J. (1994). Misconceptions reconceived: A constructivist analysis of knowledge in transition. Journal of the Learning Sciences, 3(2), 115-163. Doi: 10.1207/s15327809jls0302_1

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Technology to Support Students' Learning Mathematics From Other Students Work

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Abstract: This poster reports on a study of a digital formative assessment tool designed to provide rich, formative information to both students and teachers during (and after) classroom instruction. Nine Algebra I teachers participated in a professional development series where they learned to use the tool in their classrooms. Results from student and teacher surveys suggest that the tool was effective for short-cycle formative assessments as well as facilitating mathematical classroom discourse. It also helped teachers display student work to build off their thinking and promote a growth mindset. This study has implications for the design technology and professional development that promote formative assessment, classroom discourse, and growth mindset thinking beyond a math classroom.

Introduction

In the K-12 mathematics progression, algebra presents a unique set of challenges to both students and teachers. It demands that students evolve their thinking from the strictly procedural patterns sufficient to master arithmetic to abstract reasoning needed for algebraic thinking (Vogel, 2008). Algebra interventions focusing on the development of conceptual understanding produce an average effect size almost double that of interventions focusing on procedural understanding (Rakes, Valentine, McGatha, & Ronau, 2010). One suggested approach is that students should be afforded the opportunity to develop conceptual knowledge by modeling their thinking using graphs, tables, and manipulatives (Brenner et al., 1997). Teaching representational fluency is more challenging than teaching elementary procedures because it requires that students apply multiple procedures and connect them to abstract concepts. The platform investigated in this study, "Woot Math Polls," enables teachers to construct rich interactive tasks from an array of digital manipulatives (graphs, tables, algebraic expressions, etc.). It is designed to lower the barriers for teachers to build conceptual understanding using a wide variety of representations and to facilitate richer and more productive interactions between students and teachers.

Leahy and Wiliam (2012) report that the use of 'short-cycle' formative assessments can positively impact student achievement. In general, despite widespread awareness among practitioners of the benefits of formative assessment, there are significant challenges that limit the extent and quality of implementations. Yin et al. (2015) report some evidence that middle school math teachers may find PD on formative assessment more desirable when it is combined with training on a tool that supports the formative assessment activity. In a meta-analysis, Kingston and Nash (2011) report that "Two types of implementation of formative assessment, one based on professional development and the other on the use of computer-based formative systems, appeared to be more effective than other approaches." (p. 28). Woot Math Polls simultaneously turns student devices into clickers and digital notebooks. Students select or enter a response and show their work on a digital scratchpad. Then teachers can project student work for discussion or review it privately after the poll is finished. The tool was designed to support teachers' formative assessment practices and also to promote productive discussions about mathematics in the classroom. This study seeks to understand the affordances and limitations of Woot Math Polls, through the context of professional development seminars with nine algebra teachers.

Study design

Nine mathematics teachers who were teaching one or more Algebra I classes (in 8th or 9th grade) in the fall of 2017 were recruited and enrolled in the study. Teachers participated in four 1-2 hour PD sessions with expectations for use of 5 formative assessment tools (presented at each PD) with their students during the 3 weeks between sessions. The first PD was on offline formative assessments. Before the second session but after exposure to these assessments, students took a pre survey which includes prompts on self-assessment of algebraic reasoning and attitudes towards their mathematics class. During the second and third PD sessions, teachers were trained in the use of Woot Math Polls and its application to formative assessment. At the conclusion of the study, students and teachers took a post survey, teachers participated in a one-hour PD.

Findings

Findings from the teacher survey suggest that the teachers found the prototype for Woot Math Polls to be particularly effective for formative assessment and facilitating classroom discussions about mathematics.

Teachers answered the question "To what extent were you able to use Woot Math Polls effectively for formative assessment purposes in you classroom?" with an average response of 4.1 where 5 is "very effectively" and 1 is "not at all effectively". They also responded to the question, "To what extent were you able to use it effectively for the purpose of having classroom discussions about mathematics?" with an average of 4.0 on the same scale.

In the qualitative responses, it was also clear that teachers found the tool helpful for formative assessment. Coding was used to identify the next most common affordances of the tool. Figure 1 in the poster shows a histogram of code frequency to the 6 qualitative item responses that were coded for each of the 9 teachers. The table shows that teachers most frequently identified being able to promote a growth mindset and changes in student attitudes as an affordance of Woot Math Polls. They also identified using student work and promoting mathematics discourse as frequent benefits of the tool.

Although subtler in their connections to the research questions, student responses still provide helpful insights. Analysis of the 252 student responses to the post survey question "Please describe your thoughts about Woot Math Polls. Was it helpful? If so, why? If not, why not", the code of productive discussions only came up twice (1% of all codes) and, although formative assessment was never mentioned, "provides helpful feedback" and "helpful to see student work" were coded 3 and 10 times respectively for a total of 5%. Even though it is rare that students mention the value of the tool for formative assessment and promoting discourse, the fact that some of them notice this at all is strongly suggestive that it was happening in the classroom and was a change brought about by Woot Math Polls.

Codes also emerged relating to the perceived benefit of seeing student work (4%), promoting growth mindset (3%), and providing helpful feedback (1%) were observed. Although low in frequency, this does show that some students identified benefits of Woot Math Polls that were similar to those the teachers identified.

From the student responses on all Likert-type items on the survey, we also calculated the correlation matrix after correcting for base response style (Javaras and Ripley 2007). We then identified the survey items that most strongly correlated with students attributing greater learning gains to Woot Math Polls. We found that students were more likely to report higher scores for: how much other digital resources helped their learning, how much seeing how peers answered a question helped their learning and how much participating in class discussions helped their learning. The first of these correlations could indicate that some students rank digital tools in general with similar levels of helpfulness. The next two most highly correlated items highlight a connection between Woot Math Polls and mathematical discourse in the classroom and learning from visibility into the work of peers. The latter was, in turn, most strongly correlated with reported gains in "willingness to seek help from others (teacher, peers) when working on math problems."

Conclusion

The findings from this pilot study with Woot Math Polls indicate that approaches that link appropriate technology, manipulatives, and teaching strategies to existing curricula and practices could have promise for improving student outcomes in algebra. Responses from both teachers and students provide evidence that there are opportunities for technology to effectively support and encourage formative assessment and mathematical discourse in the classroom. A follow up randomized controlled trial study is planned in which differences in teaching practices, student attitudes, and student learning are measured as primary and secondary outcomes.

References

Brenner, M. E., Mayer, R. E., Moseley, B., Brar, T., Reed, B. S., & Webb, D. (1997). Learning by Understanding: The Role of Multiple Representations in Learning Algebra. *American Educational Research Association*, *34*(4), 663–689.

Kingston, N., & Nash, B. (2011). Formative Assessment: A Meta-Analysis and a Call for Research. *Educational Measurement: Issues and Practice*, *30*(4), 28–37. https://doi.org/10.1111/j.1745-3992.2011.00220.x

Leahy, S., & Wiliam, D. (2012). From Teachers to Schools: Scaling up Professional Development for Formative Assessment. In *Assessment and Learning* (pp. 49–71). 1 Oliver's Yard, 55 City Road, London EC1Y 1SP United Kingdom: SAGE Publications Ltd.

Rakes, C. R., Valentine, J. C., McGatha, M. B., & Ronau, R. N. (2010). Methods of Instructional Improvement in Algebra: A Systematic Review and Meta-Analysis. *Review of Educational Research*, *80*(3), 372–400.

Vogel, C. (2008). Algebra: Changing the Equation | District Administration Magazine. November 21, 2017

Yin, Y., Olson, J., Olson, M., Solvin, H., & Brandon, P. R. (2015). Comparing Two Versions of Professional Development for Teachers Using Formative Assessment in Networked Mathematics Classrooms. *Journal of Research on Technology in Education*, *47*(1), 41–70.

Playing Well With Others: An Ethnographic Examination of a Cross-Disciplinary Science-Theatre Collaboration

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Abstract: This piece describes a participatory ethnographic study of a cross-disciplinary collaboration between science education researchers and theatre educators creating a science-based play for middle-school youth that aims to dismantle stereotypes about participating in science and becoming a scientist. The ethnography aimed to identify factors that contribute to successful cross-disciplinary collaborations and to understand why interdisciplinary collaboration is essential to designing learning environments that engage students unengaged with or intimidated by typical schooling contexts.

Purpose

Informal learning environments are important and influential spaces that can foster positive attitudes towards science (Bell et al., 2009). In these environments, science can, for instance, be approached through narrative and storytelling, affect, and drama (Owen, 2014). Learning environments that fuse science education with theatre provide a unique and essential learning context for students intimidated by or otherwise disengaged with science in typical schooling environments. These cross-disciplinary designs enable students to reimagine what it means for them to participate in and enjoy science (Long, 2014) and empower students to establish personal connections between the scientific material and their own lives (Ødegaard, 2003).

Despite the benefits of designing learning environments that combine theatre with science education, significant barriers exist to creating and accessing these learning environments in the United States, particularly in public schools. For instance, in the U.S. only 28% percent of secondary public schools with high concentrations of poverty offer theatre-education classes (Parsad & Spiegelman, 2012).

From a design perspective, cross-disciplinary collaboration — particularly communication and establishing expectations — can be especially challenging between scientists and theatre artists, since these two communities generally have vastly different metrics for defining and evaluating "good" work (Friedman, 2013). Despite these challenges, researchers must understand how to foster cross-disciplinary collaborations in order to create new learning environments that benefit more students.

This piece describes a participatory ethnographic study of a cross-disciplinary collaboration between science education faculty and graduate researchers at a research institution, and theatre educators and playwrights from a professional children's theatre in the Northeast United States. The study examines the collaborative efforts of the science- and theatre-education teams throughout the preparation for and execution of the team's first intervention: an original play for middle-school-aged youth aiming to dismantle stereotypes about what it means to "do science," and who can pursue a career as a scientist. The study aimed to (1) examine and identify factors that shaped the collaborative efforts between the two disciplinary teams; (2) understand how their collaborative efforts influenced the creation and implementation of the intervention; and (3) determine implications for designing interdisciplinary science-based learning environments.

Conceptual and analytical frameworks

The conceptual framework was grounded in *collaborative creativity,* a shared creation or discovery made by two or more individuals incapable of making that discovery on their own (Hargrove, 1998). The data analysis was informed by *activity theory*, a psychological and multidisciplinary theory with a naturalistic emphasis that offers a framework for describing activity and provides a set of perspectives on practice that interlink individual and social levels (Engeström, 1999). Here, the author was interested in understanding how the collaboration between members of the science and theatre teams impacted the nature, structure, and form of the play. Using activity theory, the author discerned how power and leadership was distributed through the actions, activities, and goals of participants throughout the creation and implementation of the play.

Inquiries and data sources

Data consisted of the ethnographer's notes from group meetings and three semi-structured interviews with participants (*N*=7) — the two principal investigators (one a science education faculty member, one the producing artistic director at the partnering children's theatre), another science education faculty member, a seismologist, the playwright, and three graduate student researchers. The author conducted these interviews at the beginning, middle, and end of the play's development and implementation, which spanned 14 months, from

August 2016 to October 2017. The interview questions encouraged participants to reflect on the cross-disciplinary collaborative process; the creation, application, and effectiveness of the intervention; and the evolution of participants' thoughts about working with individuals from different disciplines. These questions aimed to capture a holistic view of the collaborative process. The participatory nature of the study emerged when the ethnographer, also the lead graduate student on the project, implemented participants' ideas after each interview.

Results

Preliminary analysis using a grounded theory approach — specifically, Initial Coding and In Vivo Coding (Saldaña, 2015) — identified three factors as crucial for a successful cross-disciplinary collaboration: (1) frequent and clear communication, (2) firm establishment of common goals at the beginning of the process, and (3) a willingness to "hear all voices." In fact, it was this openness of the team that appeared to mediate the science/story tension that drove much of the structure, nature, and design of the learning environment. Two participants explicitly acknowledged the importance of having a liaison (the ethnographer, in this case) who was comfortable working within both science and theatre education domains and who communicated regularly with both teams. Although five participants explicitly mentioned the benefits of having frequent face-to-face meetings, another suggested that frequent meetings are tedious and labor-intensive, preferable only in theory. Figure 1 captures how these elements interact during the collaborative process and illuminates whether these elements should be acted upon in person or remotely.
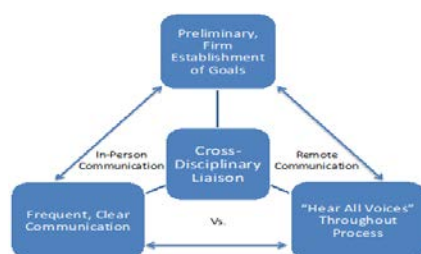

Figure 1: The interaction of preliminary findings from this study.

Significance

This work can provide guidance for future cross-disciplinary education collaborators seeking to examine and implement necessary elements for successful cross-disciplinary collaborations, particularly in reference to an intermediary who understands the working and communication styles of both or all disciplines. It also demands that future researchers further examine the roles that personality, identity, and disciplinary culture play in cross-disciplinary collaborations, and to understand how these factors can inhibit or further the design and implementation of learning environments for students.

References

Bell, P., Lewenstein, B., Shouse, A., & Feder, M. (Eds.). (2009). *Learning science in informal environments: People, places, and pursuits*. Washington DC: National Academies Press.

Engeström, Y. (1999). Innovative learning in work teams: Analyzing cycles of knowledge creation in practice. *Perspectives on Activity Theory*, 377–404.

Friedman, A. J. (2013). Reflections on communicating science through art. *The Museum Educator*, 56(1), 3–9.

Hargrove, R. A. (1998). *Mastering the art of creative collaboration*. New York: McGrawHill.

Long, S. (2014). The matchmakers: Exploring science and society stories with scientists. *Dimensions*, 34-37.

Ødegaard, M. (2003). Dramatic science. A critical review of drama in science education. *Studies in Science Education*, 39, 75–101.

Owen, T. (2014). Stories make science stick. *Dimensions* (July/August), 22-25.

Parsad, B., & Spiegelman, M. (2012). Arts Education in Public Elementary and Secondary Schools: 1999–2000 and 2009–10. *NCES 2012-014*. National Center for Education Statistics.

Saldaña, J. (2015). *The coding manual for qualitative researchers*. Sage.

Pedagogically Informed Peer Teaching as a Mechanism for Systematically Maximizing Sociocultural Theories of Learning

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Abstract: Those who have witnessed peer-to-peer teaching are familiar with the typical ritual: "This is how you do it… do you get it?" followed by a head nod from the learner and they move on. In a world where student discourse is increasingly the vehicle for learning, it is critical that we give students tools to engage effectively with each other's thinking. Over the past year, I developed and tested a web-based application that successfully shifts how students think about peer-to-peer tutoring.

What I propose to share in an ICLS poster session is an activity system that acknowledges both the constructive nature of conceptual change and the critical importance of social interaction for learning. I call it *pedagogically informed peer teaching.* This activity system is contingent upon students' abilities to learn and enact strong pedagogy, which I have been training students to do using online simulations and tutorials over the past year. In my poster session, I would share the results of a pilot study completed last spring.

Theorizing a more effective activity system for promoting learning

Socioculturalists assert that learning is a process of reciprocal transformation of self and environment, mediated by the tools, signs, and people around a learner. Critically, the nature of those tools and signs that mediate activity, along with the specific goals that focus activity, produce varying forms of practice and learning. For socioculturalists, all learning is culturally mediated and interactionally dependent. While socioculturalists recognize the central role of unique cultures and the reciprocal influence of culture on person and person on culture, they often abstain from offering a granular recipe for the process of learning. For Vygotsky (1986), learning occurs through interaction with a more knowledgeable other, through using tools and signs at the ready, and internalizing those ideas and processes that began as social and external.

Mere exposure to knowledgeable others is not enough to promote learning, though. As Vygotsky (1986) recognized, abstract thought necessitates verbalizing, a process whereby learners use language as a tool to connect complex ideas. Dialogic instruction, frequently performed by learner-centered teachers and expert tutors (Lepper, 2002), supports students in overcoming the type of disequilibrium students experience when encountering new and complex ideas that do not fit with their existing schema. Effective questioning makes visible to a learner how their current schema support and contradict the acquisition of new ways of thinking. Many expert teachers are currently being trained to use "talk moves" (Chapin et al., 2009) to elicit student thinking, probe it, and prompt reflection of it to support this process of overcoming disequilibrium, i.e. learning.

However, teachers in classrooms with 30 students cannot feasibly perform this type of questioning for each of their students who needs support. Fortunately, classrooms have many students with some degree of mastery over the content at hand. These students are the most underutilized instructional resources in classrooms, as they represent knowing others who can stretch the zones of proximal development for their peers. But we should not assume that students with mastery over content are good teachers. Studies have shown that when given a chance to teach, student tutors tend to do much more explaining than tutees (King, 1997), place minimal demand on tutees when questioning (Graesser et al., 1995), and rarely stimulate deep-level reasoning or do much to monitor the understanding of tutees (Graesser et al. 1995; Roscoe and Chi 2007).

If students learn through a process of overcoming disequilibrium, if overcoming disequilibrium is supported by effective questioning from a knowledgeable other, and if peers are the most readily available option for performing such questioning, we must discover ways of training students to serve in such a capacity for one another. This is the mission of this research project.

Design principles for training pedagogically informed peer tutors

I designed the PeerTeach web application to train students to use evidence-based discourse tools (or "talk moves") to support the learning of their peers. As a design-based research project (Brown, 1992), this application is being developed through an iterative process of implementation, analysis, and adaptation. The goal is for PeerTeach to become a robust intervention that prepares students to be effective tutors for one another. At a high level, the system is predicated on the theory that students will become more effective real world tutors if they have the opportunity to 1) practice noticing and tagging high-leverage teaching moves during animated tutoring sessions and 2) practice using those same high-leverage teaching moves when

selecting the utterances of a virtual tutor in a game-like virtual tutoring experience. Sherin's (2005) noticing framework asserts that teachers (or in this case, tutors) must attend to important teaching moments, relate them to a useful pedagogical framework, and act based on pedagogically sound reasoning. Practicing such noticing should provide useful preparation for using better teaching moves. Practice using better teaching moves in simulated contexts provides necessary application. Seeing realistic responses from an automated virtual learner, in addition to symbolic representations of that virtual character's learning, reinforces belief and fluency around the new pedagogy, which I predict will translate to real world tutoring improvement.

Last year, data was collected to test the first aspect of the aforementioned theory of change: can minimal practice noticing high-leverage teaching moves in a mediated virtual space prepare students to observe with a pedagogically trained eye. Three groups of students were assessed before and after the PeerTeach noticing intervention on their abilities to tag "good" teaching moves in realtime; their scores were compared to those of math teachers who recently graduated from a prestigious, apprentice-based Masters and credentialing program.

The results in Figure 1 suggest students across all three groups improved in their ability to accurately identify high quality moves as good, but lag far behind adult teachers. Notably, students in both East Bay, California groups identified dramatically fewer high quality moves as good than did the students in Harlem, New York, who all had prior experience as both tutors and tutees. On average, the Harlem students identified 3.18 high quality moves as good in the post-assessment while the East Bay students identified, on average, only 1.23, suggesting the importance of tutoring experience for being able to analyze observed tutoring.
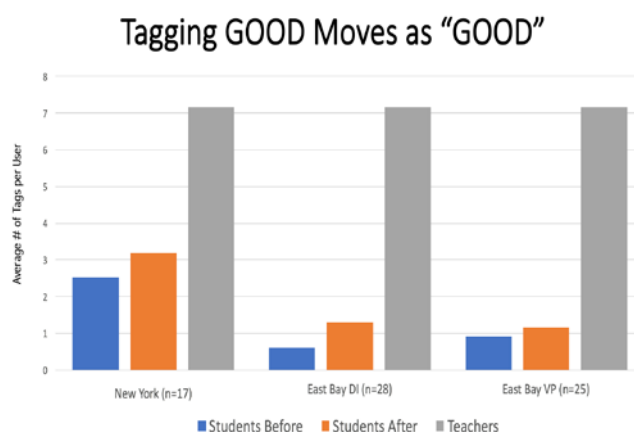

Figure 1. Tagging GOOD Moves.

This is the first in a series of studies aimed at identifying which aspects of the PeerTeach training platform are effective mechanisms for improving students' abilities to notice good teaching, choose effective teaching moves in virtual simulations, and eventually to tutor more effectively in real life. This poster session is intended as an exploration of this proposed activity system as an optimized model of learning and the student training it requires. The discussion will address both theoretical and practical points, grounded in the actual technology of PeerTeach and the data that emerged as students interacted with it.

References

Brown, A. (1992). Design Experiments: Theoretical and Methodological Challenges in Creating Complex Interventions in Classroom Settings. The Journal of the Learning Sciences, 2(2), 141–178.

Chapin, S. H., O'Connor, C., & Anderson, N. C. (2009). Classroom discussions: Using math talk to help students learn, Grades K-6. Math Solutions.

Graesser, A. C., Person, N. K., & Magliano, J. P. (1995). Collaborative dialogue patterns in naturalistic one-to-one tutoring. Applied cognitive psychology, 9(6), 495-522.

King, A. (1997). ASK to THINK-TEL WHY: A model of transactive peer tutoring for scaffolding higher level complex learning. Educational psychologist, 32(4), 221-235.

Lepper, M. R., & Woolverton, M. (2002). The wisdom of practice: Lessons learned from the study of highly effective tutors. Improving academic achievement: Impact of psychological factors on education, 135-158.

Piaget, J., & Cook, M. (1952). The origins of intelligence in children (Vol. 8, No. 5, p. 18). New York: International Universities Press.

Roscoe, R. D., & Chi, M. T. H. (2007). Understanding Tutor Learning: Knowledge-Building and Knowledge-Telling in Peer Tutors' Explanations and Questions. Review of Educational Research, 77(4), 534–574.

Sherin, M. G., & Van Es, E. A. (2005). Using video to support teachers' ability to notice classroom interactions. Journal of technology and teacher education, 13(3), 475-491.

Vygotsky, L. S. (1986). Thought and language (rev. ed.).

Characterizing Chemistry Practices:
How Teachers Design and Perform Chemistry Experiments

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Abstract: This study aims to characterize the complicated nature of science practices in an open-ended inquiry chemistry lab in which students participate in group work. In this study, the complicated nature of science practices is framed and traced by drawing on the notion of "science as a mangle of practice." From this notion, the dialectical relationship between human and non-human agency constitutes science through the dynamic process of resistance and accommodation. Tackling these dialectical agencies may allow us to effectively capture a snapshot of students' lab activities and science practices. Methodologically, the study demonstrates how the combined use of social network analysis and discourse analysis may provide insight into the complicated nature of this mangled science practice. The study also explores the advantages of using a 360 VR camera, providing an immersive view while reducing blind spots.

Student assessment on inquiry-oriented labs tends to focus on the understanding of science concepts while essentially ignoring the practical aspects, such as asking questions, designing experiments, and conducting investigations. Unfortunately, there is little understanding of how to integrate content knowledge with science practices. Today, the science content knowledge learned and procedural skills acquired are assessed separately; however, these two aspects need to be understood and analyzed in a dialectical manner in order to effectively address students' engagement in science practice. Importantly, while the understanding of content knowledge from lab activities often focuses on individual learning as the unit of analysis, collaborative work requires a look at group interaction in order to understand students' science practices.

Pickering (1995) conceptualized doing science as a dance of material and human agency in a dialectical relationship. Scientists enact their agency by making hypotheses and designing experiments to understand material phenomena. However, most material phenomena take time to understand fully, and scientists face many difficulties. To overcome such resistance from the material world, scientists reconsider and revise both their material parts (procedures and equipment) as well as their existing scientific knowledge. This integration represents what science practices actually look like. Pickering's idea of science practice aligns with social-cultural learning perspectives in that conceptual and social practices (human and material agencies) are integrated in a given community to evolve the disciplinary field (Manz, 2015). Both Pickering's 'mangle' view and social-cultural learning perspectives demolish the dichotomy between conceptual knowledge and practices. Methodologically, it is challenging to tackle the dialectical relationship between human and non-human agency, along with the process of resistance and accommodation. To address this difficulty with our study, we followed three phases for conducting open-ended inquiry chemistry labs. First, we created an initial design in which students conducted the experiment. Second, when things did not go as planned, we observed students' responses. Third, we sought to determine if students revised the experiment. We observed the resistance and accommodation between material (experimental procedure) and human agency (students as scientists, who design and conduct experiments). To align with the agency-relation view, a linkage analysis used to connect material and human agency while describing changes in agency relationship. Consequently, we utilized a method that combines discourse analysis (DA) and social network analysis (SNA) (author(s), 2015).

The study addressed the following two questions: How do pre-service chemistry teachers initiate their experiment design, change and update their experiments when they do not go as planned, and revise them? How do group interactions differ between groups when conducting experiments?

Methods and analyses

This 15-week qualitative study sought to gain an in-depth understanding of how 20 pre-service teachers plan and conduct their open-ended inquiry experiments. After conducting guided, basic experiments, they were given a week to design a freestyle open-ended experiment. The teachers also were asked to include phone-recorded video clips and pictures in their reports in order to increase the records' accuracy and to supplement note-taking. An integrated 360 VR camera was used to observe verbal and non-verbal interactions among pre-service teachers. The camera enabled the researchers to trace multi-layered interactions during experiments. That is, the camera captured both the verbal talk among students and the experimental procedure (e.g., how students dealt with the equipment as well as how they observed and measured phenomena). The 360 VR camera records an

immerse-view, making it easier to observe multiple-layered actions and verbal interactions without confusion (See figure 1, for comparison between a single lens camera and 360 VR camera). The panoramic overview of this camera also allows one to navigate science with multiple points of views, instead of having a single point of view captured by a traditional video camera. With the 360 VR, a student's movement is literally indexed spatially for subsequent verbal and non-verbal interactions (Pea, 2006). For the DA, two of five groups were selected for detailed analysis. We transcribed all verbal interactions, gestures, and facial expressions before developing free codes based on our readings of these transcripts several times. We finalized these codes after extensive discussion between the researchers: an expert in science education, three experienced science teachers, and a graduate student. To trace changes in human and non-human agency, we created detailed categorizations of how students responded to failed experiments, resulting in eight codes. For the SNA, we utilized UCINET and NetDraw as well as a matrix displaying basic interactions among participants.

Findings and discussions

Scientists actively respond to the resistance of material agency because they have a clear epistemic goal, to construct new scientific knowledge. Having students conduct a freestyle, open-ended experiment enables pre-service teachers to establish a similar epistemic goal—allowing them to create and conduct an experiment based on their own curiosity. They also are expected to negotiate and interact with uncertain and resistant phenomena from their experiments, calling on their ability to engage and integrate their conceptual knowledge with their practice. However, a few issues emerged in terms of the pre-service teachers' engagement in free-style, open-ended inquiry. These pre-service teachers selected the topics of their experiments, driven by external factors rather than their own curiosity about natural phenomena. Rarely did we see the emergent, ongoing negotiation between human agency and material agency resulting from unexpected and mysterious situations. One of the reasons for this failure was that pre-service teachers might not make a strong connection between their conceptual idea (content knowledge) and experimental design (what and how to measure and observe). When they met unexpected, unsuccessful situations, most pre-service teachers decided to repeat the exact same experiment without considering the possibility of revision. This decision diverges from how scientists handle their challenges: scientists revisit and revise both their conceptual knowledge and their material procedures. Because their epistemic goal was not to construct new knowledge, pre-service teachers rarely constructed knowledge or negotiated between human and material agency. To make inquiry-oriented experiments meaningful for students, it seems essential to have them establish an epistemic goal as scientists do. In essence, the purpose of conducting inquiry-oriented, freestyle experiments lies in experiencing a scientist-like curiosity about natural phenomena, directly connected to the establishment of an epistemic goal. Despite some disappointing findings, we noted some progress over the course of the semester. At the beginning of the semester, one group leader tended to decide on issues and proceed with tasks and experiments accordingly. The leader made decisions in isolation when things did not go successfully. However, a couple of groups differed in important ways. When the experiments failed, these groups took time to reflect and incorporated other members' ideas and opinions more actively. More members engaged in the experiments, leading to more ideas and trials. A student who pitched in with the experiments relatively late pointed out that she felt stronger responsibility, attachment, and ownership. In this study, the researchers designed more authentic, freestyle inquiry-oriented experiments and analyzed pre-service teachers' science practices. The description of pre-service teachers' practices indicates that borrowing a form of practice (e.g., freestyle, open-ended experiments) might not work as desired. It seems necessary to establish epistemic goals in order to enact the dance of agency; meanwhile, genuine curiosity toward the natural world must be triggered and activated as part of lab activities.

References

Ryu, S.& Lombardi,D. (2015) Coding Classroom Interactions for Collective and Individual Engagment. *Educational Psychologist, 50* (1), 70-83.

Manz, E. (2015). Resistance and the development of scientific practice: Designing the mangle into science instruction. *Cognition and Instruction*, *33*(2), 89-124.

NGSS Lead States. (2013).Next generation science standards: For states,by states. Washington, DC: The National Academies Press

Pea, R.D., 1321-1393. (2006). Video-as-data and digital video manipulation techniques for transforming learning sciences research, education, and other cultural practices. In J. Weiss (Ed.), *The international handbook of virtual learning environments* (pp. 1321-1393): Springer.

Pickering, A. (1995). *The mangle of practice: Time, agency, and science*. University of Chicago Press.

Assessment in a Digital Age:
Rethinking Multimodal Artefacts in Higher Education

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Abstract: Higher education institutions increasingly expect students to work effectively and critically with multiple modes, semiotic resources, and digital tools. However, assessment practices are often insufficient to capture how the complex, collaborative nature of multimodal artefacts represents disciplinary knowledge. Drawing on theories and practices related multimodality, mobility, and place, this study offers insight into the design and assessment of students' digitally mediated work.

Introduction

Digital assignments are increasingly part of the landscape of higher education, with educators in many disciplines seeking to scaffold students' competence and engagement with social, visual, interactive, and multimodal representations. However, assessment rubrics for such assignments have not always kept pace: teachers may be consciously or unconsciously working with "a paradigm of assessment rooted in a print-based theoretic culture" (Curwood, 2012, p. 232). Consequently, technical and compositional assessment criteria do not always address the richness and complexity of multimodal work. Without criteria that can account for this complexity, instruction, feedforward, and feedback cannot fully support students to develop their communicative capacities for future work in digital spaces.

This poster describes work in progress from a collaborative project between members of the Centre for Research into Learning and Innovation (The University of Sydney, Australia) and the Centre for Research in Digital Education (University of Edinburgh, UK). The aim of the research is to develop new insights into the nature of digital assignments and methodologies for their design and assessment, drawing on theories of place-based learning, mobility, and multimodality. The project addresses the following research questions:

1. How can theories of mobilities and place-based learning inform research into and assessment of multimodal student work?

2. How do university students use assessment criteria for self and peer assessment of multimodal work?

3. How do teachers in higher education effectively design and assess students' multimodal work?

Theoretical framework and literature review

Multimodality and multimodal composition: From theory to practice

Learning in a digital age involves the creation and assessment of multiple, multimodal, and multifaceted textual representations. Informed by theories of multimodality and place-based learning, the construction of multimodal texts includes decisions related to the presence, absence, and co-occurrence of alphabetic print with visual, audio, tactile, gestural, and spatial representations (Cope & Kalantzis, 2009). Whilst learning and literacy are still grounded in decoding, comprehension, and production, the modalities within which they occur extend far beyond written language. As Curwood (2012) notes, a focus on the meanings of multimodal student texts has been a central emphasis of work in this area, but there is still a need for more nuanced understanding of the "complex ways in which technical skills, composition elements, modes, and meaning interact" (p. 242). Greater attention to materiality, including artefacts (Pahl & Rowsell, 2011), movement (Leander & Vasudevan, 2009), and place (Ruitenberg, 2005) enriches this understanding, and we argue that the inclusion of multimodal compositions in formal learning environments needs to consider how the conceptualisation, design, and assessment of such texts shape teaching and learning.

Innovative digital assessment within higher education

Higher education institutions around the world are increasingly incorporating digital tools, spaces, and resources to support teaching and learning, and prepare graduates to work with technology, engage with multimodal artefacts, and be leaders within their respective fields (Adams Becker, Cummins, Davis, Freeman, Hall, Giesinger, &Ananthanarayanan, 2017), including in assessment tasks. Many teachers in higher education are seeking new approaches to incorporating technology into disciplinary learning, assessing collaborative, digitally

mediated work, and facilitating student learning across modes, tools, and semiotic resources. With assessment, grade descriptors, rubrics, and exemplars are commonly used to increase the transparency of assessment standards and assist students to develop assessment literacy, yet we argue that teachers and students alike must engage in meaning making with assessment expectations and standards. We suggest that teachers within higher education need to consider how to create a dialogue with students around assessments.

Methodology

Over two semesters in 2017 and 2018, this project analysed, in depth, the creation and assessment of work in undergraduate classes at the University of Sydney with 130 total students. The instructions given to students were to work in pairs to create a three-minute film about their "Australian cultural experience", including structured narrative, interviews, cinematic elements, and a reflective account of the process. The initial stage of the research involved analysing existing processes and assignments, conducting interview and focus groups with students, interviews with tutors, and developing an assessment framework that uses multimodal and place-based analysis to understand student learning. Through the development of an innovative multimodal assessment framework, we are redesigning, implementing, and analysing a new rubric in relation to the task, and comparatively studying students' developing understanding of multimodality and course content.

Emergent findings

In this section of our poster, we focus on the nature of the assignment rubric and how tutors and students engage with this, drawing on our preliminary analysis of interviews, artefacts, and assessment guidance. The rubric for this multimodal assignment – a three-minute film – carefully breaks down the different elements the students are expected to include in their assignment, under the headings of 'cultural narrative experience', 'cinematic elements', and 'collaboration', with three categories for each criterion ('does not meet', 'meets' and 'exceeds'). The criteria can usefully be characterised as an act of 'decomposition' (Bateman 2012, p.18) – where a holistic view of the multimodal artefact is broken down to focus on specific features or compositional elements (for example use of lighting, diegetic and non-diegetic sound, and transitions).

The tutor described an iterative process for assessing student work that aligns with the rubric but also attempts to achieve this holistic view. First, he watched all videos without making notes, so as to focus on overall impressions and affective aspects. On the second viewing, the tutor took notes according the rubric and allocated a mark to each film. On the final viewing, he made some adjustments to the marks and comments as needed. The question of what can be contained within the rubric and what, by necessity, goes beyond it in these types of assessments, is central. The rubric guided students in the use of discipline-specific vocabulary and highlighted the importance of collaboration in reflecting on the meaning of Australian culture and representing it within a multimodal composition, yet students also felt that it 'left a lot of room for interpretation'.

The next phase of the project will explore how this assignment rubric and support for students around the assignment can capture more nuanced elements, including how compositional choices build or create tensions with the narrative, how to use multimodal elements to critique oversimplification of cultural meanings, and how to construct multimodal arguments. This revised rubric will then be implemented in the subsequent semester to gain insight into how multimodal composition can be effectively assessed within higher education.

References

Adams Becker, S., Cummins, M., Davis, A., Freeman, A., Hall Giesinger, C., and Ananthanarayanan, V. (2017). *NMC Horizon Report: 2017 higher education edition.* Austin, TX: The New Media Consortium.

Bateman, J. (2012). The decomposability of semiotic modes. In K. O'Halloran and B. Smith (Eds.), *Multimodal studies: Exploring issues and domains*. New York: Routledge.

Cope, B. & Kalantzis, M. (2009). A grammar of multimodality. *International Journal of Learning, 16* (2), 361-425.

Curwood, J.S. (2012). Cultural shifts, multimodal representations, and assessment practices: A case study. *E-Learning and Digital Media, 9*(2), 232-244.

Leander, K. M., & Vasudevan, L. (2009). Multimodality and mobile culture. In C. Jewitt (Ed.), *Handbook of multimodal analysis* (pp. 127-139). New York, NY: Routledge.

Pahl, K.H. & Rowsell, J. (2011). Artifactual critical literacy: A new perspective for literacy education. *Berkeley Review of Education, 2*(2), 129-151.

Ruitenberg, C. (2005). Deconstructing the experience of the local: Toward a radical pedagogy of place. *Philosophy of Education Archive*, 2005, 212-220.

Engaging With Climate Change as a Socioscientific Issue in an Informal Science Learning Environment

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Abstract: In this study, we discuss an informal science learning environment that was designed to support student engagement with climate change as a socioscientific issue (SSI). We explore how engaging with climate change as an SSI in this context helped make student ideas more central and simultaneously strengthened students' science content learning. These research findings point to the potential value of the design of this learning environment for engaging students in meaningful learning around climate change.

Introduction

Prior research has shown that socioscientific issues, social dilemmas with links to science, "can provide a forum for working on informal reasoning and argumentation skills, [Nature of Science] conceptualizations, the evaluation of information and the development of conceptual understanding of science content" in science education (Sadler, 2004, p. 533). In this study, we discuss a learning environment that was designed to support student engagement with climate change as a socioscientific issue (SSI), exploring how student engagement with climate change as an SSI was supported and what learning opportunities were afforded to students. We found that focusing on climate change as an SSI in this learning environment helped make student ideas central and strengthened students' science content learning. In particular, we saw that discourse around social aspects of climate change, focusing on anthropogenic causes and solutions, supported students in developing their scientific understanding and that student ideas were taken up by facilitators in these instances. Our findings point to the potential value of this learning environment design for supporting meaningful learning around climate change.

This study takes the perspective that meaningful science education involves learning that holds value in students' lives by supporting and empowering students in the choices they make and the actions they take. Drawing on sociocultural theories (e.g., Lave and Wenger, 1991), research suggests that science education should be relevant for students' lives, build on student ideas and address science learning in its sociocultural context, rather than focusing *primarily* on de-contextualized scientific content knowledge which may be more removed from students' experiences (e.g., Birmingham & Calabrese Barton, 2014). Designing learning environments that explicitly support engagement with socioscientific issues (SSIs) is one such possibility for making science learning more relevant for students (Sadler, 2004). In the context of learning about climate change, providing pathways for students to engage with the sociocultural context of science is critical for meaningful student learning (Walsh & Tsurusaki, 2014). Climate change is an SSI that has far-reaching impacts on people and ecosystems across the globe (National Research Council, 2012), and we take the perspective that learning environments should support students in grappling with this complex SSI in a way that is relevant in their lives and solution focused, in contrast to ways that are more de-contextualized.

Methods and context

This research was conducted during a week-long summer program in the Western United States in which high school students worked collaboratively in small teams, with the support of a science mentor and a film mentor, to produce a film about climate change as it relates to and/or impacts participating students' lives. Students attend a short climate change workshop and then generate and develop a film topic, conduct scientific research on their topic, create a storyboard and script, interview experts, film scenes, edit their film and screen the film for an audience. Program student participants were ages 14-17 and attended the program as part of a summer science program. Participants self-identified with a wide diversity of racial backgrounds, with a majority of participants identifying as Hispanic/Latino or Native American. Many participants indicated an interest in science and/or film prior to participating in the program. Science mentors were graduate students studying chemistry or geology and the majority of mentors identified as White. All names of participants in this paper are pseudonyms. Multiple data sources were collected during the workshop including pre- and post-surveys, field notes, interviews, and artifacts. Field notes were conducted by the first author who took the role of a participant observer (Spradley, 1980). This poster presents the results of an interpretive case study (Yin, 2009) which looked at how one group of students and their science mentor engaged with climate change as an SSI while developing their film.

Findings

In presenting the case study of one climate change film group, our findings suggested this learning environment supported student engagement with climate change as an SSI, particularly by supporting student discussion about human contribution to climate change and ways that humans can address climate change. We found that this learning environment provided a way for students to engage with climate change from a scientific perspective in an authentic, purpose-driven way. Moreover, by focusing on climate change as an SSI, student ideas were made central in discussions within the film group. This film group consisted of four high school students, Lucas, Teresa, Amanda and Mateo, and their science mentor, Josh and film mentor, Amy. On day one of the week-long program, the film group quickly began discussing ideas for their film. Josh asked students to reflect on the ways that people who live in the city that the students are from are contributing to climate change, prompting the group to engage with climate change as an SSI. One student, Lucas, suggested that smoking may be a contributing factor, while another student, Teresa, suggested that her community did not contribute very much towards environmental problems because few people drive cars, there were very few factories in her city, not very much trash and people did not waste water on their yards. This conversation turned to a more general discussion of what contributes to climate change as the group continued to discuss what they wanted to present in their film, and students discussed food choices (considering the role of eating meat and the impact of packaged food vs. "healthier" options), non-renewable vs. renewable energy sources, and how trash is dealt with, whether it is littered or recycled. As students shared their ideas about environmental actions, their science mentor Josh continued to ask questions about their ideas and created a category ("Activism") on the chalkboard, listing the ideas that students were suggesting.

While discussing climate change as an SSI, the group engaged in scientific discussion that centered around or built off of the social aspects of SSI discourse. As a participant observer, the first author talked with one student, Lucas, during the research section about carbon footprints: the amount of carbon dioxide emissions associated with making something (e.g. growing a pound of strawberries) or doing something (e.g. driving a car 50 miles). She had pulled up an e-book about carbon footprints, to use as a starting point for ideas for their research. As the first author and Lucas skimmed through the book, Lucas noticed that one of the topics was the carbon footprint of sending a text message. He asked the first author and science mentor how there was a carbon footprint associated with text messages. The group had just been talking about carbon emissions of fossil fuel burning, and Lucas asked about how there was smoke associated with the text message, appearing to ask how this was connected to the carbon dioxide emissions the group had just discussed. This led to a second, more in-depth conversation about energy from power plants and burning coal and other fuels, and ultimately Josh talked with Lucas and the first author about the difference between visible smoke, made by incomplete combustion, and greenhouse gases that we cannot see, then discussed energy reflection and absorption with Lucas. Other discussion topics during and following the conversation about the anthropogenic causes and solutions to climate change included the "10% rule" (energy movement up trophic levels in an ecosystem), mechanisms by which cows emit methane and how coal is used as an energy source to generate electricity. This learning environment supported discussions of scientific content that appeared to be largely driven by student questions and ideas related to climate change as an SSI.

Conclusion

In this case study, we saw that students contributed many ideas when discussing climate change as an SSI and that these ideas, taken up by the film group science mentor, were generative of further scientific discussion which was afforded by the particular approach of this program. Supporting student engagement with climate change as an SSI appeared to create an opportunity for more meaningful learning in this informal science context. Rather than encroach on other important goals for scientific learning, these findings suggest that designing for SSI engagement with climate change can promote scientific understanding for students in a meaningful way.

References

Birmingham, D., & Calabrese Barton, A. (2014). Putting on a green carnival: Youth taking educated action on sociscientific issues. *Journal of Research in Science Teaching*, *51*(3), 286–314.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge Univ. Press.

National Research Council. (2012). *Climate Change: Evidence, Impacts, and Choices*. National Academies Press.

Sadler, T. D. (2004) Informal Reasoning Regarding Socioscientific Issues: A Critical Review of Research. *Journal of Research in Science Teaching, 41*(5), 513-536

Spradley, J. P.(1980) Participant Observation. *Wadsworth, Belmont, USA*.

Walsh, E. M., & Tsurusaki, B. K. (2014). Social controversy belongs in the climate science classroom. *Nature Climate Change*, *4*(4), 259-263.

Yin, R. K. (2009). *Case study research: Design and methods fourth edition*. Los Angeles and London: SAGE.

Activity Systems Analysis of the Social Practices by Low-achieving Students in a Knowledge-Building Environment Augmented by Reflective Assessment

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Abstract: This study aimed to understand the dynamics that characterized the social practices developed by low-achieving students in a knowledge-building (KB) environment augmented by reflective assessment (RA), using activity systems analysis (ASA). The participants were a class of 20 Grade 11 low-achieving students working with an experienced teacher. Various classroom data was collected and analyzed. Findings indicated that, the students' activities were mediated by: opportunities for collective reflection, the framing of data-driven collective discourse improvement and the development of new skills and interests. Pedagogical implications for future implications were also discussed.

Introduction

This study aimed to use ASA (Yamagata-Lynch, 2010) to analyze the social practices developed by low-achieving students, and to understand the dynamics and tensions that characterized the social practices. The study was part of a larger study that investigated the design, process and effects of KB environments augmented by RA on low-achieving students. The following research questions were investigated:

1) What was the nature of social practices from a cultural historical activity theory (CHAT) perspective?

2) What were the characteristics of the social practices from a CHAT perspective, and how did these characteristics develop?

Methods

The study was conducted at a Band-3 school in Hong Kong. The participants taking a visual-arts course inquired the topic of "design" with one-hour lesson each week in five months. The teacher used a three-phase pedagogical process to familiarize the students with knowledge building, as described in detail by Yang, van Aalst, Chan, & Tian (2016). We analyzed the following five interrelated sets of qualitative data: classroom observations, artifacts of students' work, interviews and questionnaire by using ASA.

Results

We constructed two activity systems to describe and explain the development of the reflective-assessment activities and the interaction of these activities (a) before the KCA student activity, and (B) during the KCA student activity. The activity systems are shown in Figures 1-2.

In Activity System A, the use of these tools motivated some of the students to contribute more notes, and helped them to understand that knowledge building is a collective effort to improve ideas. However, these experiences of reflection directed the students' attention to their own performance. This activity system had two tensions: (a) attaining the objective while completing SBA projects; and (b) attaining the objective with limited resources. After the introduction of the KCA, the dynamics of the student activity systems changed, as the participating students attempted to advance their KB discourse by carrying out RA afforded by the KCA. Tension (b) in Activity System A (created by the need to attain the objective in the absence of a community-oriented framework for data-driven idea improvement) was also substantially alleviated by the students' engagement in productive reflective assessment scaffolded by the KCA prompt sheets. However, prior experience of reflection around the ATK and Applets data in Activity System A and the limited framing of data-driven (the KCA data) discourse improvement as a collective responsibility exerted some negative effects on Activity System B that was some students' attention mostly on individual performance rather than community's discourse as a whole. These resources mediated against the students' productive use of the KCA data and made tension (b) in Activity System A persisted to some degree in Activity System B.

The ASA yielded three main findings that explained the nature, dynamics and tensions of the social practices that arose from the students' KCA-afforded self-directed reflective assessment. These findings offered insights into the elements that became influential cultural tools, and the ongoing activities that supported the transformation of these newly introduced artifacts into cultural tools: (1) *the new tools that mediated student*

activities developed from reflection opportunities afforded by data; (2) *framing discourse improvement as a collective responsibility acted as new tools that mediated new activities; and (3)new skills and increased interest were transformed into new tools that mediated the students' new activities*.

Tool
Knowledge Forum
Communication and note-writing skills
The knowledge wall
ATK data and the graphs
Opportunities for collaborative reflection

Subjects
The students
participating knowledge
building

(b)

Object
Collaboratively
improve knowledge-
building discourse

Outcome
Discouragement and
satisfaction
Gained communication
and collaboration skills
Gained experience

(a)

Rules
The teacher's expectations
The principles of good notes
Competing SBA projects

Community
The participating students
The course teacher

Division of Labor
Students wrote notes
Support from the teacher

Tensions
(a) Attaining object while competing SBA projects
(b) Attaining object with limited resources

Figure 1. Activity System A: Before the KCA student activity.

Tool
Communication and collaboration skills
Knowledge Forum
The KCA and corresponding prompt sheets
Reflection opportunities around the KCA data
Limited framing of data-driven collective idea
improvement

Activity System A

Subjects
The students
participating the KCA
related activities

(b)

Object
Improving community's
discourse by doing
reflective assessment
with the KCA

Outcome
Discouragement and
satisfaction
Knowledge advancement
Raised motivation and
interest
Gained skills

(a)

Rules
The teacher's and research
team's expectations
Competing SBA projects

Community
The participating students
The course teacher
The research team

Division of Labor
Students advancing discourse
Support from the teacher
Scaffolds from the research team

Tensions
(a) Actualizing the teacher's and research team's expectations while competing SBA projects
(b) Attaining object with no framing of data-driven collective idea improvement

Figure 2. Activity System B: After the KCA student activity.

Discussion and conclusions

We found that the KCA and its accompanying prompt sheets can help students to engage in productive reflective assessment—focusing on the key learning goals of knowledge building. Our findings on the interactions between the conditions of and tensions within an activity system, and the processes by which such factors become either affordances or constraints to students' collaborative use of data, suggest ways of structuring change in classrooms and even schools, particularly to meet the needs of educationally disadvantaged students. The findings also lay the groundwork for future research on students' collaborative work and metacognitive activities in relation to data use.

References

Yamagata-Lynch, L. C. (2010). *Activity systems analysis methods: Understanding complex learning environments*. New York, New York, N.Y. : Springer.
Yang, Y., van Aalst, J., Chan, C. K. K., & Tian, W. (2016). Reflective assessment in knowledge building by students with low academic achievement. *International Journal of Computer-Supported Collaborative Learning,11*, 281-311. (SSCI)

Criss Crossing Science Domains in Knowledge Building Communities: An Exploratory Study

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Abstract: The complex nature of 21st century knowledge work is forcing a shift from single-subject curriculum units to interdisciplinary perspectives. Knowledge Building pedagogy and technology aim to turn high levels of socio-cognitive control over to students to enable them to assume responsibility for functions typically assumed by the teacher. This exploratory study aims to assess the extent to which elementary-school students within Knowledge Building communities are able to criss cross science domains and, in doing so, contribute to the improvement of the community knowledge.

Introduction

Recent reforms highlighted a need for *crosscutting concepts*- linking across the domains- to "provide students with connections and intellectual tools that are related across the differing areas of disciplinary content and can enrich their application of practices and their understanding of core ideas" (NRC, 2012, p. 233). To have a successful crosscutting classroom, it is perceived that the teacher should carefully design the course plans and activities to make a connection between different concepts (Savage, 2010). The purpose of this exploratory study is to explore if students in a Knowledge Building classroom, which turns high-level agency over to students, take over levels of agency for connecting different science domains in the course of exploring core concept, and whether such connections help them improve their understanding of the core concept.

Methodology and data analysis

The dataset used for this study is comprised of 370 notes posted on Knowledge Forum by Grade 1 students, exploring "water" and "water cycle". We employed a lexical analysis tool, called Text Analyzer, to analyze students online discourse in order to extract all the words used by students. We went through the word lists and selected scientific words--the words related to a scientific concept and categorized them into two categories: core topics (*within curriculum)* and *crossing domain*. *Within curriculum words* are the words that, according to the curriculum expectations, students were supposed to discuss and learn when learning the core topic, while *crossing domain words* are the scientific words which students were not required to learn when learning the core concept. Then, we extracted all the notes that included those crossing domain words, and applied Ways of Contributing (WoC) coding scheme (Chuy et al., 2011) to analyze the notes and explore how these cross domain notes contributed to the community knowledge.

Results

Figure 1 shows the scientific words that students used in their online discourses. The "within curriculum" words were displayed in the inner circle while the "crossing domain" words were displayed in the outer circle. As Figure 1 shows, students did not limit their discussions to concepts directly related to water (e.g. water, raindrop, evaporation), but they tried to make connection between the main concept and other topics such as space (e.g. moon, Mars, Jupiter, meteor, gravity), and biology and biodiversity (e.g. body, growth, digest, animals, butterfly, breath). After finding the cross-domain keywords, we looked at the notes containing cross domain words and identified 98 notes contained cross domain key words. Two raters coded and categorized all the notes using the Ways of Contributing scheme (notes may fall under more than one category) and achieved an agreement rate of 99.27%. According to the analysis, 45.5% of the cross-domain notes were categorized as "theorizing" notes, 26.8% as "thought-provoking questions", 10.7% as obtaining information and working with information, 8.9% as synthesizing and comparing notes, and 8% as supporting discussion notes.


Figure 1. Students scientific words

Discussion and conclusion

As it is evident from the results, the main type of students' contributions is *theorizing*. Knowledge Building aims to provide opportunities for students to engage in theory building by taking collective responsibility for pursuing deeper understanding and explanations of the world (Scardamalia & Bereiter, 2006). Results suggest that concepts from extended fields of science are used in theorizing notes, seemingly a reflection of students' effort to extend and deepen their understanding of the world around them. The second most common contribution of students was thought provoking questions (26.8%). Several studies have shown that questions push dialogue forward and make the discourse more sustainable and productive, which can help increase explanatory coherence (e.g. Khanlari, Resendes, Zhu, & Scardamalia, 2017). While criss crossing knowledge domains students expressed puzzlements and possibilities, discourse moves that help to foster sustainable and productive discourse. Overall, the results show that students as early as Grade 1 exercise epistemic agency in extending and reconstructing knowledge boundaries, going beyond the traditional classroom expectations through crossing science borders. Results show that crossing science domain not only extends the range of science concepts they consider but also helps improve community knowledge--one reason why Knowledge Building has the potential to "set a knowledge building classroom off as profoundly different from even the best of traditional and modern classrooms" (Scardamalia, 2002, p. 77). For the future directions, we aim to replicate the study with a rich data set, and explore if this criss-crossing knowledge domains happens in other grades as well or not..

References

Chuy, M., Resendes, M., Tarchi, C., Chen, B., Scardamalia, M., & Bereiter, C. (2011). Ways of contributing to an explanation-seeking dialogue in science and history. *QWERTY - Interdisciplinary Journal of Technology, Culture and Education*, 6(2), 242–260.

Khanlari, A., Resendes, Zhu, G., & Scardamalia, M. (2017). Productive Knowledge Building Discourse Through Student-Generated Questions. In the *proceedings of the 12th International Conference on Computer Supported Collaborative Learning (CSCL) 2017 (pp. 585-588).*

NRC (National Research Council). (2012). A framework for K–12 science education: Practices, crosscutting concepts, and core ideas. Washington, DC: The National Academies Press.

Savage, J. (2010). *Cross Curricular Teaching and Learning in the Secondary School*. London, Routledge.

Scardamalia, M. (2002). Collective cognitive responsibility for the advancement of knowledge. In B. Smith (Ed.), *Liberal education in a knowledge society* (pp. 67-98). Chicago, IL: Open Court.

Scardamalia, M., & Bereiter, C. (2006). Knowledge building: Theory, pedagogy, and technology. In K. Sawyer (Ed.), *Cambridge handbook of the learning sciences* (pp. 97–118). New York: Cambridge University Press.

"How Do We Pack the World Into Words?" Examining the Collective of Humans and Non-Humans in the Science Classroom

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Abstract: This paper uses Bruno Latour's framework of a "collective of humans and non-humans" to consider how to construe the non-human objects of learning and their role in classroom knowledge construction. This is done by considering materials and reports from a form of a "construction site" for science: the implementation of laboratory science in a high school chemistry classroom. The paper considers how the collective operates in three domains central to the learning sciences: learning environments, discourse, and identity. Implications for the relation of this to other ways of considering artifacts and inscriptions, including material feminisms, and for the for the role of phenomena in learning are also discussed.

Keywords: science, learning environments, discourse, identity.

Introduction: Preparing metals for classroom use

In the continuing saga of my [in-school] work, yesterday I completed making up all the metal pieces for two of the labs in ChemCom--the "metal / nonmetal" and the "reactivities of metal" labs. I just calculated the number of pieces this involved and it adds to about 2500. Each was 1 cm or less in size, comprised of Zn, Ag, Cu, Mg, Fe, and also carbon and silicon. Mostly easy work, though the supplier did send us some Zn "wire" that was about gauge 10. Never tedious, though, in part because it was mostly done while class was going on. I have no idea what a "Zen experience" is supposed to mean, but this has to be one.

Figure 1. Email from a science educator supporting a high school science curriculum.

Figure 1 presents a report of an event in science instruction, with many areas of exciting activity: Samples of elements are cut into pieces; a classroom is prepared for students; a curriculum is brought into schools; a chemist has an experience that contrasts with other modes of professionalism. Within this, novel attributes accrue—for the elements: a new place to be active; for the classroom and the students: new interactions with new materials; for the curriculum: a new place for use; for the chemist: new ways of seeing himself and of being seen. How can we, in such a setting, say who are the participants in this activity? What is the subject? What is the object? Are these new attributes constructed? Are they discovered? How does this incorporate the metal pieces in the discourse of the humans? And, finally, how does this activity shape and characterize the identity of those who are here? These questions go to the heart of questions about reality and knowledge construction, including especially in science. The questions are also among those central to science studies, including the work of Bruno Latour, working across the fields of anthropology, sociology, philosophy, and science, as he documents the how *collectives of non-humans and humans* are needed to understand how to answer the question of "How do we pack the world into words?" (Latour 1999).

The collective within learning environments, discourse, and identity

Three domains are considered in this paper, to document the activity of a collective in learning: learning environments, using Latour's concept of a circulating chain of reference, discourse, using his concept of speech prostheses, and identity, using a concept of the mutual enhancement and articulation of properties. Following Latour's method, a specific "construction site" for science (Latour 2005) is considered: a secondary science learning environment (Wink et al 2008; Daubenmire et al 2011).

Learning environments are complex locations where multiple actors engage on another. In his work, Latour (1999) considers a research environment, accompanying a team of researchers studying the forest / savanna boundary. The environment is a place where the things of the world become a scientific report, not through correspondence, but across "circulating chain of reference." In much the same way, we examine how the metal is cut up to become the form of the experiment (Figure 1), the pieces are used in a chemical reaction, the reaction in a lab report, and the lab report in learning: in this construction site also, through a series of small,

traceable steps, we see how the learning environment contains another circulating chain of reference among the non-humans and the humans.

Within a construction site the non-humans become part of the *discourse*, also. This is done through a process of permitting the non-humans to speak using "speech prostheses that allow non-humans to participate in the discussions of humans, where humans become perplexed about the participation of the new entities in collective life" (Latour 2004). Within the curriculum a similar set of speech prostheses are found, permitting non-humans to enter discourse in science learning, specifically through staging of experiments, entry of results in notebooks, and claims on behalf of the non-humans in the interpretation of results.

Finally, Latour's anthropological work is also about how humans and non-humans co-construct *identity* when they "mutually exchange and enhance their properties" (Latour, 1999) with an example focused on Louis Pasteur and the "discovery" of microbes. In this paper, a similar examination of the implementation of a science curriculum over time gives evidence about how humans (students, teachers, educators) and non-humans (metals, solutions, apparatus) also gain and stabilize identity through articulation of properties with one another. This uses methods of narrative analysis in describing identity through the emergence of metapragmatic models of identity within narrative data (Sfard & Prusak 2005; Wortham, 2001; 2004).

Implications: Inscriptions, materiality, and phenomena

There are several implications considering Latour's collective for the learning sciences, including interesting points of comparison with work on artifacts and inscriptions (e.g, Roth et al 1999). In addition, the work will be related to concepts found in material feminisms (Alaimo & Hekman 2008), agential realism and literacy (Barad 2000) and their educational applications (Taylor & Ivinson 2013; Scantlebury & Milne 2017). Finally, the role of non-humans will be considered in thinking about the basis of phenomena (National Research Council 2012) and in association with the epistemological basis of disciplinary learning (Goldman et al 2016).

References

Alaimo, S. & Hekman, S., Eds., *Material Feminisms*, Bloomington, IN: Indiana University Press.

Barad, K. (2000). Reconceiving scientific literacy as agential literacy. In *Doing Science + Culture*, Reid, R., and Traweek, S., Eds., New York: Routledge.

Daubenmire, P. L., Wink, D. J. & Tarnoff A. (2011), These kids can't do inquiry, Another urban legend. In *Investigating Classroom Myths through Research on Teaching and Learning*. Bunce, D., Ed.. Washington, DC: American Chemical Society.

Goldman, S. R., Britt, M. A., George, M. A., Lee, C. D., Brown, W., Cribb, G., Greenleaf, C., Shanahan, C., Project READI (2016). Disciplinary literacies and learning to read for understanding: A conceptual framework for disciplinary literacy. *Educ. Psych.*, *51(2)*, 219-246.

Latour, B. (1999) *Pandora's Hope*, Cambridge, M. A.: Harvard University Press.

Latour, B. (2004) *The Politics of Nature*, Cambridge, MA: Harvard University Press.

National Research Council (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas.* Washington, D.C.: The National Academies Press.

Roth, W-M., McGinn, M. K., Wiszczyna, C., & Boutonné, S. (1999). Differential participation during science conversations: The interaction of focal artifacts, social configurations, and physical arrangements. *J. Learn. Sci., 8*, 293-347.

Scantlebury, K. & Milne, C. (2017). *Material practice and materiality: Too long ignored in science education.* New York: Springer.

Sfard, A. & Prusak, A. (2005), Telling identities: In search of an analytic tool for investigating learning as a culturally shaped activity. *Educational Researcher*, *34(4)*, 14–22.

Taylor, C. A., & & Ivinson, G. (2013). Material feminisms: new directions for education. *Gender and Education*, *25*, 665-670.

Wink, D. J., Daubenmire, P. L., Brennan, S. K., & Cunningham, S. A. (2008). Bringing standards-based chemistry instruction to an urban school district. *Chemistry and the National Science Education Standards*, 2nd ed., Stacey Lowery Bretz, Ed. Washington, DC: American Chemical Society.

Wortham, S. (2001). *Narratives in action.* New York: Teachers College Press.

Wortham, S. (2004). *Learning identities.* Cambridge: Cambridge University Press.

Acknowledgments

Investigating Multiple Dimensions of Student Engagement with Embodied Science Learning

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Abstract: This poster explores how the dimensions of behavioral, emotional, and cognitive engagement are related to embodiment within the STEP (Science through Technology Enhanced Play) mixed-reality environment. We will show how these dimensions of engagement help us analyze classroom interactions to better understand the learning process in this embodied activity context. We will also discuss design features that can leverage the interconnected dimensions of engagement to better support learning.

Keywords: Embodiment, Engagement, Science, Technology

Introduction

As designers of learning environments, one of our goals is to understand how we can support students in productively interacting with our designs and each other so that they learn the target content. In the Science through Technology Enhanced Play (STEP) project, a mixed-reality learning environment that relies on embodied play as a form of interaction, we are particularly interested in how embodiment can invite and support productive forms of engagement with our designs. Engagement is defined in a number of ways throughout the literature, but generally it is used as a way of characterizing students' participation in learning environments. It is typically associated with a range of beneficial student outcomes, such as higher grades, lower drop-out rates, and less disruptive school behaviors (Christenson, Reschly, & Wylie, 2012). Therefore, our goal is to better understand how our designs can encourage and enable desirable forms of student engagement. While the engagement literature is filled with disagreements over how student engagement should be defined and measured, there are a few common threads. One thread is that engagement is not a single aspect of student behavior, but rather a meta-level construct that combines several facets of student experience, such as behavior, emotion, and cognition, under one umbrella (Fredricks & McColskey, 2012). The multi-dimensionality of the construct allows for analysis of how its dimensions might interact to influence student learning in complex, overlapping ways. Another common thread is that engagement is not a stable attribute but rather an "alterable state of being" that is highly context-dependent, which highlights the need to study the dimensions of engagement in specific learning activities (Christenson, Reschly, & Wylie, 2012).

Design and approach

The STEP environment uses an embodied, mixed-reality simulation of water particles in order to help first- and second-grade students learn about states of matter (Danish, Enyedy, Saleh, Lee, & Andrade, 2015). As students move around the classroom, they can leverage their sense of individual and collective motion to reflect on how particles behave. The STEP environment further enhances this process by presenting students with a blend of the real and the digital – as students engage in embodied play, they see themselves in a projected simulation as water particles and see their movement interpreted through the lens of the computer simulation. For example, if they move slowly, they are depicted as ice, or if quickly, as a gas, etc. The blend of digital and physical experiences augments students' exploration of science concepts to make these complex ideas more tangible.

The STEP environment consists of Microsoft Kinect cameras that track student movement as they pretend to be water particles. The tracking data is then transferred to a computer that produces a simulation of water particles moving around a tank. Each student has a particle avatar that is controlled via their movements around the classroom, allowing students to use embodiment to experience being a particle in a solid, liquid, and gas. In the current iteration, students rotate between embodied and scientist-observer roles, with observers using iPad-based annotation tools in order to create drawings and graphs of their peers' movements and explore how the speed, distance, and energy of particles impacts their state of matter.

Research on embodiment has shown that embodied, mixed-reality activities have the potential to engage students in immersive learning experiences (Lindgren & Johnson-Glenberg, 2013). However, a shared definition of engagement is difficult to find, which makes it tricky to measure moment-to-moment changes in student engagement across activities (Appleton, Christenson, & Furlong, 2008). Behavioral aspects of engagement can be defined as desirable classroom-related behaviors such as asking questions, contributing to discussion, and an absence of disruptive behavior (Fredricks, Blumenfeld, & Paris, 2004; Fredricks &

McColskey, 2012). Emotional engagement has been viewed as students' positive and negative reactions to particular activities, which can include interest, excitement, boredom, and the value that students place on activities (Fredricks & McColskey, 2012). Studies have also looked at cognitive dimensions of engagement, considering how student planning, self-regulation, evaluation, and making connections between aspects of disciplinary content is connected to other forms of participation (Fredricks, Blumenfeld, & Paris, 2004; Sinha, Rogat, Adams-Wiggins, & Hmelo-Silver, 2015). In an embodied environment such as STEP, using the body for learning complicates the question of what counts as engagement by inviting new ways of interacting that may not be present in traditional classroom activities. Thus, the concept of engagement helps us to better understand how embodied activity intersects with multiple dimensions of engagement to influence student learning.

Findings and significance

Our data set consists of eight days of video-recorded activities that took place in a mixed-age classroom of first- and second-graders in a Midwestern public school. Given the theoretical disagreements in the engagement literature regarding the concept's exact dimensions, a grounded theory approach was used to construct categories of student engagement as they emerged in the data (Corbin & Strauss, 1990). To further investigate the mechanisms and characteristics of these categories, interaction analysis was also conducted (Jordan & Henderson, 1995). Through a combination of these methodological approaches, multiple types of classroom episodes emerged, and we analyzed ways in which categories of student engagement (emotional, behavioral, and cognitive) became visible and functioned differently in these different types of episodes. Some episodes were marked by playfulness and laughter, and involved students running around as they embodied water particles. Other episodes were more behaviorally restrained and characterized chiefly by discussions in which students cognitively engaged by making connections between their movements and the movements of particles. These discussions highlighted key science content that was later reflected in students' learning gains on pre-post tests. As the classroom activity shifted back and forth between multiple types of interactional episodes, the role of student engagement with embodied activity shifted as well, highlighting the inherent fluctuation and complex interactions between the dimensions of engagement and the ways that they interact to support learning.

The poster will explore ways that multiple dimensions of student engagement became visible within the STEP environment during different episodes of activity. We will present excerpts of classroom activity that demonstrate the variations in students' emotional, behavioral, and cognitive engagement with embodiment throughout different types of classroom episodes and discuss what implications these variations have for the design of embodied learning environments. These findings will help designers consider how students engage with embodiment in multiple, interacting ways over time and how teachers can support these links between behavior, emotion, and cognition as they facilitate both embodiment and subsequent discussion activities.

References

Appleton, J. J., Christenson, S. L., & Furlong, M. J. (2008). Student Engagement with School: Critical Conceptual and Methodological Issues of the Construct. *Psychology in the Schools, 45*(5), 369-386.

Christenson, S. L., Reschly, A. L., & Wylie, C. (Eds.) (2012). *Handbook of Research on Student Engagement.* New York, NY: Springer.

Corbin, J. & Strauss, A. (1990). Grounded Theory Research: Procedures, Canons, and Evaluative Criteria. *Qualitative Sociology, 13*(1), 3-21.

Danish, J. A., Enyedy, N., Saleh, A., Lee, C., & Andrade, A. (2015). *Science Through Technology Enhanced Play: Designing to Support Reflection Through Play and Embodiment.* Proceedings of the 11ᵗʰ International Conference on Computer Supported Collaborative Learning. Gothenburg, Sweden.

Fredricks, J. A., Blumenfeld, P. C., & Paris, A. H. (2004). School Engagement: Potential of the Concept, State of the Evidence. *Review of Educational Research, 74*(1), 59-109.

Fredricks, J. A. and McColskey, W. (2012). The Measurement of Student Engagement: A Comparative Analysis of Various Methods and Student Self-Report Instruments. In S. L. Christenson, A. L. Reschly, & C. Wylie. (Eds.) *Handbook of Research on Student Engagement.* (763-782). New York, NY: Springer.

Jordan, B. & Henderson, A. (1995). Interaction analysis: Foundations and practice. *Journal of the Learning Sciences, 4*(1), 39-103.

Lindgren, R. & Johnson-Glenberg, M. (2013). Emboldened by Embodiment: Six Precepts for Research on Embodied Learning and Mixed Reality. *Educational Researcher, 42*(8), 445-452.

Sinha, S., Rogat, T. K., Adams-Wiggins, K. R., Hmelo-Silver, C. E. (2015). Collaborative group engagement in a computer-supported inquiry learning environment. *International Journal of Computer-Supported Collaborative Learning, 10*, 273-307.

Relating Social Network Structure to Uncertainty and Social Interaction in an Engineering Design Challenge

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Introduction

The open-ended nature of engineering design problems implies uncertainty; there is no one, correct solution and no best path to take to achieve a viable solution (Sullivan, 2008). Moreover, engineers must learn to communicate effectively in diverse, cross-disciplinary teams (Roy, 2009), and communication is a primary tool for navigating uncertainty (Babrow, 2001). From a communication perspective, sources of uncertainty can be clustered into identity, relational, and instrumental meanings (Jordan & Babrow, 2013). Jordan and McDaniel (2014) defined uncertainty as a "subjective experience of doubting, being unsure, or wondering" (p. 492), and described how young learners experienced and responded to uncertainty from various sources in a collaborative engineering design project. These authors found peer social support to be critical for individuals working in homogenous groups (wrt: experience, and goals) to manage uncertainty and to forward design work.

However, working on engineering design problems in heterogeneous groups may increase the diversity of uncertainty sources and responses, provide different opportunities for expressing uncertainty, and more strategies for managing uncertainty. Therefore, the present study featured a diverse cohort of engineering design participants, working in small collaborative sub-groups, structured for heterogeneity. Each type of participant brought a different set of skills, background, and experience to a summer engineering research experience; the combined value of their diverse "tools" was theorized to enrich both the learning process and the potential outcomes of a modeling design activity (Page, 2007).

These understandings of using social interaction to manage uncertainty, coupled with scholarship on social networks for learning (Wasserman, & Faust, 1994; Yoon, 2011) led to the following research questions:

RQ1: What is the structure of the social network with respect to who is recognized as influential to learning?

RQ2: What uncertainty did participants report, how was uncertainty managed, and how did these sources of and responses to uncertainty relate to the structure of the network?

RQ3: How did the social network influence the outcome of the collaborative, engineering design task?

Method

The diverse cohort of 27 participants (13 female; 14 white) included 15 undergraduates from across the U.S., seven local teachers, two local high school students, and three international students. This analysis focuses on the first two weeks of the eight-week summer engineering research program when participants were assigned to nine heterogeneous three-member groups to accomplish two tasks: fabricate a solar cell and model the lab processes digitally using PC1D (PVEducation, 2017) software. The modeling objective was to maximize the solar cell efficiency by modifying parameters such as pyramid height. Although participants received an initial lecture on the modeling software and activity, the activity itself was an ill-structured design challenge. Groups were able to collaborate with other groups and access mentors for guidance.

Primary data sources included daily reflection responses (open-ended; Likert) regarding participants' uncertainty and management of uncertainty, audio-video recordings and field notes of program activities, and each group's presented maximum cell efficiency. Additionally, participants completed a post-survey at the conclusion of the two-week challenge; for this, each participant rated all cohort members (5-pt Likert) as to how influential each participant was to their learning.

Following Jordan and McDaniel's (2014) framework, two researchers independently coded and reconciled open-ended survey responses regarding uncertainty about (a) fundamental scientific content, (b) engineering identity, (c) the PC1D software operability, and (d) relationships with other program participants. The frequencies of each uncertainty source and management technique reported by each participant as well as participants' demographics, position (e.g. REU), project grouping, and dorm residency, in addition to the efficiency of each group's optimal simulated solar cell modeled in PC1D were culled into an attribute list. Finally, a social network analysis (Scott, 2017) was conducted using R from a weighted adjacency matrix

developed from the post-survey sociogram items. Bivariate correlations using Pearson's *r* between cluster formation, sources of uncertainty, and management of uncertainty were conducted in SPSS.

Results and discussion

The network formation was not random. Four participant clusters emerged (RQ1), one of which contained all of the teachers as well as the other two members of one teacher's group. A correlation analysis indicated that group assignment most related to cluster formation ($r=.833$, $p<.001$), followed by dorm lodging ($r=-.502$, $p=.009$), which differentiated another two clusters. The fourth cluster contained the two groups without a teacher. This clustering reflects tendency towards homophily.

Participants reported managing relationship uncertainty with avoidance (RQ2; $r=.343$, $p=.087$), and managing knowledge uncertainty by seeking out peers ($r=-.373$, $p=.060$) or relying on oneself ($r=-.337$, $p=.092$). Although with this small sample we don't quite see significance, this may explain why the teacher clustering; perhaps they recognized other teachers as their peers, sought to manage knowledge uncertainty, and avoided their other groupmates due to relationship uncertainty. Uncertainty about knowledge ($r=-.350$, $p=.080$) and relationships ($r=-.367$, $p=.065$) correlated with the formation of the dorm-dwelling cluster formation, shy of significance. Perhaps within this cluster, participants felt comfortable acknowledging their uncertainty.

The three clusters containing the seven teacher-member groups all produced similar cell efficiency results in their modeling task (RQ3). One group in the fourth cluster, which lacked teachers, took a different approach to the design task: they eliminated any factor, even the unavoidable, that reduced cell efficiency. This approach yielded more than twice the cell efficiency of the other groups and was lauded by the expert engineers as the best approach to the problem, but was not disseminated through the network with the other clusters.

According to a pagerank analysis, the five most influential participants include the four most advanced engineering students and a novice community college student who was highly interactive. Observations and field notes indicate that this novice student frequently sought and shared knowledge, acting as an arbiter for the highly knowledgeable international graduate student in his group. This seems to suggest that participants primarily valued knowledge, but a participant acting as a "social glue" may be equally valuable.

Significance

The results suggest that identities (e.g. teacher) and relationships (e.g. dorm-mates) developed outside of the learning arena are a bigger indicator of learning influence that formally imposed group structures, and therefore may offer unique opportunities to help novice engineers manage uncertainty through social interaction. By purposefully dispersing known identities (e.g. teachers) across formal groups, cross-group communication channels appear to form, allowing knowledge and ideas to disseminate more broadly. On the other hand, social clusters lacking connections to such broadly disseminated identities may develop alternative solutions in isolation. These preliminary findings may have implications for designing project groups for engineering design projects and other ill-structured tasks. Finally, socially recognized influence on learning typically highlights the most knowledgeabl /experienced participants as primary; however, high levels of interactivity and bi-directional engagement of the social network by a participant may be valued as equally influential to others' learning.

References

Babrow, A. S. (2001). Uncertainty, value, communication, and problematic integration. *J. of Comm.*, *51*, 553–573.

Jordan, M. E., & Babrow, A. S. (2013). Communication in creative collaborations: The challenges of uncertainty and desire related to task, identity, and relational goals. *Comm. Education*, 210–232.

Jordan, M. E. & McDaniel, R. (2014). Managing uncertainty during collaborative problem solving in elementary school teams: The role of peer influence in robotics engineering activity. *JLS, 23*, 490-536.

Page, S. E. (2007). Making the difference: Applying a logic of diversity. *Acad. of Management Persp.*, *21*, 6-20.

PC1D, PVEducation (2017) [Online]. Available: http://www.pveducation.org/pvcdrom/characterisation/pc1d

Roy, R. (2009). *Engineering education: Perspectives, issues and concerns.* Shakarpur, Delhi: Shipra.

Scott, J. (2017). *Social network analysis*. Sage.

Sullivan, F. R. (2008). Robotics and science literacy: Thinking skills, science process skills and system understanding. *J. of Research in Science Teaching, 45,* 373-394.

Wasserman, S., & Faust, K. (1994). *Social network analysis: Methods and applications*. Cambridge, England: Cambridge University Press.

Yoon, S. A. (2011). Using social network graphs as visualization tools to influence peer selection decision-making strategies to access information about complex socioscientific issues. *JLS*, *20*, 549-588.

Becoming, Being, and Sometimes Leaving: A Longitudinal Ethnographic Perspective of Climate Scientists' Participation in Science and Education

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Abstract: The learning of socio-scientific knowledge and practices in and out of school is facilitated by the participation of working scientists. In 2016, I interviewed 18 key informant climate scientists from a longitudinal ethnographic study initially conducted in 2009-2012, to examine how their participation in education and communication had evolved over time. Findings indicate that scientists' science and SEC identities were intertwined. Further, science and SEC trajectories were shaped by an increasingly polarized social context, as well as scientific structures that limited stability and at times misaligned with scientists' values.

Introduction

The participation of scientists in science education and communication (SEC) can provide current and detailed expertise in scientific content, practices and processes, as well as entry points for learners into scientific communities. Working in a societally relevant field, climate scientists in particular often have high levels of interest in increasing public engagement with climate science (Bowman et al., 2010). Currently there are limited accounts of the experiences, motivations and perspectives of those scientists who do choose to participate in communication and education, and what supports or hinders these activities. Detailed understandings of climate scientists' trajectories of learning and participation in science education and communication practices is needed, to better support ongoing participation in SEC. This poster presents findings from a five-year longitudinal follow-up to an ethnographic study and examines how scientists navigated scientific and educational identities and structures over time, and what informed the sustainability of their participation in SEC and in science itself.

Methodology

Theoretical framework

As a cultural group, the scientific community is associated with particular modes of participation in epistemic practices (Latour & Woolgar, 1987). Because the ultimate purpose of socially relevant sciences, such as climate change, is often its use by those outside of the scientific community, climate scientists are often called on or choose to act as participants whose pathways crossed boundaries between science and SEC communities. This analysis draws on Nasir & Hand (2008)'s construct of practice-linked identity to examine science and SEC-linked identity through participation in contexts over time. I examine scientists' roles over time, and how available resources, structures, values and practices shaped scientists' SEC work.

Data sources and analysis

Between 2009-2011, I conducted a longitudinal ethnography of climate scientists involved in informal outreach and K-12 education activities. In Fall 2016, follow-up interviews (semi-structured, 45-60 minutes, audio- or video-recorded) were conducted virtually with 18 key informants from the initial study, focusing on views of and experiences with science learning, education and communication, and their activities related to education and communication during the last five years. Participants also completed an online survey about their participation in SEC. I qualitatively coded transcriptions of interviews using a combination of a coding structure developed during the initial study (Walsh, 2012) and emergent coding (Lofland & Lofland, 2006). Emergent themes were explicated iteratively using memoranda, and I reviewed and analyzed the data corpus to generate and test assertions as described by Erickson (1986). Data from this round of interviews were triangulated with data from the 2009-2011 study.

Major findings

Trajectories in and out of SEC tied to science identity, career trajectory

SEC activities of the scientists were shaped by the career pathway that they took, and these career pathways in turn were shaped by available job prospects, career aspirations, geographic location of available positions and family responsibilities. All participants reported a trend to increasing specialization in a particular kind of SEC

over time, often related to their jobs. David and Kurt, both research scientists, reported an increase in work with the media, while Jason, Jennifer and Clara, who had all recently started or were about to start jobs as professors, became much more focused on their own teaching. From 2009 to 2016, there was an increase in critique of the structure of the scientific community and how science communication efforts are inadequately or inauthentically integrated into science. Some scientists who had left or were considering leaving academia connected this to a critique of how scientific jobs are structured. Kat described an "identity crisis": her struggle to find a permanent position as a scientist had affected her science identity to such an extent that she was no longer certain whether or not she should be encouraging others to pursue science as a career. Several scientists noted that their job structure did not provide room for job security or the possibility for participation in valued activities such as SEC or family life; two scientists had left or were considering leaving science as a career for these reasons.

Increasing social and political polarization and media influence

Most scientists indicated that they believed that the social context for climate change had become more polarized since their initial interviews, and many stated that this had a dampening impact on their communication activities and had shaped their SEC engagement. Since 2011, participants had become increasingly involved in communication with the media, while at the same time becoming critical of the media and its coverage of climate change, especially the proliferation of social media. For example, after graduate student Scott's first scientific paper was picked up by the media and became the target of climate deniers, he considered leaving science altogether and took a leave of absence from school. Scientists reported that they had in many cases reached their limit of trying to communicate directly with the general public outside of working with the media, in large part because of the polarization. They reported that the polarization resulted in, as several scientists stated, "preaching to the choir" when speaking to liberals, or in no impact when speaking with people who did not think climate change was happening. Grant, a professor, described his outlook as much less open to listening to or addressing climate skeptics, stating: "I'm a lot less likely to accept crap about climate change now than I was ten years ago, you know. We've been through all that." Scientists also noted a concern about the tendency to highlight the latest finding instead of contextualizing findings. The need for constant information, "flashy," "novel" findings and statistics was mirrored in concerns about the rise of social media.

Conclusions and significance

Since 2011, scientists who had started motivated and interested in education and communication had generally remained active in SEC. Scientists' modes of participation were deeply intertwined with their identity as a scientist in ways that both encouraged and at times provided a barrier to participation, and led to increased specialization over time. While supports for scientists tend to be geared toward a "general" audience, this work elucidates the dynamic nature of scientist's science communication and education experience. Previous research has described scientists as "unwilling" and "reluctant" to take part in media communication efforts, an effort they have "undervalued" in comparison to their other "professional duties and responsibilities" (Boykoff, 2011 p. 71-73). However, for participants in this study, it was not a lack of interest or reluctance on the part of the scientists to engage in SEC, but a consequence of the politically polarized social context and the structure of scientific and academic institutions. These structures threatened SEC activities, as well as other values highly important to the scientists including job stability, interdisciplinarity, and balance with family life. Some of the younger scientists expressed disillusionment or lack of motivation and others had sacrificed communities or activities that they had previously highly valued, such as SEC or even science itself. This has implications for the STEM education and learning sciences community, as we need to critically examine the institution we are preparing youth to enter and the consequences of choosing a trajectory of participation in that community.

References

Bowman, T. E., Maibach, E., Mann, M. E., Somerville, R. C. J., Seltser, B. J., Fischhoff, B., Gardiner, S. M., et al. (2010). Time to Take Action on Climate Communication. *Science*, *330*, 1048-1048.

Boykoff, M. T. (2011). Who Speaks for the Climate? Making Sense of Media Reporting on Climate Change. Cambridge, UK: Cambridge University Press.

Latour, B., & Woolgar, S. (1986). *Laboratory Life: The Construction of Scientific Facts*. (J. Salk, Ed.). Princeton University Press.

Lofland, J., & Lofland, L. H. (1995). Developing Analysis. Analyzing Social Settings: A Guide to Qualitative Observation and Analysis (pp. 181-203). New York: Wadsworth.

Nasir, N. & Hand, V. (2008). From the court to the classroom: Opportunities for engagement, learning, and identity in basketball and classroom mathematics. *Journal of the Learning Sciences*, 17(2), 143-179.

Shifting Educational Activity Systems: A Cross-Case Analysis of Science Education Reform Efforts in Large Scale Systems

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Abstract: Educational reform at a system scale is challenging due to issues of coherence. In an effort to improve science education reform efforts in the United States, learning scientists and educational leaders collaboratively engaged in design-based implementation research within a research practice partnership. This study describes three state level case studies resulting from this work and draws out the tensions and affordances that emerged.

Keywords: Design based implementation research, collaborative inquiry, equity, coherence

Introduction

The 2012 release of *A Framework for K-12 Science Education* (*Framework*; NRC, 2012) signified a shift in science education in the U.S. with the inclusion of an explicit vision of equity within science education that challenged established teaching and learning practices. Subsequent implementation work has been fragmented and uncoordinated with different actors in the system engaging in the new vision at different rates, amidst varied resources, and with diverse strategies due to localized control of educational decisions and funding mechanisms. Additionally, limited timely professional learning opportunities for all participants in science education about these implementation efforts has hindered progress.

Implementation efforts can potentially be improved by attending directly to the issue of coherence, having participants across a system come to a shared vision and a plan of coordinated action. In order to improve coherence across large educational systems that span beyond a single school or district, all participants in the system need to engage in sensemaking (Coburn, 2001) and find effective ways to collaborate to minimize challenges during implementation.

In this study we explored the implementation of the new vision of equitable science education embodied in the *Framework* across large educational systems in the United States by asking the overarching question, *How can education systems design for shifts towards new visions of education?* This study is situated within a multi-state research practice partnership (Coburn & Penuel, 2016) focused on the use of formative assessment to foster teacher learning.

Methods

We use the lens of activity theory to identify mediation points within the system to foster change (Cole & Engeström, 1993). From this perspective, individuals are viewed as situated within various communities of practice (Wenger, 1998) which have particular norms for activity, common historically based funds of knowledge (Moll, Amanti, Neff, & Gonzalez, 1992) and repertoires of practice (Gutiérrez & Rogoff, 2003). Historically contextualized positionalities (Harré, Moghaddam, Cairnie, Rothbart, & Sabat, 2009) that dictate privilege and power in any given interaction exist within and between a community's participants. From this lens, we framed this study in design based implementation research (Fishman, Penuel, Allen, Cheng, & Sabelli, 2013) to engage researchers and science education leaders from a wide range of settings and leverage the resources all participants bring to implementation of the *Framework* vision of equitable science education.

In this study, we utilized individual and cross-case analyses (Merriam, 1998) of implementation efforts at the state scale. Cases were selected to provide a range of rural and urban contexts as well as spatial distribution in the U.S. that intersected with differences in economic prosperity. Data were drawn from three focal states using artifacts from two collaborative meetings that dealt with *Framework* implementation specifically and 16 interviews of state science leaders conducted after the first year of collaborative work. Data analyses employed a critical ethnographic approach (Carspecken, 1996).

Findings

The three states used as case studies were working towards a shared vision of equitable science education; however, they took different pathways. State A focused on the creation and development of shared resources to support teachers, students and parents. State B took an approach that would help uncover gaps in student

learning to illuminate the need of a shared vision through professional learning opportunities. State C designed professional learning experiences that were informed by the work already being done by other states.

Work that each state engaged in impacted the other three states. For example, State A played an important role in drafting and prototyping shared resources with teachers develop three-dimensional formative assessments which informed the work on State B as they scaled professional learning across a regional collective. In turn, State B developed example formative assessments across different domains that were shared with other states. State C used the examples developed by State B and worked to develop a shared vision on equity internally to provide insight into attendant pedagogical moves, which then impacted the work that State A was undertaking.

All states experienced tensions in their implementation work. For example, they all struggled to support rural teachers in the coherent shift towards a *Framework* vision of equitable science education due to variations access to universities, limited numbers of substitute teachers to allow for teacher release, limited numbers of *Framework* experts, and greater travel time to reach collaborative spaces. A second tension named by all case study states, but experienced more profoundly by States B and C, was the issue of shifting or diminishing state and educator personnel. This represented an ongoing challenge to implementation coherence, as individual actors who had extensive knowledge and practice in building capacity regarding equitable science education were then lost to the system. Two solutions were seen to be essential to this challenge: shared visioning and sustained professional development in practice.

Conclusions and implications

Engaging in design based implementation work with state leaders and learning scientists allowed for states to collaborate in codesign and research work using tools such as practical measures, actor network models, and teacher education resources. The collaborative nature of this work, allowed state participants to customize these tools to their specific needs, gaining valuable insights into issues of incoherence in their state systems. They were then subsequently able to design for and iterate on options for improved coherence that were well informed by the efforts of other states. Research into these collective efforts highlights potential pathways and mechanisms that states can engage to improve implementation of the *Framework* vision of equitable science teaching as well as more generally helping to illustrate the importance of networked activity in systems reform.

References

Carspecken, P. F. (1996). *Critical ethnography in educational research: A theoretical and practical guide*. New York, NY: Psychology Press.

Coburn, C. E. (2001). Collective sensemaking about reading: How teachers mediate reading policy in their professional communities. *Educational Evaluation and Policy Analysis, 23*(2), 145- 170.

Coburn, C. E., & Penuel, W. R. (2016). Research–practice partnerships in education: Outcomes, dynamics, and open questions. *Educational Researcher*, *45*(1), 48-54.

Cole, M., & Engeström, Y. (1993). A cultural-historical approach to distributed cognition. *Distributed cognitions: Psychological and Educational Considerations*, 1-46.

Fishman, B. J., Penuel, W. R., Allen, A. R., Cheng, B. H., & Sabelli, N. O. R. A. (2013). Design-based implementation research: An emerging model for transforming the relationship of research and practice. *National Society for the Study of Education*, *112*(2), 136-156.

Gutiérrez, K. D., & Rogoff, B. (2003). Cultural ways of learning: Individual traits or repertoires of practice. *Educational Researcher*, *32*(5), 19-25.

Harré, R., Moghaddam, F. M., Cairnie, T. P., Rothbart, D., & Sabat, S. R. (2009). Recent advances in positioning theory. *Theory & Psychology*, *19*(1), 5-31.

Merriam, S. B. (1998). *Qualitative research and case study applications in education: Revised and expanded from case study research in education*. San Francisco, CA: Jossey-Bass Publishers.

Moll, L. C., Amanti, C., Neff, D., & Gonzalez, N. (1992). Funds of knowledge for teaching: Using a qualitative approach to connect homes and classrooms. *Theory into Practice*, *31*(2), 132-141.

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: National Academies Press.

Wenger, E. (1998). *Communities of practice: Learning, meaning, and identity*. Cambridge, UK: Cambridge University Press.

Acknowledgements

A Learning Sciences Perspective on the Development of Teachers' Digital Identity

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Abstract: This case study explored pre-service teachers' development of digital identity by uncovering their thinking on technology as connected with pedagogy to construct learning activities. 27 participants' learning artifacts (e.g. an open-ended questionnaire about digital tool selections) were collected throughout a 14-week licensure course. Primary findings showed that teachers' perceptions of digital tools shifted from a single-purpose to a versatile-purposed approach, presenting the growth of digital identity with pedagogical changes toward to student-centered design.

Keywords: Digital Identity, Teacher Development, Technology Integration

Introduction

From a learning sciences perspective, it is essential to know the trajectories of growth in teachers' knowledge and practice (Fishman, Davis, & Chan, 2014). With the growing need for integrating technology into teaching and learning, education in the digital age is being redefined by the ubiquitous of learning with emerging technologies. With these new learning opportunities, digital thinking along with digital identity are developed by educators who teach themselves a new technology, redesign pedagogies to amplify the use of technology, and redefine learning environments for students. In other words, our thoughts can be shifted and transformed with digital tools that foster creative learning, reconstruct learning identities (Loveless & Williamson, 2013) and situate digital identity (Goode, 2010). While teacher preparation programs are keeping up with the digital changes to develop pre-service teachers' pedagogical mindsets and skills (Ertmer, Ottenbreit-Leftwich, Sadik, Sendurur, & Sendurur, 2012), there is a need to understand how pre-service teachers reconstruct their digital thinking through their own technology integration practice (Burden, Aubusson, Brindley & Schuck, 2016).

Therefore, the purpose of this study is to understand pre-service teachers' conceptual changes on digital identity through technology integration. This study intends to provide further insight into how teachers cultivate their own digital thinking in their instruction and curriculum and transform their own pedagogy in digital age. In order to uncover pre-service teachers' thinking process, the research questions have two facets: (1) how do pre-service teachers perceive the use of technology in teaching and learning? and (2) how do pre-service teachers conceptualize their digital thinking?

Method

This study utilized case study methods (Yin, 2014) with an aim to support the development of tech-integration theories within teacher preparation programs. Data were collected from a 14-week licensure course about technology integration in teaching and learning at a midwestern university in the U.S. Throughout the 14-week course, 27 participants engaged in course discussion to reflect on general topics of technology in education, including technology integration frameworks, digital citizenship, 21st century learning skills, instructional media, classroom management, alternative assessments, differentiation, and culturally responsive teaching. In addition to course discussion, participants had opportunities to share their reflections through different digital tools and create a digital portfolio by using the features on Google Sites. Data sources were 27 pre-service teachers' learning artifacts, including: (1) open-ended questionnaires, (2) online postings, and (3) self-reflections. A content analysis was performed using both open coding and constant comparative methods (Miles, Huberman, & Saldana, 2013) to investigate the conceptual changes of teachers' digital thinking.

Primary findings

The frequency and percentage of technology tools used that were pre-service teachers' self-reported favorites both in the first week and the fourteenth week were investigated. During the first week, a majority (65.5%) of responses identified a specific device that was useful for a teacher, whereas the rest (34.5%) identified a specific software application that was useful for a teacher or student. However, at the 14th week, teachers expressed their thinking differently. The reasons these tools were named as favorites in the majority of responses were categorized by the researcher as enabling student-centered creation (32%) and enabling teacher assessment (32%). For instance, teachers liked the ability to have learners create digital stories and to evaluate learners'

performances instantly. The rest responses were categorized as classroom management (21.4%) and teaching materials (14.3%), such as recognizing a platform to manage learning materials for students or using a technology to create instructional media for students.

These results indicate a technological and pedagogical knowledge shift among pre-service teachers during the course. The researcher took a closer look at their thinking. In the first week, the device and software application responses represented a perception of the technology tool on an efficient '*single-purpose level*'. This can be seen from a participant's statement identifying the computer as a favorite tool because it "*allows students to search and become intrigued. It improved my research skills over the years and I know it can do the same for my students as well*" (PT#2). In contrast, in response to the same question at the end of semester, all the digital tools declared as favorites by participants were categorized as diverse software usages. To be more specific, their responses about these software applications showed that their thinking developed and expanded to connect technology with pedagogical knowledge, such as creation or assessment. Participants started to describe a favorite tool with mindful educational purposes by saying that "*it is a different way for students to express themselves and show what they learned in a way that isn't a written paper*" (PT#10). Given the fact that participants considered diverse educational purposes when choosing tools for their instructional design, the researcher found this perception pattern as the '*versatile-constructed level*' during their post-training.

Conclusions

Based upon this initial study, the researcher found that pre-service teachers' perceptions of digital tool usage are interfering with teaching beliefs. As participants gained opportunities to explore their choice of different technology tools throughout the 14-week course, they looked at the tools' uses from a more constructivist mindset. Thus, at the end of the course, their selection of a favorite tool was no longer based on a specific device for efficiency; rather, they considered more which tools best support teaching and learning in practical ways. The researcher argues that the development of digital identity is not only overlapped between technological knowledge (e.g, participants' self-learning of the applications of a new tool) and pedagogical knowledge (e.g., participants' reflection on how to integrate a tool with pedagogical approaches), but also fostered by community of practice (Wenger, 1998). This implies that with the rapid change in technology products, future teachers are starting to teach themselves to use a new technology tool and develop their digital identity through wider participation with an attempt to transform pedagogies for students.

In addition, professional development could foster both transformative use and learning by facilitating teachers rethinking their personal pedagogical mindsets and redefining a tool to meet students' learning purpose when integrating technology into classrooms. Furthermore, this study suggests that teachers be mindful of their development of digital thinking and identity to transform learning through technology integration. To validate primary study results and examine the above patterns and assumptions, future research of this study will continue exploring and analyzing other participants' artifacts, including teachers' digital portfolios and lesson plans to triangulate the initial findings of this study.

References

Burden, K., Aubusson, P., Brindley, S & Schuck, S. (2016). Changing knowledge, changing technology: Implications for Teacher Education Futures. *Journal of education for Teaching: International research and pedagogy, 42* (1).

Ertmer, P. A., Ottenbreit-Leftwich, A. T., Sadik, O., Sendurur, E., & Sendurur, P. (2012). Teacher beliefs and technology integration practices: A critical relationship. *Computers & Education, 59*(2), 423-435.

Fishman, B. J., Davis, E. A., & Chan, C. K. K. (2014). A learning sciences perspective on teacher learning research. In Sawyer, R. K. (Ed.). *The Cambridge Handbook of the Learning Sciences: 2nd Edition*. P750-p769. Cambridge, UK: Cambridge University Press.

Goode, J. (2010). The digital identity divide: how technology knowledge impacts college students. *New media & society, 12*(3), 497-513.

Loveless, A., & Williamson, B. (2013). *Learning identities in a digital age: Rethinking creativity, education and technology*. New York, NY: Routledge.

Miles, M. B., Huberman, A. M., & Saldana, J. (2013). *Qualitative data analysis: A methods sourcebook*. Thousand Oaks, CA: SAGE.

Wenger, E. (1998). *Communities of Practice: Learning, Meaning, and Identity*. Cambridge: Cambridge University Press.

Yin, R. K. (2014). *Case study research: Design and methods. Fifth Edition*. Thousand Oaks, CA: SAGE.

Using Web 2.0 Technologies to Facilitate Scaffolding of Student-Led, Collaborative Learning Outside of the Classroom

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Abstract: Collaborative Learning (CL) is a well-established pedagogy for formal learning in the classroom, but there is little research into CL in non-formal learning environments. 'Scaffolding' required to structure CL activities, is often absent in non-formal CL. 'Shadow Modules', student-led, student-focused CL groups which parallel the taught module/course, provide this scaffolding. Shadow Modules correlate with positive grade outcomes and resources produced by CL activity are shared using Web 2.0 technologies, and utilized widely. Shadow Modules provide a sustainable format for CL outside of the formal classroom.

Keywords: Collaborative Learning, Scaffolding, Web 2.0, non-formal learning, social media

Introduction

Collaborative learning (CL) is a powerful pedagogy (Dillenbourg, 1999), but it requires 'scaffolding' (activities or tasks defined by the teacher or facilitator, to structure the collaborative interactions; Wood, Bruner, & Ross, 1976) to be effective. CL also has potential to support CL in non-formal learning (self-directed learning, reinforcing information, revision, or assignments). However, non-formal CL often lacks scaffolding, resulting in loss of direction and focus (Scott, Moxham, & Rutherford, 2014). A framework for scaffolding for non-formal CL activities is needed, therefore. We have developed and approach, 'Shadow Modules'- voluntary student-led, student-focused CL communities, which run alongside a formal taught module/course, reinforcing the content,
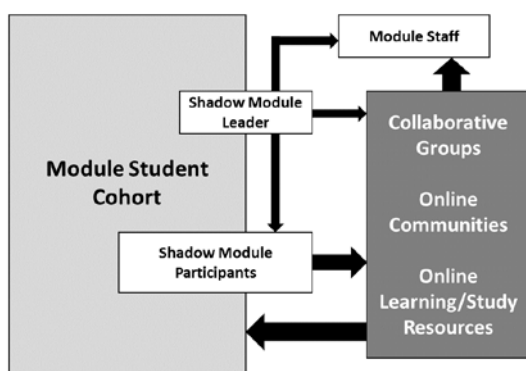
Figure 1. The Shadow Module format, showing interactions between stakeholders.

but are not part of the formal taught curriculum (Scott et al., 2014). The Shadow Module (Figure 1) is run by a 'Shadow Module Leader (SML) who organizes and leads CL sessions. The SML liaises with the teacher(s) for guidance, but other than this, the Shadow Module has no formal link with the formal taught course. Shadow Modules are either face-to-face CL groups, online collaborative social media communities, or a fusion of both. Resources created in Shadow Module activities are shared with all students *via* Web 2.0 collaborative technologies. Feedback from the SML to academic staff can have positive impact on the ongoing development of the taught module itself. This study evaluates the impact of Shadow Modules on student outcomes and investigates potential factors influencing students' engagement with the Shadow Module CL activities.

Methodology

Shadow Modules were associated with Year 1, 2 and 3 undergraduate Bioscience modules/courses. Accessions of student-generated Shadow Module resources were counted, to reveal student engagement patterns. The relationship between Shadow Module engagement and module grades was also investigated. Open-question questionnaires, and semi-structured interviews with participants were analyzed using Grounded Theory.

Results

Shadow module resources are used actively by students

Figure 2 shows number of accessions of resources, in the time period prior to, and after, the end of module exam. Usage levels suggest both participant and non-participant students were utilizing shadow module resources. The most effective Web 2.0 medium for authoring resources was the shared document in Google Drive. Social media was the most common platform for sharing resources and outputs (Facebook or Learnium).

Shadow Modules correlate with improved student outcomes

High levels of engagement in the Shadow Module correlated with a significantly greater module grade than students who did not engage in any shadow module activity (Figure 3; unpaired t-test, P = 0.05).

Complex factors influence student engagement with Shadow Modules

Figure 4 summarizes the codes from the interview analyses. The codes show that students faced a range of influencing factors, with positive and negative interactions affecting their engagement with Shadow Module activities.

Figure 2. Number of accessions of online resources/day. Date of module examination is indicated by an arrow.

Figure 3. Module grade versus engagement with CL activities. Module grade normalized against overall degree average. High engagers, *n* = 17; non-engagers, *n* = 278. Error bars = SEM. Unpaired t-test shows significance, P = 0.05
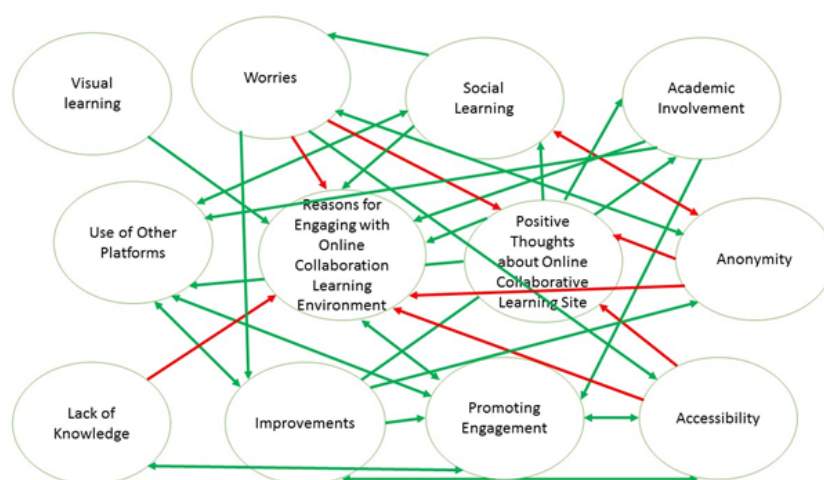
Figure 4. Associations made between themes identified in codes developed from interviews. Arrows represent positive (green arrow), or negative (red arrow) effects on one another.

Discussion

Web 2.0 collaborative technologies appear to facilitate a positive impact of the shadow modules to broaden the scope of non-formal CL activities. Either by developing mutually-supportive online communities, or sharing the outputs of face-to-face CL activities with the wider cohort. Shadow Modules conform to frameworks for scaffolding (Applebee, 1986). By encouraging students to work in partnership – both with each other and with academic staff – they become active agents in co-constructing their own learning and that of their peers.

References

Applebee, A. N. (1986). Problems in process approaches: Towards a reconceptualization of process instruction. In A. R. Petrosky & D. Bartholomae (Eds.), *The Teaching of Writing. 85th Yearbook of the National Society for the Study of Education*. Chicago: University of Chicago Press.

Dillenbourg, P. (1999). What do you mean by 'collaborative learning'? In P. Dillenbourg (Ed.), *Collaborative-learning: Cognitive and computational approaches* (pp. 1 -19). Oxford: Elsevier.

Scott, J. L., Moxham, B. J., & Rutherford, S. M. (2014). Building an open academic environment - a new approach to empowering students in their learning of anatomy through 'Shadow Modules'. *J Anat, 224*(3), 286-295. doi:10.1111/joa.12112

Wood, D., Bruner, J., & Ross, G. (1976). The role of tutoring in problem-solving. *Journal of Child Psychology and Child Psychiatry, 17*, 89-100.

Making Mathematical Thinking Visible Through Technology

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Abstract: At this session, we will discuss new and evolving technology that helps students make their thinking about mathematics visible to their peers and teachers. Building on prototypes that have been successful in algebra and pre-algebra classrooms, we will illustrate how technology may afford new opportunities for collaborative learning and mathematical discourse that exceed what is possible when supports are limited to written artifacts. Opportunities for automated analysis of digital artifacts will be discussed.

Introduction

In a mathematics class, student work provides insight into students' thinking as well as how teachers can best support them in improving their understanding of the content (Borko, Mayfield, Marion, Flexer, & Cumbo, 1997). Reviewing student work in whole class or small group settings can be an effective way to show students that the process of doing mathematics is valuable and that the correct answer is just one component of mathematics. By building off of student thinking and highlighting things that students do well, discussions of student work can be an encouraging and formative process (Carpenter, Fennema, & Franke, 1996). It also acts as a formative assessment by making the expectations and path forward clear to the student and by providing information to the teacher that can inform instruction (Black & Wiliam, 2009). This process helps clarify the learning goals and improves both teaching and learning (Penuel & Shepard, 2008; Shepard, 2005). Student work also provides an opportunity for mathematical discourse, a practice that has been suggested to promote equitable classroom environments where traditional power structures can be disrupted (Nasir, Hand, & Taylor, 2008). In this sense, learning mathematics is viewed as a byproduct of classroom activity and participation in discourse (Cobb, Wood, & Yackel, 1993).

Description of relevant features of Woot Math Polls

Woot Math Polls is a math-specific digital formative assessment tool where students complete tasks on a cloud-connected device (e.g., laptop, tablet, mobile device, etc.). These tasks can involve various formats such as multiple choice, gesture-based graphing, select a point or region of an image, fill in the blank or other constructed response. Students show work using a mouse or touch screen on a scratch pad that includes a function editor, a graphing environment, a drawing tool, a calculator and a table feature. One of the features of Woot Math Polls is that after students respond, the teacher can choose to display individual responses or an aggregate of the class' responses. The teacher may also choose to display the work that the student did on the digital scratchpad. Figure 1 shows an example of hypothetical student work where they showed their work but did not get the question right. The teacher could display the work and highlight what the student did well and allow the class to suggest where they went astray.

Problem #3 | INCORRECT ⊗

Simplify:

$-2(3x + 7) = 2y$

Use the scratchpad to show your work.

−y=6x-7

Show your work

$-2(3x + 7) = 2y$
$-6x + 7 = 2y$
$-y = 6x - 7$
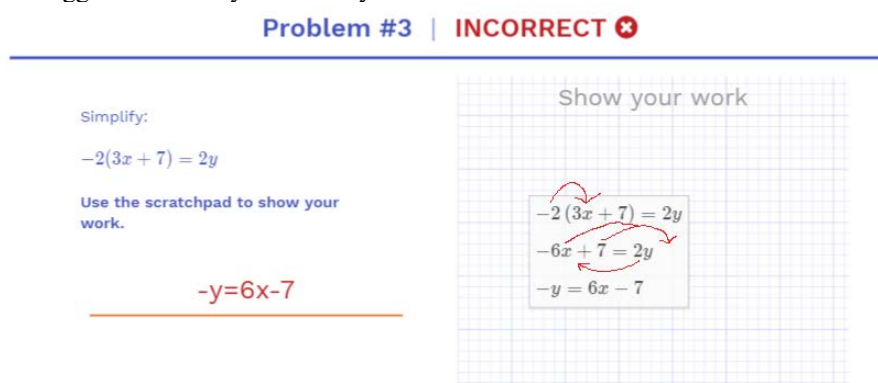
Figure 1. A screen shot of hypothetical student work displayed using Woot Math Polls.

Teacher perspective

A recent professional development study that used Woot Math Polls found that teachers highly value the displaying student work feature of the tool. In a post survey, an Algebra I teacher described how she used the display student work feature.

It allows me to see their understanding and examples of student work (not just answers). Sometimes students are really close to getting the correct understanding and I really liked how I could pull of examples for the whole class to see and have them help pinpoint mistakes. There were a lot of 'a-ha' moments where the students could totally see what they did wrong and make a positive connection to fixing a misconception. (Teacher A, 2017)

This teacher pointed out how the students seemed to gain from being able to see examples of work that were close to correct and identify the errors. Beyond identifying errors, another teacher remarked about how the feature promoted discussion and comfort with talking about mistakes and how to address them.

I think it started to make students feel more comfortable about talking about common mistakes and why/how they are made especially when reviewing student work. I also think that it made students excited about sharing what they understood and interested in sharing it with each other. (Teacher B, 2017)

This teacher claimed that the tool helped promote mathematical discourse in the classroom in ways that influenced students' interest in having their solution strategy contribute to the mathematics being discussed. That is, students wanted to position their mathematical activity as part of the lesson in ways that were not observed without Woot Math Polls. This teacher also talked about how she could use the tool to move towards more mathematical discourse, once she became more familiar with using student understandings. The tool supported teachers' promotion of a classroom culture that was supportive of mistakes, positioning students' own products as opportunities to learn (De Corte, 1995). It also shows how the tool has potential in helping the teacher facilitate productive student dispositions and discussions about mathematics.

Future directions and final thoughts

Digital technology affords new opportunities for collaborative learning by automatically recognizing students' work that is proximal to valid solutions. Such tools facilitate the display and analysis of student work in a classroom setting allowing the analysis to be more efficient and more immediate compared to the use of written artifacts of student work that must be analyzed by hand.

In addition to discussing the implications of this tool for teachers and classrooms, this poster also hopes to suggest future directions for how Woot Math Polls and similar technology can help use examples of student work to support mathematical discourse and growth-oriented classroom norms. Other applications include having the tool automatically display discussion questions, pre-determined by the teacher or task designer, that would help support teachers in facilitating these types of discussions. Another idea is to have the tool automatically analyze student work and learn patterns of common errors or misconceptions. Then this could be used to categorize student responses and provide examples that would afford productive classroom discussions.

References

Black, P., & Wiliam, D. (2009). Developing the theory of formative assessment. *Educational Assessment, Evaluation and Accountability*, *21*(1), 5–31.

Borko, H., Mayfield, V., Marion, S., Flexer, R., & Cumbo, K. (1997). Teachers' Developing Ideas and Practices about Mathematics Performance Assessment: Successes, Stumbling Blocks, and Implications for Professional Development. *Teaching and Teacher Education*, *13*(3), 259–278.

Carpenter, T. P., Fennema, E., & Franke, M. L. (1996). Cognitively Guided Instruction: A Knowledge Base for Reform in Primary Mathematics Instruction. *The Elementary School Journal*, *97*(1), 3.

Cobb, P., Wood, T., & Yackel, E. (1993). Discourse, mathematical thinking, and classroom. *Contexts for Learning: Sociocultural Dynamics in Children's Development*.

De Corte, E. (1995). Fostering cognitive growth: A perspective from research on mathematics learning and instruction. *Educational Psychologist*, *30*(1), 37–46. https://doi.org/10.1207/s15326985ep3001_4

Nasir, N. S., Hand, V., & Taylor, E. V. (2008). Culture and Mathematics in School: Boundaries Between "Cultural" and "Domain" Knowledge in the Mathematics Classroom and Beyond. *Review of Research in Education*, *32*(1), 187–240.

Penuel, W., & Shepard, L. A. (2008). *Assessment and Teaching Science. International Journal of Learning* (Vol. 15).

Shepard, L. A. (2005). Formative assessment: Caveat emptor. *ETS Invitational Conference, New York, NY.*

Teacher A. (November 10, 2017). Post PD Reflection Survey

Teacher B. (November 10, 2017). Post PD Reflection Survey

Networks in Small-Group and Whole-class Structures in Large Knowledge Building Communities

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Abstract: This study compared small-group and whole-class structures in two large knowledge building communities. We analyzed students' online notes on Knowledge Forum by KBDex (Oshima, Oshima, & Matsuzawa, 2012). Results found that students in the small-group structure showed better community knowledge advancement. However, the unbalanced distribution of expertise in the small-group class was also observed.

Introduction

Knowledge building is a community-oriented approach emphasizing knowledge creation (Scardamalia, 2002). Research on collaborative knowledge building showed that small-group practices could contribute productive community-level interaction (Resendes, Scardamalia, Bereiter, Chen, & Halewood, 2015; Yang, van Aalst, Chan, & Tian, 2016). The small-group social configuration within a community is an attractive option for my research program, which aims to investigate knowledge building in large community with more than 50 students. To this end, we used KBDex to compare the advancement of community knowledge between the two social configurations, and to visualize different groups' contributions to the community knowledge.

Method

This study was carried out in two Grade Four classrooms from a primary school in Mainland China, with 54 students in Class A and 53 in Class B. The two classes investigated the topic of *Force & Motion* with the support of KF for about 9 weeks. In Class A, students discussed face-to-face in groups before the whole community online interaction. As a comparison, Class B conducted Knowledge Forum (KF) activities without such group discussions. 463 online notes from Class A and 356 from Class B were collected on KF.

Data analysis and findings

We first compared the advancement of collective knowledge between two classes through visual inspection of semantic relationships from KBDex. We selected three different phases (five notes created, 200 notes created and the final one created) of the word network to trace students' online activities in these two classes. Figure 1 shows that in the beginning of the discussion, words were less concentrated as three separate parts in Class A. However, due to constantly combination, all the words were combined in the end. Conversely, Class B shows a trend of decentration. Overall, students in Class A spontaneously formed cross-group interactions that facilitate community knowledge.

Figure 1. Snapshots of the network of word through time (Class A).

Figure 2. Snapshots of the network of word through time (Class B).

To explore different contributions within groups of the better knowledge advancement class (Class A), we compared groups' word networks through KBDex. We chose three groups according to the number of key words they used: low/ medium/ high active groups. Then we compared their word networks through KBDex. In Figure 3, all the balls represent key words of the whole community, while red ones indicate which words were used by the selected groups. Results illustrates unbalanced distribution of expertise: (1) different groups focused on different areas; (2) high active groups could focus on the center of the whole community, as well as marginalized areas; (3) even the low active group can also rise bridging words, such as stride and frequency of walking; (4) even the high active group could not cover all the key words of the community; (5) large learning gaps existed among all the three-level groups.
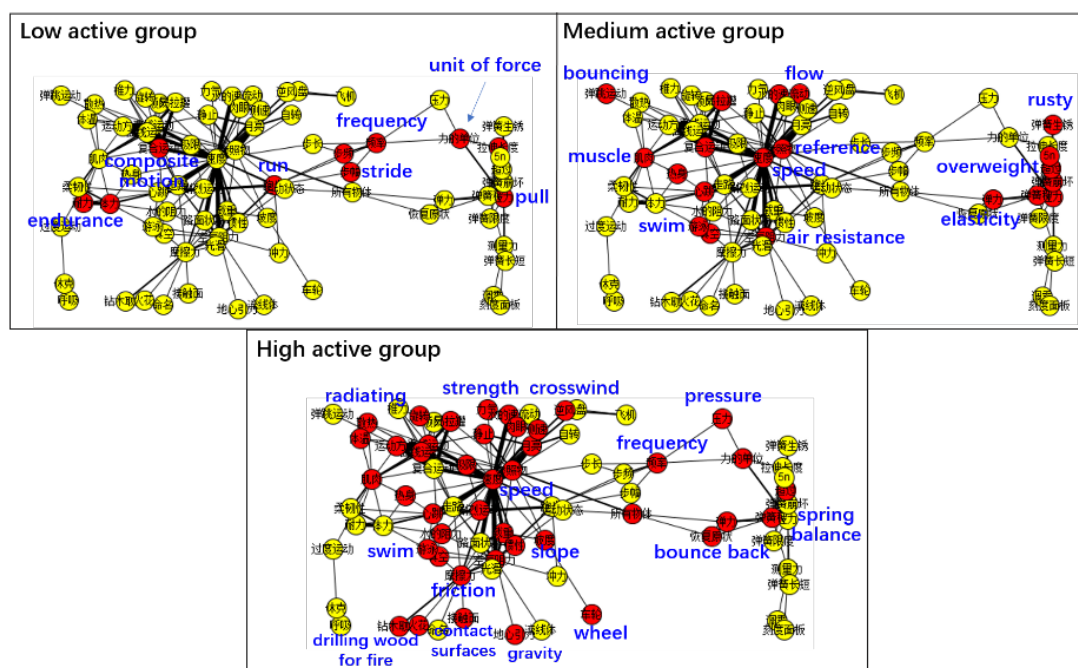
Figure 3. Social network of words in low/medium/high active groups.

Conclusions

By analyzing students' word networks of the two social configurations, we can see that the small-group class showed higher socio-dynamics of community knowledge advancement. However, groups in the small-group class showed different degree of contribution to the whole community. Substantial future work is needed to explore new tools to visualize the comparation of contributions among groups as well as the comparation of groups with the whole community. Furthermore, future instructional design should focus on deeper cross-group interactions to achieve the transformation from group knowledge to community knowledge.

References

Oshima, J., Oshima, R., & Matsuzawa, Y. (2012). Knowledge Building Discourse Explorer: a social network analysis application for knowledge building discourse. *Educational technology research and development, 60*(5), 903-921.

Resendes, M., Scardamalia, M., Bereiter, C., Chen, B., & Halewood, C. (2015). Group-level formative feedback and metadiscourse. *International Journal of Computer-Supported Collaborative Learning, 10*(3), 309-336.

Scardamalia, M. (2002). Collective cognitive responsibility for the advancement of knowledge. *Liberal education in a knowledge society, 97*, 67-98.

Yang, Y., van Aalst, J., Chan, C. K., & Tian, W. (2016). Reflective assessment in knowledge building by students with low academic achievement. *International Journal of Computer-Supported Collaborative Learning, 11*(3), 281-311.

An Initial Examination of Designed Features to Support Computational Thinking in Commercial Early Childhood Toys

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Abstract: A number of commercial toys have been developed and marketed for young children that purportedly support the development of computational thinking and coding skills. However, we have yet to specify how these toys are supposed to support computational thinking. In this poster, we provide an initial examination of designed features in 20 commercial toys marketed to 5 and 6 year old children.

Introduction

Several toys have begun to appear commercially that purport to help children with computational thinking and coding skills. For instance, Learning Resources has released a "Programmable Robot Mouse" toy that is intended to help children develop computational thinking skills by interacting with a series of buttons on the toy's body that determine how the toy will move. The Robot Mouse is just one example in a marketplace that is becoming rapidly populated with computationally-themed toys. As a research team, we are interested in how such toys are actually used and the extent to which they support computational thinking among young children. As a first step, we present in this poster the beginnings of an analytical framework for viewing the computational potential of these toys and an initial frequency analysis of some designed computational features in coding toys currently on the market.

Commercial toys as designed play artifacts

Play has been recognized as fundamental, both developmentally and socially (Piaget, 1962; Vygotsky, 1978). Indeed, learning scientists have argued that play is an underutilized resource that can be made more prominent in the design of novel immersive learning environments (Enyedy, Danish, Delacruz, & Kumar, 2012). As a parallel point, we believe that specific handheld artifacts are also an important component of play to examine. With commercial toys, we assume that particular forms of play are intended in the design of those artifacts.

Taking that assumption seriously, we posit there are a set of intended features associated with coding toys that we designate as *ideational* and *physical*. Ideational features rely upon the primitive operational meanings and the presumed perspective of the designer. For instance, pressing a button with a forward facing arrow on the Robot Mouse toy is intended to map onto a forward move instruction. It is akin to aspects of what Norman (1988) refers to as the mental model mapped to a user interface. It refers to the way in which the behavior of the artifact could be understood. The physical features are those visible and manipulable aspects that are associated with material affordances (Norman, 1988). The button on the Robot Mouse with the forward facing arrow affords pushing, implying it is part of the toys operation. Other computational-themed toys may have physical features such as instruction tiles that afford grasping and placing in specific locations.

We characterize intended play with these toys as involving a dynamic integration of physical features and ideational features. Intended play practice may be that the child is supposed to help an agent (such as a modified mouse) navigate a space (the floor) to complete a journey by way of giving algorithmic instructions. The purported computational relations are then assumed to be particular mappings of ideational features to physical features that instantiate some aspect of computational thinking. Given those assumptions, we provide an examination of several computation-themed coding toys marketed for young children.

Data sources and analysis

Each toy found in our initial search was screened for inclusion/exclusion based on the following criteria (1): proposed target audience of children ages five to six years old and (2) marketed as a learn-to-code toy or product. A final sample of twenty toys were selected, including Bee-Bot, Blue-Bot, Code-a-pillar, Coding Jam, Coji Robot, Cubetto, Dash, Dot, Finch Robot, FurReal Proto Max, Bunny Trails, Robot Races, Kibo, Let's Go Code Activity Set, Ozobot, Puzzlets, Robot Mouse, Robot Turtles, Siggy Scooter, and Unruly Splats.

As a next step, these toys were examined and reviewed based on evaluation of their components, structure, manuals, and/or observation of their use in some informal youth play activities. From review of these toys, we identified five categories for how coding is 'physically' instantiated. These include tangible, screen-based, button-based, non-electronic, and blended forms. Five computational thinking skills were also identified

from comparable recent research (e.g., Ehsan, Beebe, & Cardella, 2017). We coded each toy with one or more of the following: *algorithmic thinking*, defined as requiring a sequence of steps to complete a task; *scaffolded debugging*, defined as support for finding or fixing goal-deviant errors, *problem decomposition*, defined as breaking a goal into subgoals or more restricted actions; *abstraction*, defined as defining reusable routines or sequences; and *pattern recognition*, defined as identifying repeating sequences or structures.

Figure 1. Youth playing with some of the examined toys, including Robot Mouse (left), Cubetto (center), and Ozobot (right).

Findings

Figure 2 below shows the distribution of physical features across the twenty toys. *Button-based* media involve physical button features and are represented by the Robot Mouse and Bee-Bot. *Tangible* media are physical pieces that are placed or manipulated as represented by Cubetto. Figure 3 also shows the distribution of computational thinking skills that are presumed to be specific ideational/physical mappings intended by design. We found that all of the examined toys incorporated algorithmic thinking. Only six covered abstraction. Initial findings indicate the primary focus of most current coding toys targeting five and six year old children is on teaching algorithms and scaffolded debugging.
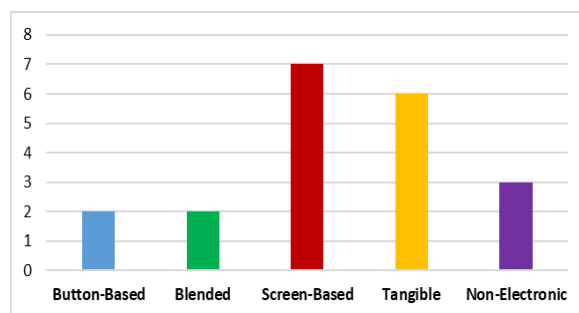
Figure 2. Physical Features.
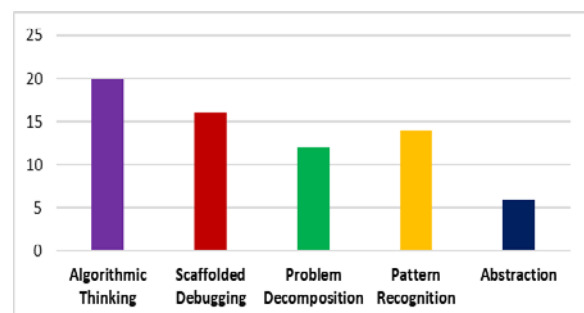
Figure 3. Computational Thinking Skills.

Conclusion

Within the commercial sector, toys that are intended to promote computational thinking are mobilizing a variety of ideational and physical features. The primary emphases tend to be through tangible and screen-based (i.e., tablets) media using visual programming languages. Algorithmic thinking and scaffolded debugging appear to receive more emphasis. Future research should explore how commercial early childhood toys can be integrated with curriculum to include lesser represented computational thinking skills such as abstraction. In future work, we will examine whether these intended features and computational thinking skills are indeed realized when children are playing with these toys in early childhood education settings.

References

Ehsan, H., Beebe, C., & Cardella, M.E. (2017) *Promoting Computational Thinking Using Apps* Paper presented at P-12 Engineering & Design Education Research Summit, Chicago, Illinois.

Enyedy, N., Danish, J., Delacruz, G., & Kumar, M. (2012). Learning physics through play in an augmented reality environment. *International Journal of Computer-Supported Collaborative Learning, 7*(3), 347-378.

Norman, D. (1988). *The Design of Everyday Things*. New York: Basic Books.

Piaget, J. (1962). Play, dreams, and imitation in childhood. New York, NY: Norton.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes* Cambridge, Mass.: Harvard University Press.

Socialization and Cognitive Apprenticeship in Online Doctoral Programs

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Abstract: Research to date on the effectiveness and popularity of online doctoral programs has looked largely at either quantitative measures of student satisfaction or of administrative effectiveness and design. This qualitative study reports findings from four online doctoral programs in one UK university. We analyse the data through the lens of cognitive apprenticeship to help us better understand the individual trajectories of students in the thesis portion of their programs.

Research background

The claims of effectiveness and quality of online/distance education programs are often based on generally perceived advantages of technological affordances such as accessibility, flexibility, or interactivity rather than issues concerned with pedagogical goals, such as providing opportunities for online/distance students with enculturation of scholarship, who normally do not experience research apprenticeship typically enjoyed by on-campus students (Brett, Lee, & Oztok, 2016). Two of the most common perspectives on this research that appear in the current literature are: 1) student experiences of or satisfaction with their online/distance post-graduate program (Bolliger & Halupa, 2012), and 2) administrative or institutional reviews of the process and outcomes of the planning, design and implementation (Kumar & Dawson, 2012). A growing number of enrolments in the program is often considered as primary evidence of program success. Here, we use the term *socialization* to conceptualize both the implicit and explicit processes by which post-graduate students acquire the knowledge and skills necessary for their scholarly development and professional career (Brett et al., 2016). In order to examine and articulate how socialization happens throughout online doctoral studies, we also use the notion of *cognitive apprenticeship*. We define and explain how we are using these terms in more detail in the following section.

Theoretical framework

Post-graduate education

Post-graduate education, particularly at the doctoral level, is traditionally characterized as an apprenticeship in which students are learning the practice of research by working with supervisors and peers. According to Lave and Wenger (1991), learning occurs through various apprenticeship arrangements through a relational process of legitimate peripheral participation: "activities, tasks, functions, and understandings do not exist in isolation; they are part of broader systems of relations in which they have meaning. These systems of relations arise out of and are reproduced and developed within social communities" (p. 53). The community, Lave and Wenger assert, implies "participation in an activity system about which participants share understandings concerning what they are doing and what that means in their lives and for their communities" (p. 98). However, the ways in which scholarship is learned in face-to-face spaces cannot simply be applied to online programmes. Online/distance programmes are not naturally built on these principles and thus the range of experiences needed for the apprenticeship model of learning may become decontextualized due to the lack of sense of research group.

Cognitive apprenticeship

In this model, learning is about acquiring domain-specific methods through a combination of observation, coaching, and practice. The concept of cognitive apprenticeship is built on these principles but it goes beyond practical skills and focuses on cognitive skills in two distinct ways:

> First, the term apprenticeship emphasizes that cognitive apprenticeship was aimed primarily at teaching the processes that experts use to handle complex tasks. Like traditional apprenticeship, cognitive apprenticeship emphasizes that knowledge must be used in solving real-world problems. … Second, the term cognitive emphasizes that the focus is on cognitive skills, rather than physical ones. Traditional apprenticeship evolved to teach domains in which the target skills are externally visible, and thus readily available to both student and teacher

for observation, refinement, and correction, and bear a transparent relationship to concrete products. (Collins & Kapur, 2014, p. 110).

Cognitive apprenticeship, thus, is concerned with knowledge required for expertise: not only learning subject matter specific concepts, facts, and procedures but also acquiring nuanced knowledge about how to learn and when to apply, new concepts, facts, and procedures.

Socialization in graduate schools

It refers to the "process through which individuals gain knowledge, skills, and values necessary for successful entry into a professional career requiring an advanced level of specialized knowledge and skills" (Weidman, Twale, & Stein, 2001, p. iii). Socialization into graduate school requires different level of understanding and commitment depending on individual needs, goals, profession, and the nature of the discipline.

Methodology

This study was conducted in 4 different online/distance doctoral programs in a UK university. 22 students agreed to participate in a semi-structured interview. Here, we summarize our initial findings due to limits.

Findings

Students seemed to internalize their isolation as a natural process for their development as a researcher or scholar. The *personal nature of the doctoral thesis* was the main theme in their explanation of the doctoral education. However, the concept of cognitive apprenticeship posits that through participating in communities, students not only learn subject matter specific concepts and facts but also acquire knowledge about how to learn new concepts, facts, and procedures. Unfortunately, our results indicate that students lack enculturation in the principles of cognitive apprenticeship. This lack of enculturation is manifest in how they internalized their isolation as a natural process inherent in the doctoral work. The result is that they are inaccurately equating the unstructured and personal nature of the thesis work with the experience of working alone which has resulted from the lack of program structure at this phase of the doctoral journey.

Discussion and conclusion

Despite the inconclusive nature of our findings, it is evident that we have to rethink the theory and practice of online/distance post-graduate education. We need to think differently about traditional notions of apprenticeship. Perhaps, the first step towards a more effective direction is to focus less on quantitative measures for *success*, like enrolment statistics or graduation rate but rather to employ qualitative judgements of the post-graduate experience. What might be the guidelines for such qualitative judgments? The answer may lie within the principles of the learning sciences: knowledge is distributed across individuals within the environment. That is, learning is not an in-the-head phenomenon but a matter of engagement with, participation in, and membership to a community (Oztok, 2016). It is through this notion of learning that we may develop a more effective framework to reconceptualise the theory and practice of online/distance post-graduate education within the cognitive apprenticeship model of learning.

References

Bolliger, D. U., & Halupa, C. (2012). Student perceptions of satisfaction and anxiety in an online doctoral program. *Distance Education, 33*(1), 81-98. doi:http://dx.doi.org/10.1080/01587919.2012.667961

Brett, C., Lee, K., & Oztok, M. (2016). Socialization and Social Capital in Online Doctoral Programs. In S. Cranmer, N. B. Dohn, M. de Laat, T. Ryberg, & J. A. Sime (Eds.), *Proceedings of the 10th International Conference on Networked Learning 2016* (pp. 264 - 268). Lancaster, UK: Lancaster University.

Collins, A., & Kapur, M. (2014). Cognitive Apprenticeship. In R. K. Sawyer (Ed.), *The Cambridge Handbook of the Learning Sciences* (2nd ed., pp. 109-127). Cambridge, UK: Cambridge University Press.

Kumar, S., & Dawson, K. (2012). Theory to practice: Implementation and initial impact of an online doctoral program. *Online Journal of Distance Learning Administration, 15*(1).

Lave, J., & Wenger, E. (1991). *Situated Learning: Legitimate Peripheral Participation*. New York, NY: Cambridge University Press.

Oztok, M. (2016). Cultural Ways of Constructing Knowledge: The Role of Identities in Online Group Discussions. *International Journal of Computer-Supported Collaborative Learning, 11*(2), 157-186.

Weidman, J. C., Twale, D. J., & Stein, E. L. (2001). *Socialization of graduate and professional students in higher education: A perilous passage?* San Francisco, CA: Jossey-Bass.

Game Design Literacy as a Problem-Solving Disposition

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Abstract: In this paper, we argue that developing game design literacy supports learners' disciplinary engagement as well as skills needed in different situations in life, especially problem-solving and decision-making. Designing games for both their own learning and others' play challenges learners to develop a disciplinary understanding while transforming their ideas into communicative, coherent, and playable games. We define game design literacy and present our findings on how learners identified and solved problems in designing games.

Learners' creative expressions, i.e., designing personally meaningful artifacts, have been advocated in various learning settings for many decades (Dewey, 1934). On the other hand, it is difficult to engage learners in design activities that offer the continuity beyond their personal meanings, conceptual understanding, or identity development. Scholarship of constructionist gaming (i.e., creating games in the classroom) has offered in-depth perspectives on how learners could develop coding skills and academic understanding through designing digital games, and started to investigate learners' collaboration and identity development in this process (Kafai & Burke, 2015). When we call something a game, it has a system of rules, symbols, and models. Game design requires a deep sense of this system (Gee, 2008). When a game is played, its system is enacted and evolves as players become part of it. We argue that game design literacy involves this anticipation of players beyond the designers' personal meanings. In this paper, we describe how students identified and solved problems as they designed board/card games for educational goals, in anticipation of players' actions. We define game design literacy as problem-solving dispositions, and present our findings from a western Canadian middle school.

Game design literacy

Sheridan and Rowsell (2010) sought to theorize "design literacies" by studying designers of varying disciplines. Building on these efforts, we are investigating how the process of designing games can indicate learners' problem-solving dispositions. When learners engage in a participatory design, they identify what is worthy of knowing in their design, develop and redefine the group and class norms within the socio-cultural context, and express their identities through discourse and artifacts (Kim, Tan, & Bielaczyc, 2015). Game design can have a very special place in education: it requires incorporating different modes of knowledge and skills to create a system for players to participate in it through play (Zimmerman, 2013). It is not only about the designers' personal meanings, but also about the future players' creation of new meanings. To become game design literate, one needs to understand and create a complex set of meanings for a specific system, to symbolically represent the components of the system, and to structure the play based on the rules (Gee, 2008). Game design, however, entails not only one's understanding of how the system operates, but also one's anticipation of how it might be transformed when played (Zimmerman, 2013). Specific meanings, therefore, are both designed and emerged as players participate in the gameplay. Within the task of game design, we argue that there are varying levels of design tasks that emerge as problems for designers to solve. We suggest that game design literacy, which calls for learners understanding and anticipation of systems, design, and play, indicates complex problem-solving dispositions that Sheridan and Rowsell (2010) observed from professionals.

Research design and findings

We worked with two Grade 8 teachers (Math/Science and Humanities) and a learning specialist to design and implement the board/card game design approach, addressing the learning outcomes from Grade 8 Programs of Study: Mechanical Systems, Origins of a Western Worldview (Renaissance Europe), Number Sense (Rates, Ratio, Proportions), and Communication/Presentation Skills. The teachers asked the students to develop games that would be fun to play but also integrate curriculum. A board game designer visited the class twice to introduce board/card game designs and to give feedback when the groups had early prototypes. They finished their projects on the school's celebration of learning day. We took an ethnographic approach to observe and document this process, including video-recordings and collecting their game design artifacts, and conducted interviews with the teachers and the students. Two researchers individually noted the kinds of problems and solutions that the students identified while designing games, and discussed them for consensus. We observed that many students looked for information beyond the topic knowledge, and engaged in problem-solving and decision-making processes. Their engagement in this process showed relevance to the complexity of students'

games, which ranged from board-based trivia games to sophisticated role-playing or strategy games. We briefly summarize the groups' identified problems and the solutions, using examples from two groups.

Incorporating learning content. Some groups took the task of incorporating multiple disciplines in their games as their important problem to solve. For example, the goal of Renaissance: Rebirth (R:R) game was to build ships and houses (i.e., using simple machines) within the context of Renaissance. Players needed to visit universities, trading posts, and shops to gain knowledge and purchase goods and resources, within the context of applying Da Vinci's early concept of hydraulics. After creating the game context of Renaissance and bringing ideas from Mechanical Systems, one of the group members suggested incorporating Number Sense (rates and ratio) in their point and trading system. In the end, they also symbolized this system in their game title acronym (R:R). Their work demonstrates creating a complex set of meanings (i.e., Renaissance as background, science/math knowledge, rules, and interactions) that open possibilities for players to create different meanings.

Enacting the historical figures. Some groups solved the problem of how to create a dynamic narrative with historical figures and their roles within the historical time of Renaissance. One group's solution was to create a role-playing card game, using the important Renaissance figures as their characters. They called their game, Race of Renaissance. They decided to use Da Vinci, Galileo, Gutenberg, and Kepler for the roles of four players. As they were creating decks for each figure, they realized that they needed to learn about their accomplishments in order to create enough Action and Accomplishment cards. They described themselves as "researchers", as they decided to do research on each figure beyond their textbook. They explained that it helped them have more choices on what information to use in their game. Their final game involved players unlocking actions to eventually win by unlocking the masterpiece of their chosen figure. Their work demonstrates how they materialized their understanding into a system that has constituents, actions and rules.

Balancing the game. As the groups tested their games within their groups as well as with other classmates, they learned that the gameplay needed to be sustained by balancing its system and rules. This problem was not only identified by the students themselves, but also reminded by the game designer who visited them. The initial design of the R:R game's chance cards could make players quickly lose their resources, which made players' efforts to change their situation meaningless. The group decided to refine their cards when they noticed that players were frustrated drawing those cards. They also made players make their own decision about taking risks (i.e., chance cards) based on feedback. The change was for players to choose their desired route in order to take or avoid the risk of getting a chance card. For Race of Renaissance, the group realized that certain characters were likely to win because of the differences in their "strengths". They modified the decks of each figure or the points of action cards to balance the game through playtesting within the group multiple times.

Conclusion

We briefly described our findings of how game design practices provided opportunities for learners to develop game design literacy and deepen their disciplinary understanding. They not only engage in deciding the set of rules, which are informed by their disciplinary understanding, but also make sense of games as dynamic systems with emergent patterns and outcomes. We witnessed that learners' designing games for both their own and others' learning challenged them to transform their ideas into the creative, communicative and coherent expressions of a playable game. This study contributes to the scholarly discourse of advocating game design as an approach to help learners think creatively, flexibly and systematically for multiple, but connected disciplines.

References

Dewey, J. (1934). *Art as experience*. London, UK: Penguin Books.

Gee, J. P. (2008). Learning and games. *The ecology of games: Connecting youth, games, and learning*, *3*, 21-40.

Kafai, Y. B., & Burke, Q. (2015). Constructionist Gaming: Understanding the Benefits of Making Games for Learning. *Educational Psychologist*, *50*(4), 313–334. http://doi.org/10.1080/00461520.2015.1124022

Kim, B., Tan, L., & Bielaczyc, K. (2015). Learner-generated designs in participatory culture: what they are and how they are shaping learning. *Interactive Learning Environments*, *23*(5), 545-555.

Sheridan, M. P., & Rowsell, J. (2010). *Design literacies: learning and innovation in the digital age*. New York, NY: Routledge.

Zimmerman, E. (2013). Gaming literacy: Game design as a model for literacy in the twenty-first century. *The video game theory reader*, *2*, 23-31.

Acknowledgments

Computational Discourse in a Role-Playing Game Podcast

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Abstract: Tabletop role-playing games are a discourse-rich environment in which participants are frequently confronted with narrative and computational problems. By observing documented gameplay of a tabletop role-playing game (*Edge of the Empire*) and coding the discourse, we observe computational discourse being used to address narrative and mechanical problems. The contribution of this work is in presenting evidence of and examining the role of computational discourse in an under-explored environment.

Introduction

Computational literacy has been posited as one of the primary new literacies of the 21st century - it has the potential to afford students new perspectives, new agencies, and new opportunities for professions (diSessa, 2001). A core element of diSessa's computational literacy work is the concept of social computational literacy, or *computational discourse*. Recent work in games (Berland and Lee, 2011) has found evidence of complex computational discourse in the naturalistic talk around board games.

Role-playing games (RPGs), combining elements of board games and improvisational storytelling, provide high-discourse problem-solving scenarios. Within a framework of game mechanics, participants collaboratively construct a narrative. The mechanics of these systems create environments in which participants must assess situations and solve problems within the constraints of rules. Many situations in RPGs are resolved with role-play, where participants collaboratively act out or narrate events in the game to progress the story. These narrative situations – that is, situations grounded in the narrative of the game rather than in the game's mechanical rules – often require assessment and problem solving even though they are not dependent on the rules of the game system. In this work, we examine a recorded session of a RPG and examine naturalistic computational discourse. We hypothesize that computational discourse may be used to assess and solve both narrative and mechanical problems. The contribution of this work is in presenting evidence of and examining the role of computational discourse in podcasts and the use of podcasts as a source of interesting data for the learning sciences.

Methods

We collected the data from a recorded session of the CAMPAIGN Podcast (Kuhl, 2014), where four players used the Edge of the Empire game system (Fantasy Flight Games, 2013) published by Fantasy Flight Games to create a narrative in a Star Wars setting. We chose the earliest possible "normal gameplay" episode (Episode 3, 66min, Kuhl, 2014), as the expectation was that the participants might take a couple sessions to get settled into the new campaign. This group was chosen because: it is one of the most popular RPG podcasts; they explicitly focus on improvisation and storytelling; and the group consists entirely of expert roleplayers who are professional improvisers. Comedian Kat Kuhl is the gamemaster (GM). The GM has the most narrative control; she facilitates and arbitrates the game. Each other player controls one protagonist and (as a result) has less overall narrative control.

We used a coding scheme developed by Berland and Lee (2011) to observe computational discourse in collaborative strategic board games. As per their coding scheme, the first author coded for *conditional logic*, *algorithm building*, *debugging*, *simulation*, and *distributed computation*. *Conditional logic* is the use of "if-than-else" and involves thinking globally about consequences of a specific statement. *Algorithm building* is creating reusable instructions for current situations and future unknown situations. *Debugging* is identifying and resolving problems when something is not functioning. *Simulation* involves modeling future events based on logic. *Distributed computation* occurs when multiple participants contribute information that leads to a result which would not have occurred without the shared contributions. Coding categories were not mutually exclusive, so some events were coded for multiple categories. No events of algorithm building occurred; we are not sure why.

Observed speech events are categorized as either *mechanical* or *narrative*. *Mechanical events* are coded speech events in which the discourse concerns the discrete rules and mechanics of the game system. *Narrative events* are those events in which the discourse concerns the story or narrative aspects of the game.

Finding computational discourse being used to assess and solve narrative situations (in addition to the mechanical) will support the hypothesis that computational discourse can emerge in narrative situations.

Findings

Using the coding scheme described above, we observed instances of the four computational discourse codes in both mechanical and narrative events (see Table 1 below, full data available upon request). Some events are coded as both mechanical and narrative. In these situations, the dialogue was typically narrative, but there was a clear mechanical element of the game influencing the discourse. Table 2 contains examples of coded events.

Table 1: Coded events

	Conditional Logic	Debugging	Simulation	Distributed Computation
Mechanical	5	4	1	3
Narrative	11	11	23	18
Both M+N	2	1	3	4
Total	18	16	27	25

Table 2: Examples of mechanical and narrative events

	Discourse	Code(s)	Explanation
Mechanical	"If you got a good roll, it would be like two solid hours work."	Conditional logic	Resolution is determined by game rules, in this case by rolling dice.
Narrative	"We can wait for her to come back. See if we can start a dialogue. Or we can get the hell off of this planet."	Simulation	There are no rules in the game system which determine how this will play out.
Both M+N	"Look, their ship's a scout. Ours has firepower." "Worst comes to worst, we can take them out."	Simulation, distributed computation	Players assess narrative elements but know that the ships likely have different rules and likely consider that.

One noteworthy event occurred when a player rolled dice to attempt an action; the player failed according to the rules, but the GM decided that this failure was 'wrong' for the story ("you should get it; you're just spending time") and so 'debugged' the situation by overruling the game mechanics in favor of the narrative.

Conclusions and limitations

The observed instances of computational discourse occurred in both mechanical and narrative situations. This supports the expectation that narrative problem solving can use the same discourse tools as computational problems. Although the collected data contains a substantially higher number of narrative codes than mechanical codes, this does not necessarily indicate that such discourse is more useful for narrative situations. It may be representative of this specific session. We predict another session with either more combat or more skill challenges would show a higher number of mechanical events.

This case study looks at a single session of a single gaming group with a specific game system. It is not intended to generalize - it is a proof by example of the existence of a meaningful mechanical/narrative spectrum in computational talk and the utility of understanding computational talk through podcasts. Future studies will look more closely at the evolution of computational discourse in a group over time.

References

Berland, M., & Lee, V. R. (2011). Collaborative strategic board games as a site for distributed computational thinking. International Journal of Game-Based Learning, 1(2), 65-81. doi: 10.4018/ijgbl.2011040105

DiSessa, A. A. (2001). Changing minds: computers, learning and literacy. Cambridge, MA: The Mit Press.

Fantasy Flight Games (2013). *Star Wars Edge of the Empire roleplaying game*. (2013). Roseville, MN: Fantasy Flight Games.

Kuhl, K. (2014, October 22). Episode Three. CAMPAIGN Podcast. Podcast retrieved from http://oneshotpodcast.com/podcasts/campaign/episode-3/

Examining Parent-Child Communication and Affect During Tabletop Gameplay in a Children's Museum: Implications for Learning

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Abstract: Parent-child communication during collaborative play in children's museums can strengthen exhibit engagement and contribute to child problem-solving and content learning. We present pilot data examining parent-child communicative acts and affect during digital tabletop gameplay. Across dyads, results show diverse communication and affect. However, consistently less nonverbal communication was observed compared to verbal communication, and almost no touch was observed. Within dyads, patterns of verbal and nonverbal acts were similar across parent and child partners.

Importance of study

Parent-child interactive play with museum exhibits increases child engagement and learning (Crowley et al., 2011). Supportive parent communication encourages children to have a positive experience, and includes using questions that produce meaningful discussion, warmth and a positive tone, immediate positive feedback, and building on previous knowledge (De Ru et al., 2015; Jant et al., 2015). Museum visitors make meaning of their museum experiences by interacting with people and materials, and focusing more on process than knowledge (Falk & Dierking, 2012). Although published literature has reported on the importance of both positive tone and specific types of communicative acts for parents and children separately, there is a dearth of remarks on the study of communication, affect, and content together during parent-child play. Therefore, this presentation of data from a pilot study describes affect and communication during parent-child interactive tabletop play and implications for parent-child learning experiences.

Method

Participants

Seven parent-child dyads participated with children between the ages of 4 years 11 months and 8 years 8 months (Mage = 6 years 4 months), who were beginning kindergarten through third grade. Of the parent-child dyads, 2 were father-daughter, 2 were father-son, 2 were mother-son, and 1 was mother-daughter.

Coding measures

Data were generated using project-developed observation codes for verbal and nonverbal communication applied to videotaped and transcribed sessions of parent-child tabletop gameplay. Observation codes were developed by modifying existing parent-child interaction codes (see Eyberg et al., 2009; Roggman et al., 2013). For each dyad, and separately for parent and child, each verbal communicative act was coded as one of six possible communication categories (e.g., command, question, response/answer, behavioral description, evaluation, neutral talk) and additionally as one of three categories of affect (e.g., positive, negative, neutral). Each category is defined for coding. For example, the category "command" is defined as "a statement in which speaker directs vocal or motor behavior of the other." Examples and non-examples are provided. Similarly, affect for verbal communication is defined. For example, "positive" verbal communication is "positive, tender, enthusiastic, warm;" "neutral" is "flat, lacking inflection and identifiable support or criticism;" and "negative" is "critical, sharp, directive without warmth or encouragement." Nonverbal communicative acts were coded as touch or nonverbal and as either positive or negative. Each communicative act could be coded as verbal and nonverbal or touch communication; however, only one category per code could be recorded per act.

Study and coding procedures

Upon IRB approval and consent, each dyad was scheduled by the museum Director for a one-hour session at the Children's Museum to allow at least 15 minutes for gameplay and 10 minutes for paperwork. When sessions were

complete, two coders transcribed videos of parent-child gameplay independently, producing a written record of all communicative acts. Every disagreement was discussed until consensus was reached. Then, using both transcripts and videos, parent-child conversations were coded by two coders independently. Inter-coder reliability was calculated between coders with attention to agreements and disagreements using Cohen's kappa (k = .96 verbal; k = .95 nonverbal).

Data analysis

Coded data were analyzed for parent-child partners in dyads to produce seven unique case studies, allowing for examination of communicative acts of individuals within dyads and across dyads.

Results

Overall, coded data for individual and collective dyads represented the full range of verbal communication categories, and within dyads, the verbal communications were fairly consistent across parents and children. For most dyads, neutral affect dominated verbal communication. Within and between dyads, verbal affect, touch, and nonverbal communication varied substantially. Overall, children were more likely to engage in verbal communicative acts with negative affect than parents, although infrequently overall. Additionally, verbal communication with negative affect was most often attributed toward gameplay rather than toward the parent. Numerous occurrences of nonverbal communication were observed across parents and children, and minimal communicative touch was observed from both parents and children. Figure 1 shows data from one dyad.
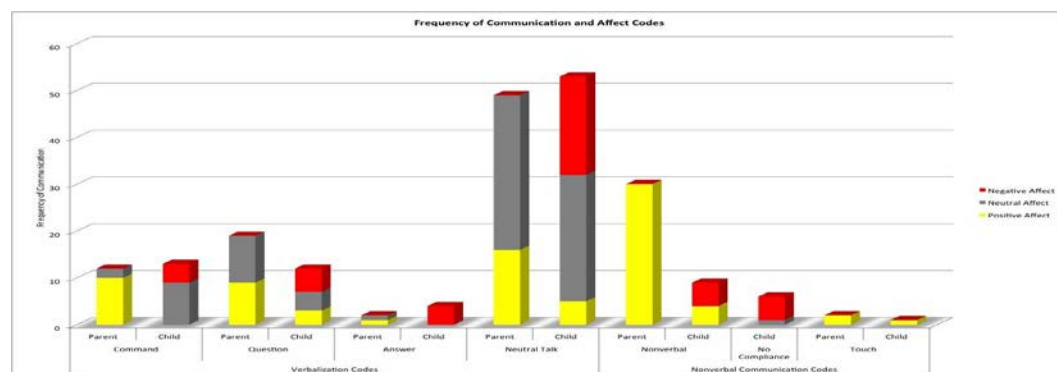
Figure 1. Occurrences of verbal and nonverbal communications and affect from one dyad.

Implications

Given that parent-child dyads naturally engaged most often in verbal interaction and within dyads, parents and children tended to produce similar types of communication, this pilot study suggests dyads may benefit from examples of approaches to gameplay to increase what appears to be naturally-present collaborative and problem-solving verbal communication. Further, given that a range of affect was observed across dyads and children were more likely to engage in negative verbal communication than parents, parent-child dyads may benefit from strategies to help children use positively-framed verbal communication during gameplay. Results indicate that the interactive gameplay platform encourages parents to use positive verbal communication, which is known to support learning in museum settings (De Ru et al., 2015; Jant et al., 2015).

References

Crowley, K., Callanan, M. A., Jipson, J. L., & Shrager, J. (2011). Shared scientific thinking in everyday parent-child activity. *Science Education, 85*, 712–732.

DeRu, J., Peters, C., Stokking, K., TenCate, O., & VanDeRidder, J. (2015). Framing of feedback impacts student satisfaction, self-efficacy, and performance. *Advances in Health Science Education, 20,* 803-816.

Eyberg, S. M., Nelson, M. M., Duke, M., & Boggs, S. R. (2009). *Manual for the dyadic parent-child interaction coding system* (Draft 3.07). Author.

Falk, J. H., & Dierking, L. D. (2012). *The museum experience revisited*. New York, NY: Routledge.

Jant, E. A., Haden, C. A., Uttal, D. H., & Babcock, E. (2014). Conversation and object manipulation influence children's learning in a museum. *Child Development*, 85(5), 2029-2045.

Roggman, L., Cook, G., Innocenti, M., Norman, V., Anderson, S., & Christiansen, K. (2013). *Parenting interactions with children: Checklist of observations linked to outcomes*. Baltimore, MD: Brookes.

Professional Development of Science Teachers in Underserved Communities: an Initial Report from the Field

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Abstract: This paper presents a preliminary study regarding the first phase of a large project that aims to develop a constructionist-based teacher training for public school settings in Sobral, Brazil. We illustrate the initial change that four science middle-school teachers went through after participating in training and co-designing lesson-plan's for their classrooms. The goal of this study was to explore teachers' initial changes in the form of instructional practice, by the end of the training phase.

Introduction

In the past few years, major international and national efforts have been made to develop new science standards (e.g. NGSS, Common Core in the US, and more recently BNCC in Brazil). Although the new standards emphasize a series of higher order goals and learning expectations essential for effective K-12 STEM learning (Glenn, 2002; Wise, 2001), they offer few suggestions on how teachers are to achieve these skills, leaving teachers feeling like they are missing instructions. Studies have shown that if the goal is to develop a sustainable innovative curriculum, the process of implementation must be prioritized (Fishman et al., 2003). In addition, it is important to involve teachers in designing learning materials for their own classrooms (Kali et al., 2015). Using the co-design approach, teachers can be supported in the design and implementation of educational innovation in "a highly-facilitated, team-based process in which teachers, researchers and developers work together" (Penuel, Roschelle, & Shechtman, 2007). In this work, we present a preliminary study of the first phase of the "Sobral Science Project," a program aiming to develop a curriculum and improve science learning as part of the city's commitment to achieve levels of excellence in basic education. We describe here the proof-of-concept phase, intended to become a prototype that will be scaled up to the entire city's educational system.

Context of the study

Sobral science project

The city of Sobral is located in the state of Ceará, Brazil (population ~ 200,000 people). The public school system includes 55 schools, serving 22,000 students. This project was initiated by the secretariat of education of Sobral to redesign the science curriculum of the city's K-9 public schools. In 2017, a collaboration with a US-based research university team was established to reform the curriculum and teaching of science in Ceará.

Timeline of the "Sobral science project" initial phase

The first phase of the project included 4 main stages, summarized in the following timeline:

- *Stage 1. Training at a US research institution* (May/17): Sobral's secretary of education, a professor from a local university, and a teacher who leads teacher trainings in the city attended a 1-week training in the US, focused on "Strategic Planning, Design and Implementation of Educational Makerspace Programs."
- *Stage 2. Introductory workshop in Sobral* (August/17): Researchers led a 2-day workshop for teachers and policy makers in Sobral. During the workshop, teachers defined a curricular unit to be redesigned using the co-design approach and then implemented in the classroom during the last quarter of the year.
- *Stage 3. Weekly redesign meetings* (August-November/17): The process of redesigning the units was supported by researchers through online meetings. Using the Backward Design framework (Wiggins et al., 2011), teachers identified "big ideas," learning goals, and alignment with science curricular standards.
- *Stage 4: Implementation of the redesigned curricular units in the classroom and reflection* (November/17): During this phase, teachers were encouraged to discuss the implementation of the unit in their classroom and reflect on the new presented approach.

Methods: Setting and data sources

Researchers worked in collaboration with four teachers (two male and two female) from different schools in the municipality of Sobral. Teaching experience ranged from six to fifteen years. Data presented here refers only to teachers who participated in Stages 2-4. Data was collected from periodic conversations with teachers and self-assessment instruments. Data was analyzed using standard techniques in the field (e.g. theory-driven top-down verbal analysis) (Chi, 1997).

Preliminary findings and discussion

Preliminary results focus on how teachers changed, based on two categories: 1. instructional practices and 2. assessment practices. Below, we provide examples of teachers' change in a continuum between traditional and constructionist practices.

- *Change in teachers' instructional practices from traditional to constructionist:* Teachers reported that they usually started the lesson by reading the textbook or presenting a lecture, followed by exercises. When a practical activity took place, there was usually a "cookbook" procedure to be strictly followed, where teachers demonstrated an experiment and students observed. After the experiment, students copied the experimental procedures and conclusions written by the teacher on the blackboard. After the first phase, teachers unexpectedly started to try more action-based activities in their classrooms. For example; Teacher #4, who started to pose open-ended questions for students' reflection instead of asking them to copy from the blackboard.
- *Change in teachers' assessments practice from traditional to constructionist:* Assessment of students' learning was originally based mainly on homework activities and students' performance in prescribed tasks, such as answering textbook questions after instruction, or taking standard exams. In this first phase, we observed teachers beginning to transition towards more progressive, formative assessments, where they would assess students' previous knowledge or pose questions, so that students could construct their knowledge with the teacher's mediation, rather than by instruction only.

Conclusion

Our preliminary results suggest that an initial impact on teachers' practices was illustrated mostly with the resources they used to teach, and on how they assessed students' learning. We observed changes in teachers' classrooms, including transitions from focusing on readings, lectures and exams, to a more constructionist approach, based on inquiry and reflection. These observations are consistent with theories about teachers' change after professional development programs, indicating that there is a continuum in teachers' change that includes a few steps: changes initially occur in teachers' classroom practices, followed by changes in student learning outcomes, which ultimately leads to a change in teachers' beliefs and attitudes (Guskey, 2002).

Endnotes

(1) The two first authors contributed equally to the work.

References

Chi, M. T. (1997). Quantifying qualitative analyses of verbal data: A practical guide. *The journal of the learning sciences*, *6*(3), 271-315.

Fishman, B. J., Marx, R. W., Best, S., & Tal, R. T. (2003). Linking teacher and student learning to improve professional development in systemic reform. *Teaching and teacher education*, *19*(6), 643-658.

Glenn, C. L., & De Groof, J. (2002). Finding the right balance: freedom, autonomy and accountability in education (Vol. 1). Boom Koninklijke Uitgevers.

Guskey, T. R. (2002). Professional development and teacher change. *Teachers and teaching*, *8*(3), 381-391.

Kali, Y., McKenney, S., & Sagy, O. (2015). Teachers as designers of technology enhanced learning. Instructional science, 43(2), 173-179.

Penuel, W. R., Roschelle, J., & Shechtman, N. (2007). Designing formative assessment software with teachers: An analysis of the co-design process. *Research and Practice in Technology Enhanced Learning*, *2*(01), 51-74.

Wiggins, G. P., & McTighe, J. (2011). The understanding by design guide to creating high-quality units. ASCD.

"I Have an Opinion About Science I Think Part Is True and Part Is Not" Emergent Bilingual/Multilingual Adolescents 'Figuring' Science Learning Through Virtual Labs

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Abstract: Based on a year-long ethnographic research in two eighth-grade science classrooms, with 25 Latinx emergent bilinguals, the study examines the affordances/limitations of virtual labs as mediators of science learning. Employing sociocultural theories and ontological views of learning, we explore students' learning of science with virtual labs and their evolving epistemic, conceptual, and identity trajectories with disciplinary knowledge and practices as enacted in formal-learning settings.

Introduction

Drawing on a year-long ethnographic study in two eighth-grade science classrooms with 25 Latinx emergent bilingual students (otherwise identified as English Learners (ELs) by school districts), we examine the ways in which efforts to incorporate digital technologies (e.g., software and hardware) into the domain of science education affords and/or limits various possibilities for science meaning-making for diverse learners.

Conceptual framework

We employ sociocultural theories and ontological views of learning (Lave & Wenger, 1991; Nasir & Hand, 2006; Wortham, 2006) to explore how availability of digital technologies might influence the context for learning science in formal-learning settings, potentially impacting students' evolving epistemic, conceptual, and identity trajectories with disciplinary knowledge and practices enacted and "figured" in traditional science classrooms. Specifically, we draw upon Holland et al.'s (1998) notion of "figured worlds" as frames of meaning constituted in cultural activities of formal-learning settings, into which learners enter with their personal, social, and epistemic histories. To this end, we examine the emergence of students' science figured worlds, heterogeneous and (often) tacit epistemologies learners draw upon (Sandoval, 2005), as they conceptually and performatively construct new meanings, understandings, and identity trajectories (subjectivities) in the context of technology- mediated science learning.

Methods: Data collection and analysis

Data collection was based on ethnographic methods such as participant observations, field notes, structured and semi-structured interviews, personal and group dialogues with students, audio-recordings of classroom events, extensive artifact and document collections in two eighth-grade science classrooms during one academic year. In the first phase, the classroom data, i.e., observations, field-notes, audio and images related to students' engagement with digital technology, specifically "virtual labs," was analyzed inductively, using both categorizing and connecting approaches (Maxwell & Miller, 2008). To check our biases and presumptions as researchers, during the ensuing phase, we invited focal groups of Latinx students as critical research-partners (each focus group had between 3-5 participants at a time, with total of 5 groups) to participate with us in the second stage of systematic data analysis (Delgado-Gaitan, 1993).

Findings

When we presented the data to our critical research partners, Latinx students in all groups challenged some of our initial findings/interpretations and provided us with "countering voices," see Table 1: Technology in the Figured World of Technology-Mediated Classroom Science.

Table 1: Table 1: Technology in the Figured World of Technology-Mediated Classroom Science

Students said…	We learned…

"On the computer, it takes 3 seconds for water to boil, in reality it takes about 10 minutes. Most of us do not believe most of the science, why would we believe it? Not everything that you can do or see virtually is real in life, you know, some of it is an imagination." (Alejandro -Group (G.) A) "Our teachers say that science is about discovery. Doing hands on labs would help a lot more because like – it's better to prove in many ways. I always believed it – I don't think those things will really happen. Our friends also say that they don't believe in science." (Maria -G. C)	While we, as educators and researchers, appreciate the affordances of virtual labs to provide interaction with scientific phenomena which occur at unobservable spatial and temporal scales, students do not share this value. Students saw the virtual labs as not representative of social phenomena constituted in the experienced, lived-in world, through legitimate peripheral participation in ongoing social and hands-on practice (Lave & Wenger, 1991). Research in science learning shows that students from traditionally non-dominant backgrounds hold a variety of forms of cultural, linguistic, and embodied knowledges, experiences, and resources that often might be at odds with "settled" expectations of normative science content and teaching (Bang, 2016).
"The first time that I understood [science] when she [teacher] was explaining about combustion and heat. When the car builds a lot of heat pressure the engine's eventually going to blow up. And she had a talk and I was automatically saying oh yes, that's like a car. As soon as it reaches its highest point it blows up. But no, most of the time we need to follow a URL, or a YouTube, or those virtual labs. Maybe they think they try to make it in our times. But I bet they learned all this with 3D objects, cars, we can make a wooden inclined plane and roll a toy car. I do not know teachers are getting lazy thinking to use a technology. Just sit there. Good luck learning it. Good luck. Hopefully you'll do it and go for it." (Davon -G. B)	The students' responses to the technology-mediated learning in the virtual labs puts a visible fissure in the connection between the pedagogical assumptions embedded in the notions of efficiency and the assumptions related to student's "technological savviness." Davon's "well wishing" sentiment is particularly poignant in the face of all that is at stake for his emerging science identity. In the figured world of this science classroom, students are reminding us that the social and haptic aspects of learning act as valuable mediators of holistic and "connected" science practices. Otherwise they risk creating epistemic, conceptual, and ontological dis-identification with science knowledge and reproducing docile bodies that will "just sit there" and maybe have "good luck."

Discussions and conclusion

In thinking about the disconnect we uncovered between what we, educators and researchers, might think is occurring in terms of digital technology-mediated activities/learning, and what is *really* going on in the "figured worlds" of students, we are reminded that technology is a "human activity," laden with complex values and subjectivities. Our challenge as educators, researchers, and innovators in the learning sciences is to find the ways to harness collective and heterogeneous epistemologies and ontologies into the designs and utilization of digital learning technologies in formal learning environments. It is important that future studies consider how new digital learning technologies contribute to not only students' knowledge construction, but also their diverse ways of knowing and being, their long-term identity trajectories (Bell et al., 2017) in ways that equitably support and validate their episto-ontological developments and evolving identification with disciplinary knowledge and practices as enacted in formal learning settings.

References

Bang, M. (2016). A Case Study: Native Perspectives of Gardening. In *Sowing Seeds in the City* (pp. 247-256). Springer Netherlands.

Bell, P., Van Horne, K., & Cheng, B. H. (2017). Special Issue: Designing Learning Environments for Equitable Disciplinary Identification. *Journal of the Learning Sciences*, 26(3): 367-375.

Delgado-Gaitan, C. (1993). Researching change and changing the researcher. *Harvard Educational Review*, *63*(4), 389-412.

Holland D., Lachicotte W. Jr., Skinner D., & Cain C. (1998). *Identity and agency in cultural worlds*. Cambridge: Harvard University Press.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge Univ. Press.

Maxwell, J., & Miller, B. (2008). Categorizing and Connecting Strategies in Qualitative Data Analysis. *Handbook of Emergent Methods*. 461–479. New York: Guilford Press.

Nasir, N. I. S., & Hand, V. M. (2006). Exploring sociocultural perspectives on race, culture, and learning. *Review of Educational Research*, *76*(4), 449-475.

Sandoval, W. A. (2005). Understanding students' practical epistemologies and their influence on learning through inquiry. *Science Education*, 89(4), 634-656

Wortham, S. (2006). *Learning identity: The joint emergence of social identification and academic learning*. Cambridge University Press.

Linking Identity Resources Across Roles: Family Science Workshops and Badging

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Abstract: With the goal of broadening participation in STEM, this paper reports on research that combined ideas of identity resources to support STEM-identity development and digital badge systems that combine social, emotional, and academic achievements. Specifically, we examined the identity resources linked to badges in a family robotics workshops held through a northwest library system. We found that badges, if framed correctly, can support transitional STEM-identity development by linking qualities across different roles.

Major issues addressed

Populations of youth that have limited or no access to STEM education are at greater risk to fall behind their counterparts as STEM fields continue to require more technical expertise, rendering such youth less able to direct their own social and economic success. Research on broadening participation has shown the interaction between STEM learning and STEM identity development (Bell et al., 2013; Calabrese Barton & Tan, 2009). Further, this work has explored how learning environments can be designed to better support participants' identity development. In this paper we ask: What are the family shared identity resources in an informal science learning setting and what role can badging play in supporting STEM identity development?

Potential significance of the work

Key design components of this work are to afford opportunities for families to work together and explore what it means to do robotics and e-textiles. The unique structure of the workshops is to combine tasks, such as programming, with other areas of expertise such as storytelling. In addition, participants are awarded badges to recognize achievements in the program. We argue the combination of critical analysis of badges supported by a conceptual framework of identity resources we can better understand how identity resources are and can be utilized in informal learning spaces. We hope to add to the conference theme of rethinking the learning sciences in the digital age by a) specifically addressing inequity in STEM, b) challenging standard practices of digital badge use in educational settings, and c) exploring how digital advances can usefully support identity development.

Theoretical framework

We take a sociocultural perspective on identity, viewing identity as formed not only by actions, but also by interactions with other people within the structures of the learning environments that they encounter (Holland et al., 1998; Wortham, 2006). In this work, we consider identities as one of the ways people mediate participation and demonstrate learning (Nasir, 2012) and look at identity as not just identification, but changes in practice. In addition, to marking learner trajectories and establishing membership in a community, we view badges as a tool that allows program values to be made explicit and visible to participants and educators and further develop their identities as learners. We seek to identify how badges can purposefully build identity development, recognizing that identity development is an interactive process as individuals participate within and across specific contexts (Holland et al., 1998; Wenger, 1998).

Methodologic approaches

This paper represents a portion of a 4-year NSF funded project *Robotics Backpacks for Family Learning*. The overarching project utilizes a design-based research approach (c.f. Barab, 2006) of iterative cycles of design and implementation. Data used for this paper was collected from January-February 2018 and included five workshop dates in one location, involving five number of families (fourteen individuals total). We gathered video data (one camera per family) to capture family interactions and used these data to identify and classify moments of role-specific activity along with interactions and discussions about badges. Through collaborative qualitative analysis of recorded family activity, discourse, and timeline of family generated artifacts, we mapped to the workshop roles as identified through the badging system provided enough context to determine which identity resources were or were not taken up.

Major findings, conclusions, and implications

There are two major findings associated with this work. First, using roles as the organizing structure for a badge system affords the opportunity to highlight a range of practices associated with those roles. We found that badges, if framed correctly, can support transitional STEM-identity development by linking qualities across different roles. In each workshop learners earned badges as a roboticist, artist, computer scientist, electrical engineer, researcher and storyteller. The roles bound specific characteristics while exposing shared qualities.

What surfaced through workshop play are qualities such as *attention to detail* and *precise* that participants who are skilled at programming and others skilled at storytelling, both possess. This interdisciplinary approach afforded the opportunity for badges to highlight skills that can be found in multiple types of roles and opening moments for participants to see themselves as "programmers", "artists", and/or "electrical engineers" who may not normally identify as such. Though qualities such as *attention to detail* or *precise* have specific requirements for each role domain (an electrical engineer is precise through different practices than a storyteller is precise). However, through linking participant activity to qualities of different roles, we are able to demonstrate through proximity that Participant A was precise in her depiction of her family story as indicated by the continual modification of her storyboard in the same way her brother was precise in correcting his coding. Both ensured their work represented the end results accurately. Employing a broad definition of "precise" in badge criteria permits the type of flexibility needed in order for participants to be able to see themselves in different roles. They can begin to identify qualities they already possess as being applicable to domains where they have little or no experience.

Second, we identified when practices shifted in the context of the program. For example, how families imagined robotic components in their story shifted as their understanding of how to make the robotics work developed. One father played with LED configurations in week 2 that informed the families' use of lights in their final diorama (week 5). With shifting practices, individual participation within families also shifted, as too did the resources available to participants in the activities. An example of this occurred when one mother shifted her practice from "project coordinator" to "programmer", changing the family dynamics and the resources available for identity development. Badges, if framed correctly, can support transitional STEM-identity development by linking qualities across different roles.

We propose badges and STEM practice-linked identity resources work together in two directions. In one way, badges support roles and practices that impact identity development by highlighting specific activities and marking achievement. In the other way, badges tell us in what ways the program is supporting identity development through the analysis of the types of resources and practices required to earn each badge. Badging can then serve as a design tool and as an analytical tool for examining the type and quantity of specific identity resources geared towards a specific aim, such as STEM.

References

Barab, S. (2006). *Design-Based Research: A Methodological Toolkit for the Learning Scientist*. Cambridge University Press.
Bell, P., Bricker, L., Reeve, S., Zimmerman, H. T., & Tzou, C. (2013). Discovering and supporting successful learning pathways of youth in and out of school: Accounting for the development of everyday expertise across settings. In *LOST Opportunities 23* (pp. 119-140). Springer Netherlands.
Calabrese Barton, A. C., & Tan, E. (2009). Funds of knowledge and discourses and hybrid space. *Journal of Research in Science Teaching, 46(1)*, 50-73.
Holland, D. C., Lachicotte, W., Skinner, D., & Cain, C. (1998). *Identity and agency in cultural worlds*. Cambridge, Mass.: Harvard University Press.
Nasir, N.S. (2012). Racialized identities: Race and achievement among African American youth. Stanford: Stanford University Press.
Wenger, E. (1998). *Communities of practice: Learning, meaning, and identity*. Cambridge, U.K.; New York, N.Y.: Cambridge University Press.
Wortham, S. (2006). *Learning identity: The joint emergence of social identification and academic learning*. Cambridge; New York, NY: Cambridge University Press.

Accessibility, Making and Tactile Robotics: Facilitating Collaborative Learning and Computational Thinking for Learners With Visual Impairments

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Abstract: This poster focuses on accessibility concerns that learners with visual impairments (LVIs) face in making environments, particularly with contemporary toolkits. This exploratory study was conducted over a three-day summer making workshop with visually impaired high school students to explore some major challenges and potentials of tangible making and robotics platforms, utilizing KIBO as a model. We explored how a tangible coding platform (KIBO) and accessible design modifications affected individual and collaborative group interaction and cognition.

Introduction

With the development of inexpensive maker tools such as the Raspberry Pi and Arduino microcontroller, making and robotics have become more accessible for novices and children than ever before (Halverson & Sheridan, 2014). However, learners with disabilities, in general, have had limited access to the maker movement, along with other opportunities to learn coding and design (Brady, Salas, Nuriddin, Rodgers, & Subramaniam, 2014). Drawing upon our framework for accessible makerspaces (Figure 1), this paper details a robotics-based maker workshop tailored for high school and young adult learners with visual impairments (LVIs). We investigated the following research questions: How do LVIs engage with platforms that are tangibly accessible? How does the accessibility of the tools affect learners' self-efficacy and collaborative interactions? What design elements do LVIs express would be beneficial for equitable co-creation and collaborative learning?

Methods

All data were collected from five of the nine participants (aged 15 through 19) who fully consented. Participants attended a three-day making workshop (each session between 1-1.5 hours) for high school and young adult learners with visual impairments in the Northeastern United States. KIBO (Kinder Lab, 2017), a wooden block-based tangible robotic kit (Figure 2) designed to learn core programming concepts through play, was utilized for workshop activities both without (Day 1) and with (Day 2 and 3) accessibility modifications. The study utilized comparative case study research design (Stake, 2008), with microanalytic video analysis, open-response pre- and post- questionnaires, in-depth focus group interviews, and think-aloud protocols where learners would vocalize their actions. We analyzed each source to understand how accessibility affected both individual and collaborative group interaction and cognition with the artifacts. Due to limited space, this poster focuses on two participants: Aaron (19-year-old, African American male), who had functional low vision from group A, and Mary (16-year-old, Caucasian female), who was nearly blind, from group B.
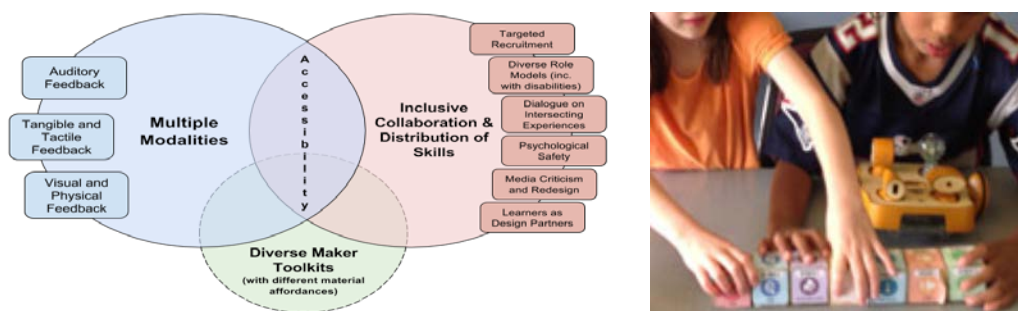
Figure 1 (left). Framework for Accessible Makerspaces. Figure 2 (right). Kibo Robot (Kinder Lab, 2017).

Case studies

On the first day, a full set of KIBO robotics kits were distributed to each group without any accessibility modifications. Aaron often deferred to his completely blind group member, who had some experience coding and constructing model cars. He primarily participated peripherally or by assisting others, such as when he helped the completely blind group member look for a battery and tried to assemble the robot collaboratively at the instruction

of others. In group B, Mary who was nearly blind kept asking a fellow groupmate with a moderate visual impairment to identify each block. When scanning each block, Mary tended to observe closely or listen to her fellow group member with better visual acuity. Though this better sighted group mater tended to dominate most activities, Mary moved from peripherally observing to block finding.

On the second day, two accessibility considerations were added to the kits: (1) braille labels for each of the function and parameter blocks for additional tactile cues; and (2) an organizing system using three different plastic containers (i.e., input/sensor; output/actuator; and condition/loop groups). The organizing system provided students a logical and tangible structure for finding blocks and parameters. During day 2, with the absence of more vocal group members, Aaron changed from a peripheral observer to a block scanner. However, he did not benefit from the braille addition since he did not know braille. During scanning, he tried to employ alternative sensory feedback, such as the auditory cues, from KIBO after each scan. However, he was still sensitive to including the completely blind group mate, who would play with the blocks while they discussed them and hit the "play" button on KIBO to start the actions they scanned. Despite his efforts, scanning blocks was not a simple enterprise due to KIBO's inherent scanner inconsistencies. Though Aaron had some visual acuity, the finicky nature of scanning made it even more difficult to have a mastery experience with the toolkit. Mary missed this session so her experience with the accessibility modification was captured on the following day.

On day 3, we integrated a race competition between groups A and B to encourage the use of different computational concepts and practices. Aaron was the only active participant in group A on the last day while the others remained uninvolved. He handed the KIBO scanner to one of the other group members who could see better than him to scan what he programmed. Their KIBO did not work as intended and Aaron began to debug his code by vocalizing it out loud. Because Aaron and his teammate spent too much time solving the first mission, they had to end their program in the middle of race; however, in contrast to the first day, Aaron was actively engaged in the hands-on activity and attempted to keep solving the problems collectively by allowing other group members to contribute. In group B, Mary was more actively engaged in the workshop compared to the first day by reading the braille labels on each block. When the group struggled with their coding for the first mission, she took the lead to debug the program. She tried to scan the blocks even though the scanner did not have an accessibility modification: "May I scan?" she asks as she tries to take the KIBO from the more sighted group member. When the group was addressing the final mission, Mary debated with the member with more visual acuity, who had taken on a dominant role: "You have to put the 'forward' before the 'repeat'…. You're having it repeat the song." While Mary's new code was not technically correct, it is more important to note her changing role within the group over time from a peripheral observer to block-finder and active problem solver.

Discussion and conclusion

Throughout the activities, we found some expected finings as well as some surprising ones. For example, we found that visual acuity affected participation. Learners who were completely blind or had lower vision were sometimes limited in their full participation and engagement. Conversely, engaging in hands-on practices alone were not necessarily evidence of understanding; sometimes a learner took on that role due to their visual acuity while a lower vision learner provided content expertise. However, we also found that visual impairments did not speak to the full range of complexity observed. For example, some lower vision learners were vocal in being included in the collaborative work, whereas, some learners with better visual acuity self-selected to engage in peripheral learning for a variety of other complex reasons, such as Aaron, who had never had the opportunity to engage in comparable activities. Moreover, the addition of braille was helpful for some, but limiting for others for similar issues related to prior opportunities. As learners with a range of visual impairments and access to resources, they helped reveal that design for accessibility has to be more reflexive. We recommend that the field be cognizant of including varied material affordances that would be accessible to a wide range of learners with disabilities, but also consider participatory design practices for a diverse range of learners.

References

Brady, T., Salas, C., Nuriddin, A., Rodgers, W., & Subramaniam, M. (2014). MakeAbility: Creating Accessible Makerspace Events in a Public Library. *Public Library Quarterly, 33*(4), 330-347.

Halverson, E. R., & Sheridan, K. (2014). The maker movement in education. *Harvard Ed Rev*, 84(4), 495-504.

Kinder Lab Robotics. (2017). KIBO. Retrieved from http://www.shop.kinderlabrobotics.com/

Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas.* Basic Books, Inc.

Stake, R. E. (2008). Qualitative case studies. In N. K. Denzin 8c Y. S. Lincoln (Eds.), *Strategies of qualitative inquiry*, *3rd Ed.* (pp. 119-150). Thousand Oaks, CA: Sage.

Wing, J. M. (2008). Computational Thinking and Thinking about Computing. *Philosophical Transactions: Mathematical, Physical and Engineering Sciences,* 366(1881), 3717-3725.

An Analysis of Collective Knowledge Advancement and Emergent Nature of Ideas in Subject-Matter Learning

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Abstract: The idea emergence is a critical nature of collective knowledge advancement in collaborative learning contexts. Although recent advancement of data-mining procedure makes it possible to detect emergent ideas, classroom teachers also like to know how much their students engaged in the discourse around their study topics. In this study, we propose an analysis combining socio-semantic network analysis for collective knowledge advancement and data-mining for detecting students' ideas in their discourse.

Keywords: idea emergence, collective knowledge advancement, subject-matter learning

Background and research purpose

For analyzing student learning in the classroom from the perspective of knowledge creation, we need to develop a new analytic framework to capture collective knowledge advancement and the emergence of ideas through student discourse (Scardamalia & Bereiter, 2013). We have been developing metrics of student collective knowledge advancement in their discourse by socio-semantic network analysis (SSNA) (e.g., Oshima et al., 2012). Ordinary social network analysis (SNA) visualizes the social patterns of learners. As de Laat et al. (2007) suggested, this approach is informative when we examine developments or changes in the participatory structure of learners. However, several studies argued that existing social network models are not sufficient to examine how learners engage in their collective knowledge advancement through their collaboration (e.g., Schaffer et al., 2009). Instead, we used a procedure similar to ordinary SNA but proposed a different type of social network, one based on the vocabulary learners use in their discourse. We compared this socio-semantic network—in which words were selected as nodes representing learners' knowledge or ideas during a discourse on a study topic—with a network of words from the discourse of a group of experts on the same topic. The results showed critical differences in the collective knowledge of elementary school students and experts regarding the vocabulary centered on the networks. SSNA could provide a new representation of collective knowledge advancement, enabling researchers to adopt a new complementary assessment technique for investigating models of knowledge-building communities. In recent years, this SSNA approach has been adopted in CSCL studies to analyze student roles in collaboration and to detect productive interaction patterns (e.g., Ma et al., 2016; Oshima et al., 2012).

Studies in the field of learning analytics have accelerated the development of SSNA to analyze student communication online. One recent advancement in the field is the implementation of the data-mining procedure to select vocabulary for SSNA from natural discourse in collaboration (Lee & Tan, 2017). If we are more interested in the emergence of new ideas through learners' discourse, we cannot determine a list of vocabulary beforehand. The data-mining procedure can make it possible to detect vocabulary by which learners intensively use at any point in time of their discourse. On the other hand, however, when students are working on any subject matter, teachers are more interested in how much their students engage in the discourse related to the subject matter they study. If we use SSNA with the aim to examine student knowledge advancement in the subject matter, we should determine and use a list of vocabulary representing the study topic.

In this study, for solving the conflict in methodological approaches to examining idea emergence and learning of subject matter knowledge in the classroom, we examine student collective knowledge advancement in discourse by combining the advantages in both approaches discussed above.

Method

Study context

The target data in this study was student collective discourse in jigsaw instruction (Miyake & Kirschner, 2013). In the jigsaw instruction, three students in a group were given a challenge such as "Can you explain how vaccinations protect us from infections?" then provided three study documents, each of which was necessary for solving the challenge. In the first phase, one student from each group gathered to form an expert group and worked on their allocated materials over 1.5 lesson periods (each lesson period was 50 min.). After the expert group activity, students returned to their original group (the jigsaw group), where students had different pieces

of knowledge to share and integrate for solving the challenge problem. This jigsaw activity took another 1.5 lesson periods. Group composition in both group activities (thirty-nine students in twelve groups) was designed by the teacher.

Data collection and analysis

We used two types of data for the analysis. The first was students' learning outcomes. The pre- and post-tests were conducted for evaluating their conceptual understanding. Based on their performance, we categorized each jigsaw group into high or low learning-outcome group.

The second data was video-record of their collaboration in the jigsaw group activities. Their discourse was transcribed for SSNA. In the first phase of our analysis, we calculated term frequency tf(t, d) of words representing students' understanding of the human immune system by using the following equation: $tf(t, d) = 1 + \log(ft, d)$. Then we further tested significant differences in the means of word vectors between the high and low learning-outcome groups. In the second phase of analysis, we visualized student collective knowledge advancement by SSNA with a list of vocabulary representing their study topic, human immunity system, and presented critical differences between the high and low learning-outcome groups.

Results and discussion

We found three high learning-outcome groups and nine low learning-outcome groups based on our criteria (Oshima et al., 2017). There were no significant differences in the means of tf word vectors among groups, $F(11, 198) = 2.35$, $p > .05$. SSNA revealed that students in the high learning-outcome groups were more engaged in transactive interaction such as building their ideas on others. With results of our analysis, we conclude that students who acquire higher learning-outcomes do not necessarily talk much about the study content but manipulate their ideas in the transactive way that are not usual in lower learning-outcome groups.

References

de Laat, M., Lally, V., Lipponen, L., & Simons, R.-J. (2007). Investigating patterns of interaction in networked learning and computer-supported collaborative learning: A role for social network analysis. *International Journal of Computer-Supported Collaborative Learning*, *2*(1), 87–103.

Lee, A. V. Y., & Tan, S. C. (2017). Temporal analytics with discourse analysis: Tracing ideas and impact on communal discourse. In *Proceedings of the Seventh International Learning Analytics and Knowledge Conference* (pp. 120-127). ACM.

Ma, L., Matsuzawa, Y., Chen, B., & Scardamalia, M. (2016). Community Knowledge, Collective Responsibility: The Emergence of Rotating Leadership in Three Knowledge Building Communities. In Looi, C. K., Polman, J. L., Cress, U., & Reimann, P. (Eds), *Transforming Learning, Empowering Learners: The International Conference of the Learning Sciences (ICLS) 2016*, Volume 1 (pp. 615–622). Singapore: International Society of the Learning Sciences.

Miyake, N. & Kirschner, P. A. (2013). The social and interactive dimensions of collaborative learning. In K. Sawyer (Ed.), *The Cambridge Handbook of the Learning Sciences, the Second Edition*. (pp. 418–438). NY: Cambridge Univ. Press.

Oshima, J., Ohsaki, A., Yamada, Y., & Oshima, R. (2017). Collective knowledge advancement and conceptual understanding of complex scientific concepts in the jigsaw instruction. In Smith, B. K., Borge, M., Mercier, E., and Lim, K. Y. (Eds.), *Making a Difference: Prioritizing Equity and Access in CSCL, 12th International Conference on Computer Supported Collaborative Learning (CSCL) 2017, Volume 1* (pp. 57–64). Philadelphia, PA: International Society of the Learning Sciences.

Oshima, J., Oshima, R., & Matsuzawa, Y. (2012). Knowledge Building Discourse Explorer: A social network analysis application for knowledge building discourse. *Educational Technology Research & Development*, *60*, 903–921.

Scardamalia, M. & Bereiter, C. (2013). Knowledge building and knowledge creation: Theory, pedagogy, and technology. In K. Sawyer (Ed.), *The Cambridge Handbook of the Learning Sciences, the Second Edition*. (pp. 397–417). NY: Cambridge Univ. Press.

Schaffer, D. W. et al. (2009). Epistemic network analysis: a Prototype for 21st Century assessment of Learning. *International Journal of Learning and Media*, *1*(2), 1–21.

Acknowledgments

Facilitation in Informal Makerspaces

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Abstract: This paper presents data from three Makerspaces and examines the extent to which facilitative roles, as articulated by facilitators and their supervisors, are subsequently practiced within the Makerspaces. The data was coded for themes of facilitation as captured in field notes and interviews with personnel at three different levels of seniority (senior executive, manager and on-the-ground facilitator). We suggest possible institutional factors that impact the emergence and expression of facilitative roles and seek to improve Makerspace pedagogy.

Introduction: Informal learning environments and facilitation

Makerspaces are celebrated as innovative, student-centered learning environments. As such, much of the existing literature on Makerspaces has focused on the learner. Additionally, studies of Makerspaces examine the importance of informal learning settings (Halverson, E.R. & Sheridan, K., 2014) and the complex interplay between culture, power, and equity (Vossoughi et.al., 2016). However, facilitators play an essential role in sustaining Makerspaces. While existing work highlights tools and learners (Martin, L., 2015), future work should elucidate how facilitative roles are defined and enacted across different types of institutions.

Prior literature

While the preponderance of Makerspace research has focused on learners, there are a handful of studies that touch above facilitation, albeit, in passing. For example, Petrich et al. (2013) described facilitation through roles that served to 1) welcome and interest participants in the studio, 2) focus participant attention on an individual project, and 3) engage in dialogue with participants about their making process. This role was primarily supportive and intervention occurred when deemed necessary (Petrich et.al, 2013; Gutwill et.al., 2015). Litts (2015) found that facilitators were unwilling to push participants to explore areas that the facilitators themselves had no experience in. These findings suggest that facilitators can be instrumental to the processes and tools that participants utilize in Makerspaces. As we examine the roles that emerge within the three Makerspaces studied, we expect to see a number of themes from prior research re-emerge, particularly through a comparison between what facilitators say about their role and what they actually do. Furthermore, we hope to contribute to the discussion of how institutional factors may impact the adoption of the different roles.

Methods

Semi-structured interviews and field notes were taken at each of the three Makerspaces. Interviews were conducted on-site, one-on-one (with either a senior executive, manager, or a facilitator), and for 20-40 minutes. They were recorded, transcribed, and coded for themes of facilitation. The coded responses from interviews were then used to examine facilitation-in-action as observed and noted in field notes.

Open coding was used on the interviews and field notes. Codes were documented in conjunction with examples from each institution, where applicable, and then grouped under larger themes. These methods were chosen in order to ground comparisons between facilitation across the various Makerspaces.

Results

This paper focuses on interview responses to the prompt "describe the role of facilitators". We identified three themes of facilitative roles: 1) following the participant's lead while supporting them, 2) treating each participant as a unique individual, and 3) creating the Makerspace environment. Not surprisingly, many of these codes bear resemblance to, and at times mirror, prior research. For example, Pietrich et al. (2013) found that welcoming participants to the space is one of the roles that facilitators mention in interviews under the theme "Creating the Environment." It is worth noting that these responses, and the corresponding codes, generally emphasize and support the learner-centered approach in Makerspaces. However, the extent to which these practices are effective and implemented in the field warrants a closer look at the institutions housing a Makerspace. Comparisons between interview responses and actions observed through field notes highlight the extent to which institutional frameworks guide and shape facilitation. For example, within one institution, the idea of Leading by Supporting emerged through the mantra: "wait, watch, follow", while in other spaces, the idea of building relationships

through mentorship simply did not exist. Hence, a number of the facilitative approaches stem from an understanding of broader institutional goals and it is examining these potential institutional factors and differences that we hope to contribute to the improvement of Makerspace pedagogy.
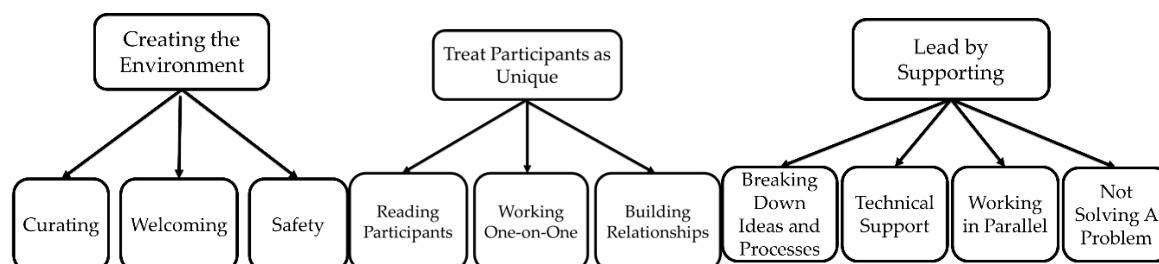
Figure 1. Codes that emerged from participant interviews about facilitation.

Conclusion

We have provided preliminary examples of Makerspaces situated within institutional structures that have noticeable impacts on the roles that facilitators occupy. Primary differences were observed in the level of personal relationships that facilitators aim to foster with participants. Within the community-oriented space, relationships were paramount, and this was clearly articulated across levels of seniority. However, in the two museum-based Makerspaces, we saw some disconnect between the stated roles of facilitators as communicated by senior executives, and the understood roles mentioned by facilitators. Furthermore, we saw a heavier focus on elements of safety, and providing technical assistance. In general, this work aims to promote conversation around differential facilitation strategies to shape a more equitable understanding of facilitation (Peppler, 2009, 97), thus improving Makerspace pedagogy. A closer look at the influence of institutional goals on facilitation within informal Makerspaces improves the professional development of facilitators in such spaces. It also advances the broader pedagogy of informal learning environments. Future work should closely examine the extent to which articulated roles of facilitation find real-time enactment and practice within informal learning environments.

References

Charmaz, K. (2006). Constructing grounded theory: A practical guide through qualitative analysis. London: Sage Publications.

Gutwill, J. P., Hido, N., & Sindorf, L. (2015). Research to practice: observing learning in tinkering activities. Curator: The Museum Journal, 58(2), 151-168.

Halverson, E.R. & Sheridan, K. (2014) The maker movement in education. *Harvard Educational Review, 84*(4), 495-504. doi:10.17763/haer.84.4.34j1g68140382063

Kafai, Y., Peppler, K., & Chapman, R. (2009). *The computer clubhouse: creativity and constructionism in youth communities.* New York: Teachers College Press.

Litts, B. K. (2014). Making learning: makerspaces as learning environments (Doctoral dissertation, University of Wisconsin-Madison).

Martin, L. (2015). The promise of the maker movement for education. *Journal of Pre-College Engineering Education Research (J-PEER),* 5(1). doi: 10.7771/2157-9288.1099

Noam, G. (2008). A new day for youth: creating sustainable quality in out-of-school time. *Issuelab.* The Wallace Foundation.

Peppler, K., Chiu, G., & Moya, J. (2009). The multiple roles of mentors. *In Kafai, Y.B., Peppler, K., & Chapman, R. (Eds.)*

Petrich, M., Wilkinson, K., & Bevan, B. (2013). It looks like fun, but are they learning. *Design, make, play: Growing the next generation of STEM innovators*, 50-70.

Vossoughi, S., Hooper, P.K., & Escudé, M. (2016). Making through the lens of culture and power: toward transformative visions for educational equity. *Harvard Educational Review, 86*(2), 206-232. doi:10.17763/0017-8055.86.2.206

Acknowledgments

How Do Multilingual Learners Support One Another's Science Learning and Participation?

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Abstract: As superdiversity becomes the new mainstream in U.S. schools, how multilingual learners support one another's learning and participation warrants better understanding. We analyzed interactions of four dyads of multilingual Burmese youth in an afterschool science program as they made predictions about region-specific climate changes in the next 100 years. Findings suggest they used multiple languages and various communicative modes to create an equitable learning environment.

Introduction

Changing patterns of migration across the world create superdiverse learning environments to which learners bring diverse languages, ethnicities, religions, race, and cultural practices (Gogolin, 2011). In the U.S., where our research is situated, superdiversity is the new mainstream (Enright, 2011). In our study, we engaged resettled refugee youth from Burmese backgrounds in collaborative scientific practices in a community-based afterschool program. These practices include asking questions, analyzing data, and arguing from evidence. In schools, opportunities for engagement can be limited for multilingual students (often labeled English Learners or ELs) when they are marginalized or are not supported in navigating multilingual collaborative contexts to achieve specific communicative and sense-making goals. In our afterschool program, we sought to provide a learning environment in which youth with varying levels of proficiency in English and multiple indigenous languages of Burma (e.g., Hakha, Falam, Zophei) agentively pursue their own learning and participation opportunities while supporting their peers' learning. Our study aims to contribute knowledge and provide implications that promote equitable participation and learning in superdiverse learning settings. To that end, this paper addresses the question: How do multilingual learners support one another's science learning and participation?

Methods

We implemented a year-long afterschool program (1.5 hours per session; 22 sessions) to engage youth in learning about climate change, and collected data in the form of video-recordings, field notes, screencasts of computer use, and artifact images. In this paper, we analyzed data from Session 17 in which participants formed pairs, conducted online research, and created a poster to answer the question: "What will the earth be like 100 years from now if climate change continues?" We micro-analyzed video-recordings drawing on principles of video analysis (Derry et al., 2010) from an ethnographic perspective. We selected events for close analysis and transcribed them to capture utterances, gesture, body posture, gaze, computer use, organization of artifacts and use of space (Norris, 2004). Exchanges spoken in participants' L1 were translated into English by an external translator. We collectively wrote analytic notes of the microanalysis of each event and created a matrix to generate themes through constant comparison (Lincoln & Guba, 1985) between events within and across focal four dyads.

Findings

Close analysis of the four focal dyads showed that the youth facilitated one another's access to the learning task and collaborative sense-making by using multiple languages and various communicative modes (gesture, gaze, proxemics, images, etc.); thereby leading to a more equitable learning environment. An excerpt from one dyad, Thiri (**T**) and Da Zin (**DZ**), illustrates how they negotiated between their differing ideas on what to research regarding the impacts of climate change in Sydney, Australia. A facilitator, **MJR** asks **T** and **DZ** about what they know about the impacts of climate change. **DZ** forwards the idea that farmers "couldn't farm" because of the scarcity of water. Building on **DZ**'s idea, **T** asks whether farming is a common practice in Sydney. **MJR** urges them to find out and walks away. The following conversation then ensues. Utterances in *italics* are spoken in Hakha (**T** and **DZ**'s L1). Annotations of non-verbals are in **((Bold))**.

01	**DZ**: So*, why don't we write about* farm*ers that we just talked about?*
02	**T**: *Do they also do* farm*ing in* Sydney Australia?
03	**DZ**: *In what she* [**MJR**] *said*

04	**T**: Uhuh **((T angles her body towards DZ))**
05	**DZ**: *We will write the* effect *of* climate *change first,* and then *with* Sydney *like, you know we will make that effect* connect **((DZ makes an open palm gesture on the poster paper))** *with* Sydney. *Like with* Sydney*, does this happen in there as well?*
06	**T**: Ahhhh. Do you want to do it like that?
07	**DZ***: I guess it is like that. In what she* [**MJR**] *just said, we will find* climate effects *and then see if that also* affects Sydney and what it's going to be like after in 100 years*, I guess it's something like that*
08	**T**: Uhuh **((in agreement))** I was thinking we should just like find out how it is like you know in Sydney right now **((T taps on the keyboard. DZ leans in towards T))** and then uhm the problems that it's facing **((T taps on the poster paper))** and then after the problems we can write out what will happen
09	**DZ**: Hmmm. Yeah, we can do that
10	**T**: Yeah or *what you said was* all of the climate change problems **((T makes an open palm gesture to DZ))** and then like similarity **((T makes a circular gesture over the poster paper))** to the Sydney Australia problems. Which one do you wanna do?

T and **DZ**'s flexible use of Hakha and English throughout the exchange along with the gestures that punctuate their explications (Turns 4,5,8, and 10) has allowed them to engage in exploratory talk wherein they explored one another's ideas critically and constructively (Mercer, 2000). Through translanguaging (García & Wei, 2014), they negotiated their approach to the science problem without constraining language use to English only. They considered their general knowledge of climate change (Turn 7), the specific regional considerations (Turn 2), and negotiated research directions related to their task (Turns 5, 7, 8 and 10). More specifically, at the beginning of this episode, **T** evaluates and challenges **DZ**'s idea of farming by suggesting a criterion of relevance – whether farming is also done in Sydney (Turn 2). **DZ's** recognition of this underlying criterion of relevance compels her to reframe her idea (Turn 5). This then led to **T** considering **DZ**'s idea (Turn 6) and offering a new idea (Turn 8). In addition, the two girls fostered collaboration by being attentive, open to one another's ideas, and sharing cognitive authority. They showed this by soliciting and taking up each other's perspectives (Turns 1, 2, 5, 6, and 10), adjusting the angles of their body postures (Turns 4, 8, and 10), and sharing of tools relevant to the task (poster paper and laptop; Turns 8 and 10). In this sense, equitable participation is achieved through translanguaging, sharing of cognitive authority, openness to one another's ideas, and mutual engagement in the task.

Conclusions

We explored the ways multilingual youth engaged in collaborative science practices and supported one another's science learning and participation. Through the use of multiple languages and communicative modes beyond the spoken word, they were able to leverage their sense-making practices to further their own and their peer's understandings. The facilitators created space for equitable learning to take place by affording youth the opportunity to use multiple languages. Open-ended, peer-led tasks enabled multilingual youth to share and value one another's scientific contributions in ways that a teacher may not be able to access. By propelling one another's science learning, the youth created a more equitable environment.

References

Derry, S.J., Pea, R.D., Barron, B., Engle, R.A., Erickson, F., Goldman, R., ... & Sherin, B.L. (2010). Conducting video research in the learning sciences: Guidance on selection, analysis, technology, and ethics. *The Journal of the Learning Sciences*, *19*(1), 3-53.

Enright, K.A. (2011). Language and literacy for a new mainstream. *American Educational Research Journal, 48*(1), 80-118.

García O., Wei L. (2014) Translanguaging and education. In *Translanguaging: Language, bilingualism and education*. London: Palgrave Macmillan.

Gogolin, I. (2011). The challenge of super diversity for education in Europe. *Education Inquiry*, *2*(2), 239-249.

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry* (Vol. 75). Sage.

Mercer, N. (2000). *Words and minds: How we use language to think together*. London: Routledge.

Norris, S. (2004). *Analyzing multimodal interaction: A methodological framework*. Routledge.

Acknowledgment

The Structures of Embodied Play Activities and Their Impact on Students' Exploration of the Particulate Nature of Matter

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Abstract: This study investigates how activity structures influence how students represent their understanding of complex science concepts. Twenty-four second grade students were quasi-randomly assigned to either a modeling-play or game-play condition. In both conditions, students took on the role of embodying particles within a mixed-reality simulation to explore particulate nature of matter. Results showed that game-play influenced prompts and explanations to be more activity oriented, while modeling-play led conversations to encompass more conceptual nuances.

Introduction and theoretical framework

The role of embodiment in cognition, along with the increased availability and uses of motion tracking technology, has led to an increase in instructional designs that aim to support learning through embodiment (Lindgren & Johnson-Glenberg, 2013). Game-like technology such as mixed reality (MR) interfaces can leverage embodied play within learning environments in ways that allow students to explore complex concepts through movement and gesture (Danish et. al, 2015). In an effort to document how distinct forms of embodied activity play a role in shaping student learning, the present analysis contrasts two forms of play within the same MR environment to better understand how the structures of play influence student interaction and learning.

This study builds upon the prior success of the Science Through Technology Enhanced Play (STEP) project, which is a unique platform that allows students to learn about the particulate nature of matter through different types of embodied play within a mixed reality learning environment (Danish et. al, 2015). In this study, two forms of play are contrasted: modeling-play and game-play. The modeling-play condition is unstructured in design to orient students towards producing their own scientific models, spontaneous narratives and negotiable rules. The game-play variation is more structured by focusing on winning as an end goal, having overt rules and a fixed narrative. Our theoretical assumption is that the combination of imaginary situations and rules within play helps students build accurate understandings of complex processes that are situated within the learning environment (Vygotsky, 1978). Centering our framework on Activity Theory (Engeström, 1999), we focus on how student learning is mediated by the division of labor, rules, and tools that structure the play activity. Our assumption is that the different forms of play become visible to the participants through these mediators. For example, the modeling-play activity draws upon classroom norms for how to represent concepts, while the game-play activity draws upon the explicit rules of the game to inform students' activity. In both conditions, the same underlying rules drive the MR simulation so that students can explore those rules through their play.

As students navigate through the STEP learning activities a particularly important mediator of their activity is the teacher. The teachers in this study were aware of the planned play structures, and brought their understanding to how they worked with the students and the software interface. Therefore, our analysis aims to unpack how the teacher and other designed features of the activity worked together to structure the students' ongoing activity, and how these distinct structures supported the students in learning the content. Our goal in contrasting these two conditions is to better understand how different features of play are taken up by students and teachers as they engage in learning activities. We aim to answer the following two research questions: 1) How does the structure of the environment appear to influence teacher prompt patterns? and 2) What is the interaction between the students and the teachers based on those structures?

Methods and learning environment design

The participants were 24 second grade (7 to 8 years old) students in an elementary school in a small Midwestern city. The students were quasi-randomly assigned into four groups, two in the modeling-play condition and two in the game-play condition. Two partner teachers each worked with two groups of 6 students, one in the modeling-play condition, one in the game-play condition. Students in both conditions participated in the STEP environment by embodying the role of either water particles or energy sources and interacting with peers. As the students move within an open space, Microsoft Kinect cameras track their motion and feed it into the STEP computer simulation; a projected video display then depicts their movements and provides a visual feedback

state meter that shows how successfully students are jointly creating certain states of matter. In the modeling-play activity, students are free to create and revise models of the states of matter in whatever manner they collaboratively choose. In contrast, students in the game-play condition need to represent specific states of matter at the right time to help a fictional robot navigate a volcanic island. Although the curricula for each condition are parallel, the rules for each activity differ in the amount of flexibility the students have to attempt to show the states of matter. After each activity, students participated in a debrief discussion to reflect on the concepts being explored. All activities and debrief discussions were videotaped for later analysis.

To better understand how the structure of the activities influenced the teachers as well as the students' sense making processes as they engaged in producing scientific explanations, we conducted a thematic analysis (Braun & Clarke, 2006). We iteratively identified 4 types of prompts that teachers used: 1) asking for description, 2) asking for reflection, 3) soliciting information about concepts, and 4) encouraging students to communicate with each other. We used the teacher prompts as a way of subdividing the activities, given that they frequently framed the students' engagement with the content. These categories were then the basis for quantitative comparisons across the conditions as we sought to see whether there were different patterns of interaction and student explanations between the two conditions.

Results

In the modeling-play condition students could freely explore the rules of "how to be a particle", and thus teachers were more likely to prompt students to reflect on and describe their embodied experience as they communicated with their peers during the exploration activity. This seemed to allow students to make more salient connections from the embodied play activity to the concepts about states of matter. In the game-play condition, the students' goal was to "win the game"; to win, students needed to collectively create the necessary states of matter to help the robot survive within the simulation. Because of this, the teachers mainly focused on helping the students win the game by using more prompts that encouraged students to give guiding directions to one another within the space, rather than prompting students to explicitly converse about their conceptual understanding of particle behavior. Overall, the thematic analysis revealed that as students navigated through the modeling-play activities, their verbal and gestural responses were more science-concept oriented, while students in the game-play condition directed their responses towards making physical moves to win the game.

Discussion

Play is a common, and powerful way of organizing embodied learning environments. However, play can mean many different things, including either freedom to pursue student interests, as in our modeling-play condition, or aiming to "win" in a more structured environment as in our game-play condition. Thus, our goal was to better understand how these different features of play support learning activities. Furthermore, teachers are key mediators of how students engage in play activities within the learning environment. In the current study, teachers' questions provided a space for students to engage with the science content, and the teachers were more likely to pose these questions in the open-ended modeling activity. Students showed a similar pattern of engaging more directly with the concepts in the modeling conditions, and instead focusing on winning in the game condition. Nonetheless, teachers were able to use the debrief discussions in both conditions to explore the concepts, resulting in similar learning gains across conditions. Moving forward, it will be valuable to continue exploring how different facets of play support student learning both during play, and during post-play debriefs.

References

Alibali, M. W., & Nathan, M. J. (2012). Embodiment in mathematics teaching and learning: Evidence from learners' and teachers' gestures. *Journal of the Learning Sciences*, *21*(2), 247-286.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77-101. doi:10.1191/1478088706qp063oa

Danish, J., Enyedy, N., Saleh, A., Lee, C. (2015). Science through technology enhanced play: Designing to support reflection through play and embodiment. In *Proceedings of the 11th International Conference on Computer Supported Collaborative Learning (CSCL 2015)* (pp. 332-339).

DeLiema, D., Saleh, A., Lee, C., Enyedy, N., Danish, J., Illum, R., & Mahoney, C. (2016). Blending play and inquiry in augmented reality: A comparison of playing a video game to playing within a participatory model. Singapore: International Society of the Learning Sciences.

Engeström, Y. (1999). Activity theory and individual and social transformation. In Y. Engeström, R. Miettinen, & R. L. Punamäki (Eds.), *Perspectives on activity theory.* New York: Cambridge University Press.

Lindgren, R., & Johnson-Glenberg, M. (2013). Emboldened by embodiment: Six precepts for research on embodied learning and mixed reality. *Educational Researcher*, *42*(8), 445-452.

Vygotsky, L. S. (1978). *Mind in society: the development of higher psychological processes.* Cambridge, MA: Harvard University Press.

Assessing the Validity of Peer Feedback in a Sixth Grade Mathematics Class

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Abstract: To better understand the possible benefits of using peer assessment in middle school mathematics classes, we examined how the quantity and quality of peer feedback compares to teacher feedback. In general, students not only received more feedback from peers, but the amount of feedback was also more consistent. Moreover, the sixth-grade students focused on similar issues and provided just as many solutions. Detected differences in focus and type of solution could inform instructional design.

Introduction

In the US, emphasis in mathematics is moving away from computational fluency and focusing on student's construction of mathematical arguments or explanations and analyzing the reasoning of others. While policy makers recognize the importance of mathematical communication, students are rarely asked to write in mathematics classes (Mastroianni, 2013). Writing is important because it can help students organize and refine their ideas, think deeper about concepts as they explain their ideas, and connect new concepts to existing knowledge (Flores & Brittain, 2003). However, teachers are concerned that grading writing tasks will take more time than traditional mathematics work, and they lack the knowledge how to incorporate writing tasks (Teuscher, Kulinna, & Crooker, 2015).

One way to address these issues is through the use of peer assessment. Peer assessment (often also called peer review) is the quantitative evaluation or qualitative feedback of a learner's performance by another learner among students. Peer feedback is particularly beneficial because students can receive more total feedback from multiple peers that is articulated using more understandable terms and represents diverse audience perspectives from peers than when receiving feedback from an over-taxed instructor (Patchan, Charney, & Schunn, 2009). Moreover, peer feedback can be just as effective as an instructor's feedback in helping students improve their drafts (e.g., Gielen, Tops, Dochy, Onghena, & Smeets, 2010) and sometimes more effective (e.g., Cho & MacArthur, 2011).

To examine quality in the current study, we focus on two feedback features that had large, positive effects on revision: the focus of the comment and providing a solution (Nelson & Schunn, 2009; Patchan, Schunn, & Correnti, 2016). The use of these features appears to depend on the reviewer's prior knowledge. For example, a content instructor focused more on substance issues than a writing instructor, whereas the writing instructor focused more on writing issues; college students (having less substance and writing knowledge than both instructors) fell between the two instructors (Patchan, et al., 2009). Similarly, a writing instructor provided double the amount of solutions as a content instructor, and college students again fell between the two instructors. Similar differences were observed among secondary students—they focused less on skills and more on content, and they provided fewer solutions (Hovardas, Tsivitanidou, & Zacharia, 2014). To extend this work, the goal of the current study is to examine how the quantity and quality of feedback provided by middle school students compares to teacher feedback.

Method

Participants and context

This study was conducted in a sixth-grade mathematics class in a small rural town located in West Virginia. Thirty-one students (24 females) from two sections participated in this study.

Design and procedure

Participants created study guides with worked examples of word problems posed by the student. Then, students evaluated and commented on four peers' drafts, and the teacher reviewed all students' drafts. Finally, the students were randomly assigned to receive feedback from only their peers or only their teacher, and they revised their study guide using this feedback.

All of the participants' feedback was segmented by idea units, and a total of 1,660 comments were coded. Using a bottom-up approach, 38 issues were identified and coded, including seven general issues (e.g., difficult to read or follow), 12 issues with the word problem (e.g., problem not solvable), and 19 issues with the solution (e.g., incorrect formula). In addition, each comment was coded for the presence of three independent features: problems, general solutions, and specific solutions.

Results

Although students received more feedback from four peers, the comments from the teacher were longer. More importantly, students received a consistent amount of feedback from peers, whereas the amount of feedback provided by the teacher decreased over time (see Figure 1). Quality of drafts did not vary across time.
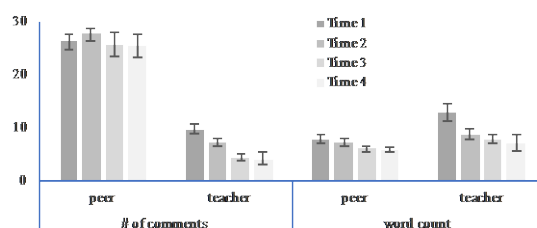
Figure 1. Amount of feedback (i.e., number of comments and word count) across time by reviewer type.

Peer feedback was much more likely to provide praise (16%) than teacher feedback (3%). When peers criticized students' work, they focused on similar issues as the teacher (i.e., missing question and incorrect formula). However, they were also more likely to complain that the work was difficult to read or follow (8% vs. 4%); whereas the teacher was more likely to notice missing measurements (8% vs. 1%).

Finally, both peers and teachers included solutions. However, the peer was more likely to provide a general solution (49% vs. 20%; e.g., "Make sure you use the correct formula"), and the teacher was more likely to provide a specific solution (32% vs. 10%; e.g., "Use: $SA=2\pi rh+\pi r^2$ to exclude top.").

Discussion

This study demonstrated that students could benefit from more consistent feedback from peers that focuses on similar issues and includes a similar amount of solutions as teachers. Future analyses will also examine the impact of these differences on implementation and revision quality. Findings could inform future work on what additional support students may need to provide helpful feedback.

References

Cho, K., & MacArthur, C. (2011). Learning by reviewing. *Journal of Educational Psychology, 103(1)*, 73-84.

Flores, A., & Brittain, C. (2003). Writing to reflect in mathematics methods course. *Teaching Children Mathemaics, 10*, 112-118.

Gielen, S., Tops, L., Dochy, F., Onghena, P., & Smeets, S. (2010). A comparative study of peer and teacher feedback and of various peer feedback forms in a secondary school writing curriculum. *British Educational Research Journal, 36(1)*, 143-162.

Hovardas, T., Tsivitanidou, O. E., & Zacharia, Z. C. (2014). Peer versus expert feedback: An investigation of the quality of peer feedback among secondary school students. *Computers & Education, 71,* 133-152.

Mastroianni, M. P. (2013). Writing in mathematics. In A. N. Applebee & J. A. Langer (Eds.), *Writing instruction that works: Proven methods for middle and high school classrooms* (pp. 71-93). New York, NY: Teachers College Press.

Nelson, M. M., & Schunn, C. D. (2009). The nature of feedback: How different types of peer feedback affect writing performance. *Instructional Science, 37(4)*, 375-401.

Patchan, M. M., Charney, D., & Schunn, C. D. (2009). A validation study of students' end comments: Comparing comments by students, a writing instructor, and a content instructor. *Journal of Writing Research, 1(2)*, 124-152.

Patchan, M. M., Schunn, C. D., & Correnti, R. J. (2016). The nature of feedback: How feedback features affect students' implementation rate and quality of revisions. *Journal of Educational Psychology, 108(8)*, 1098-1120.

Teuscher, D., Kulinna, P. H., & Crooker, C. (2015). Writing to learn mathematics: An update. *The Mathematics Educator, 24(2)*, 56-78.

Parents' Decontextualized Talk During Early Childhood Predicts the Neural Basis of Narrative Processing in Later Childhood

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Abstract: Early parental language input strongly predicts children's language development and academic success. Little is known about relations between early input and the neurobiology of language. Among different measures of input, parents' decontextualized utterances about abstract topics predict children's language outcomes more strongly than parental socioeconomic status and input quantity. Here, using fMRI, we show that preschool parental language input is associated with school-aged children recruiting different neurocognitive systems for language processing.

Introduction

Children are expected to converse in *academic language* once they arrive school. This language is used to tell a story, to make an argument, to comprehend a text, to give a presentation, to integrate information across multiple passages, etc. (Snow, 2010). Academic language is dense, abstract, and decontextualized. Thus, it presents distinct challenges from the conversational language that young children are typically exposed to in their daily lives. Other types of linguistic input must help prepare children for the challenges of academic language. We argue that early decontextualized language parents provide is just this type of input. Decontextualized language include talk about the past and future (e.g. Mom is going to go to the foot doctor tomorrow), pretend play talk (e.g. Come on horsies, gallop back to your stall), and explanations (e.g. Yes, let's turn the blocks so you can see the patterns on them). Here we ask whether children's early home environments vary in the opportunities to hear decontextualized language and, if so, whether parental decontextualized language input predicts the neurocognitive basis of children's language processing during school years.

Prior literature highlights strong relations between environmental factors, specifically parental socioeconomic status (SES), and *brain structure*. However, little is known about how the *neurofunctional basis* of academic performance varies as a function of environmental factors. Further, SES is a composite construct. Which component of SES is most strongly relates to neural differences is unknown (Hackman & Farah, 2009). Parental input might be a more proximate measure of children's day-to-day experiences than SES. Here we leveraged a neuroimaging method, fMRI, to provide additional information about the underlying neural processes that contribute to behavioral performance as children are engaged in a task. Specifically, we asked whether as a function of early parental decontextualized input, children recruit similar neural systems but with varying degrees of efficiency or they recruit different systems during a decontextualized language task – namely narrative processing.

Methods

Participants. Seventeen typically developing children and their parents participated in the study. Children and parents were drawn from a larger, monolingual sample participating in a longitudinal study of children's language development in the greater Chicago area. Children were 14 months at the time of their first visit, and were visited in their homes every four months after that point. To be included in the current analysis, the dyad needed to have the relevant home visit at 30 months and participated in the neuroimaging study at age 7-9 years. The children interacted at home with their primary caregiver. The average income for the sample was $59,322 ($SD$ = 3,294). The average years of education for the primary caregiver was 16 (SD = 2) years, corresponding to a Bachelor's degree.

Behavioral procedure. Parental input measure was based on parent-child interactions. Parents were asked to interact with their children as they normally would, and parent-child dyads were videotaped for a 90 minute period. All parent and child speech in the videotaped session at child age 30 months was transcribed (percent agreement 95%). Decontextualized language utterances produced by parents and children were identified (percent agreement 96%, Cohen's kappa 0.73). All utterances that were not coded as decontextualized were considered contextualized.

Neuroimaging procedure. Neuroimaging measures were collected when children entered school. When children were 7-9 years old, we administered a narrative comprehension task in a scanner using fMRI. Children passively viewed a storyteller narrating a story. When children came out of the scanner, they were asked comprehension questions about the stories they heard. Using partial least squares analysis (McIntosh & Lobaugh, 2004), we examined which brain networks show activation that covaries with early parental decontextualized input at the whole brain level.

Results

We found two networks in the brain that were related to the decontextualized input children received. The first network was positively related to input - that is the higher was the amount of decontextualized talk children received at 2.5 years of age, the higher was the recruitment of bilateral middle and superior temporal cortices (LV1, $p = .02$, Figure 1a). The second network was negatively related to input - the lower was the amount of decontextualized input, the higher was the recruitment of bilateral superior/inferior parietal, premotor cortices, and angular gyrus (LV1, $p = .02$, Figure 1b. No significant relations between neural activation in these clusters and parental SES or contextualized input were observed ($p > .10$). Parental input did not correlate with performance on comprehension questions ($p > .10$).
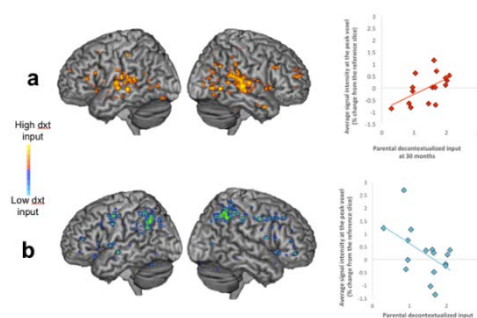
Figure 1. a) Brain networks that show a positive correlation (red) with parental decontextualized input. The singular image showing reliable clusters was mapped to the atlas and thresholded to show bootstrap ratios ≥ |+/-3| and number of nodes over 20. Scatterplot shows the relation between input and average signal intensity at the peak voxel of the network. b) Brain networks that show a negative correlation (blue) with parental decontextualized input. The singular image showing reliable clusters was mapped to the atlas and thresholded to show bootstrap ratios ≥ |+/-3| and number of nodes over 20. Scatterplot shows the relation between input and average signal intensity at the peak voxel of the network.

Discussion

Prior work established relations between parental SES and brain structures. However, not much is known about the relations between environmental factors and the neurofunctional basis of children's academic performance. Further, which aspect of SES most strongly predicts differences in brain function is also not known. We focused on parental language input and its relations to neural basis of narrative processing. In narrative processing, temporal areas are involved in verbal, semantic processing, whereas the parietal regions are involved in visuo-spatial mental building. Although correlational, results suggest that children respond adaptively to their early environments by relying on different neural systems to succeed at narrative processing. Our results suggested that children who are exposed to decontextualized language to a greater degree early in life rely on verbal, semantic networks in narrative processing, whereas children who heard decontextualized input to a lesser extent recruited visuospatial networks instead. Importantly, the two groups did not show behavioral differences. Although neuroscience's role in education research remains highly debated, we show that neuroimaging methods has the potential to reveal whether children might reveal different systems in the brain even when their behavioral performance is the same. This finding might have implications for interventions aiming to close the achievement gap. Children might need interventions that target different neural systems depending on input history.

References

Hackman, D. A., & Farah, M. J. (2009). Socioeconomic status and the developing brain. *Trends in Cognitive Sciences*, *13*(2), 65-73.

McIntosh, A. R., & Lobaugh, N. J. (2004). Partial least squares analysis of neuroimaging data: applications and advances. *Neuroimage*, *23*, S250-S263.

Snow, C. E. (2010). Academic language and the challenge of reading for learning. *Science*, *328*(5977), 450-452.

The Impact of Evidence-based Professional Development on Classroom Dynamics

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Abstract: Evidence-based data use in teacher professional development (PD) programs has been proposed as an effective way for supporting teacher learning and reflection. However, few studies provided empirical evidences on its impact on teachers' and students' classroom behaviour across PD sessions. This paper reports the findings of how a video-based mathematics teacher PD program, in which teachers reflected on self-captured videos supported by Classroom Discourse Analyzer (CDA), influenced the teacher and students' classroom engagement over time.

Introduction

Data use to inform educational decision making has been increasingly emphasized in the fields of teaching, learning, and teacher education in recent years (e.g., Gold & Holodynski, 2016; Mandinach & Gummer, 2013; Marsh & Farrell, 2015). Among the data use literacy, the use of classroom videos is increasingly popular as a method for enhancing teaching and learning in the classroom-based settings (Borko, 2016; Nolan, Paatsch, & Scull, 2017), for measuring teacher knowledge and teaching competence (Kersting et al., 2016; Santagata & Yeh, 2016) and for supporting teacher professional development (PD) and 'noticing' (Sherin & Dyer, 2017) for example. However, relative to the large potential of data use in teacher PD, the evidence of systematically using self-captured classroom videos in teacher PD and its impact on teachers' and students' classroom behaviour was not sufficient (e.g., Poortman, Schildkamp, & Lai, 2016).

The present study

To address this gap, the study uses an analytics-supported PD model in which mathematics teachers use the Classroom Discourse Analyzer (CDA; Chen, Clarke, & Resnick, 2014, 2015) to analyze and reflect on their self-captured classroom videos and discuss about their classroom behaviour with peer teachers. CDA allows teachers and facilitators to use a visual representation of classroom discourse as a lens to identify meaningful discourse patterns for discussion, learning and reflection in the PD community. The aim of the program was to help enhance the mathematics teachers' classroom talk competence in a school district in China. There were 30 mathematics teachers from 12 schools who received analytics-supported PD to learn about classroom talk (using Academically Productive Talk [APT] as part of the training materials; Michaels, O'Connor, & Resnick, 2008; Resnick, Michaels, & O'Connor, 2010).

The preliminary results

In this poster presentation, we report the participating teachers' data regarding the influence of the three PD sessions on their classroom dynamics back to teaching. We report the preliminary findings from four perspectives of the changes of classroom dynamics: (1) percentages of teachers' and students' words; (2) percentages of students who spoke at least once; (3) average words per turn spoken by teachers and students; and (4) percentages of various teacher talk strategies used in the classroom.

Percentages of teacher's and students' total words

We counted percentages of teachers' and students' words by dividing the teacher's and students' words by total words in each classroom and then averaged the teachers' data. We found that the percentages of teachers' words seemed to decrease and that of students' words seemed to increase across the three PD training sessions (the training interval was 1-2 months). In another word, after each PD session, the teachers tended to spoke less and allowed their students to speak more.

Percentages of students who spoke at least once

The results showed that the percentages of students who spoke at least once in the classroom increased across the PD sessions, which suggests that the teachers engaged more students into classroom talk.

Words per turn spoken by teachers and students

Interestingly, the words per turn in the student's data increased across the three PD sessions. It is likely that the students had deeper thinking and hence produced more words per turn during the discussion. This hypothesis would be further cross-validated and investigated in the project.

Percentages of various teacher talk strategies used in the classroom

We then draw on theories and examples of teacher APT (adapted from Michaels et al. [2008] and Resnick et al. [2010]) to code the teachers' classroom discourse into two dimensions: (1) encouraging students to elaborate their own thinking (e.g., "Revoice", "Say More", "Press for Reasoning", and "Challenge"), and (2) encouraging students to think with others (e.g., "Restate", "Add On", "Agree/Disagree", "Explain Other"). We counted the percentages of various teacher talk strategies by dividing the number of teacher turns with a specific talk strategy by the total number of teacher turns and averaged the teachers' data. First, we found that in general the teachers used limited "Revoice" and "Challenging" talk moves in the three teaching occasions, but they seemed to be familiar with "Say more" talk strategies regardless of the PD training. Another large share of talk strategy used by the teachers, especially after the PD training sessions, is "Press for Reasoning", which increased gradually across the sessions. It suggests that the teachers used the strategy "Press for Reasoning" more in the classroom across the PD sessions. Second, we found in general the teachers used few talk strategies to encourage students to think with others. For example, the percentages of "Restate" and "Explain other" occurrences out of total teacher turns remained at a low level, so were the percentages of "Add on" and "Agree/Disagree."

References

Borko, H. (2016). Methodological contributions to video-based studies of classroom teaching and learning: A commentary. *ZDM, 48*(1-2), 213-218.

Chen, G., Clarke, S. N., & Resnick, L. B. (2014). An analytic tool for supporting teachers' reflection on classroom talk. Paper in *Proceedings of the 11th International Conference of the Learning Sciences*. Boulder, CO.

Chen, G., Clarke, S. N., & Resnick, L. B. (2015). Classroom discourse analyzer (CDA): A discourse analytic tool for teachers. *Technology, Instruction, Cognition and Learning, 10*(2), 85-105.

Gold, B., & Holodynski, M. (2017). Using digital video to measure the professional vision of elementary classroom management. *Computers & Education, 107*, 13-30.

Kersting, N. B., Sutton, T., Kalinec-Craig, C., Stoehr, K. J., Heshmati, S., Lozano, G., & Stigler, J. W. (2016). Further exploration of the classroom video analysis (CVA) instrument as a measure of usable knowledge for teaching mathematics: taking a knowledge system perspective. *ZDM, 48*(1-2), 97-109.

Mandinach, E. B., & Gummer, E. S. (2013). A systemic view of implementing data literacy in educator preparation. *Educational Researcher, 42*(1), 30-37.

Marsh, J. A., & Farrell, C. C. (2015). How leaders can support teachers with data-driven decision making. *Educational Management Administration & Leadership, 43*(2), 269-289.

Michaels, S., O'Connor, C., & Resnick, L. B. (2008). Deliberative discourse idealized and realized: Accountable talk in the classroom and in civic life. *Studies in the Philosophy of Education, 27*(4), 283-297.

Nolan, A., Paatsch, L., & Scull, J. (2017). Video-based methodologies. *International Journal of Research & Method in Education*, 1-12.

Poortman, C. L., Schildkamp, K., & Lai, M. K. (2016). Professional development in data use: An international perspective on conditions, models, and effects. *Teaching and Teacher Education*, (60), 363-365.

Resnick, L. B., Michaels, S., & O'Connor, C. (2010). How (well structured) talk builds the mind. In D. Preiss & R. Sternberg (Eds.), *Innovations in educational psychology* (pp. 163-194). New York, NY: Springer.

Santagata, R., & Yeh, C. (2016). The role of perception, interpretation, and decision making in the development of beginning teachers' competence. *ZDM, 48*(1-2), 153-165.

Sherin, M. G., & Dyer, E. B. (2017). Mathematics teachers' self-captured video and opportunities for learning. *Journal of Mathematics Teacher Education, 20*(5), 477-495.

Game-Talk: Media-Based Mentoring as a Process of Reframing Relationships and Reframing Perspectives

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Abstract: In this study, we used a unified discourse lens and the constant comparative approach to develop an emergent framework about media-based mentoring in the context of an academic social network and a science video game. In this framework, media-based mentoring is characterized as a process of reframing person-to-person relationships, reframing person-to-game relationships, and reframing person-to-world relationships.

Introduction

In this paper, we provide an analysis of media-based mentoring as enacted in conversations around a science video game. We used methods of unified discourse analysis (Gee, 2015) and grounded theory (Charmaz, 2006) to characterize a form of productive talk among middle school students and college student mentors in a digital space built around a science video game. We characterize this media-based mentoring as a process of reframing relationships and reframing perspectives. Specifically, participants reframed relationships with each other, reframed relationships with the science game, and reframed relationships with real and future worlds.

Method

Participants and setting

We collected data for this study from a process of mentoring that linked 28 middle school students with 16 science-affiliated college student mentors. The school was in a rural community located sixty miles from the nearest city. The middle school students in our study identified as 79% Hispanic, 17% Caucasian, and 4% mixed-race. 91% of the students at the school qualified for free or reduced lunch. The 16 volunteer mentors were undergraduate students affiliated with a science or engineering course at a large university.

Design

Digital media was central to the process of media-based mentoring we examined and report on in this study. Digital media provided the information and tools to support collaborative inquiry, a platform for communication, and a virtual world for media-based interactions and scientific inquiry (Gould & Parekh, 2017). We employed group mentoring (O'Neill, 2004) using the media of the Mystery of Taiga River video game (Barab & Arici, 2014) and the academic social networking platform, Ed Modo. Groups of three or four middle school students interacted with two or three mentors over a period of twenty class sessions.

Research approach

To analyze the discourse, we examined the online discussion logs for each of eight groups. We also examined the sixteen Mystery of Taiga River video game plays. The discussion logs were composed of 2845 lines of interactive discourse. The game plays were composed of actions, decisions, and written arguments as enacted collaboratively in the virtual world. These game plays were composed of unique interactions and affordances used to test out and make things happen in the game world. In other words, the way the game responded was part of the enactment and part of the discourse that we analyzed (Gee, 2015). We initially coded transcripts of the discussions, observations, enactments, and interactions line-by-line to compare, conceptualize, and categorize (Charmaz, 2006). After this initial coding, we used a unified discourse lens to refine and elaborate patterns among the categories (Gee, 2015).

Findings and emerging framework

Based on our analysis of the transcripts and the video game plays, three forms of reframing emerged. 1) Participants reframed their roles and relationships with each other from strangers to acquaintances and friends. 2) Participants reframed their roles and relationships with the science game. 3) Participants reframed their roles and relationships with the broader world beyond the game. An example of each of these forms of reframing is shown in Table 1.

Table 1: Framework for a theory of media-based mentoring

Form of reframing	Example
Reframe roles and relationships with each other	Mentee: What do you mentors do? Mentor: Just like all of you, I am playing the Taiga River game. If you have any questions as you try to solve the fish problem, let me know and I will do my best to help? Even more, if you have any questions about STEM or college, please feel free to ask.
Reframe roles and relationships with the video game	Mentee: My claim was that factories are causing acid rain but the claim failed. Mentor: That's okay, just make sure you write why the factories are not causing the fish to die in your report. Keep investigating! What hypothesis are you going to try next?
Reframe roles and relationships with the video game	Mentee: We are in the future checking to see if our new rules have worked out. Mentor: That's good! Did the rules work?
Reframe roles and relationships with real and future worlds.	Mentee: That is so cool! Glowing jellyfish! I never thought about that until now! Mentee: That is really cool. I want to take that class when I go to college! Mentor: You both could take that class in college! There are lots of cool concepts in science so if you have any questions about them, let me know and we can talk about them!

Discussion and implications

Our findings illustrate the emergence of a media-based mentoring process characterized by a central theme of reframing relationships and reframing perspectives. Through collaborative reflection, participants reframed their perceptions of roles with each other and reframed their perceptions of roles with science and the video game. The dialogue wasn't just about content. It was about relationships to that content and what participants could do with those relationships. They could test out a hypothesis, think about a novel idea, build an argument, or plan for their futures. For example, as the middle school youth and their mentors interacted around an acid rain hypothesis, they stepped back from the action in order to perceive their action and potential actions from different viewpoints. They discussed their relationship with the game when they talked about going to the future "to see if our new rules have worked out." Throughout the mentoring process, participants discussed what they could do with the content or with the game and what they could do with their relationship with the content. The process of media-based mentoring impacted the ways our participants talked about and viewed their real and future worlds. In alignment with unified discourse theory, we found that the language of mentoring functioned not only as a vehicle for conveying information, but also as a means for building things and doing things in the world. The language of media-based mentoring functioned to enact changes in relationships and changes in perspectives for the participants in our study.

References

Barab, S.A., & Arici, A. (2014, April 4). *Game-infused science curriculum: From transformational play to real-world impact*. Paper presented at the 2014 annual meeting of the American Educational Research Association. Retrieved July 1, 2015, from the AERA Online Paper Repository.

Charmaz, K. (2006). *Constructing grounded theory: A practical guide through qualitative analysis*. Los Angles, CA: Sage.

Gee, J.P. (2015). *Unified discourse analysis: Language, reality, virtual worlds, and video games*. New York, NY: Routledge.

Gould, D. & Parekh, P. (2017). Mentoring and argumentation in a game-infused science curriculum. *Journal of Science Education and Technology*. doi:10.1007/s10956-017-9717-x.

O'Neill, D.K. (2004). Building social capital in a knowledge-building community: Telementoring as a catalyst. *Interactive Learning Environmnents 12*(3), 179-208.

Using Multiple Perspectives to Study Identity Development in Digital Environments

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Abstract: Within the field of identity research, our understanding of the interplay between digital technology, identity, and learning has been impeded by differences in vocabulary. This paper reviews two main theories and proposes a new integrated model of identity development that uses measurable constructs in place of discrepant terminology for similar concepts. This model has the potential to further enrich our understanding of identity and the ways we can improve the designs of digital learning environments.

Divisions in the field of identity research

Digital technology impacts the process and outcome of identity development (Turkle, 1984) which in turn affects how people learn (Steele, 1997). However, scholarship around the construct of identity and the process of identity development is variant which has led some to argue that the construct of identity is too poorly defined to be useful. Additionally, there is a wealth of research that focus on specific domains or expressions of identities, e.g., racial identity (Sfard & Prusak, 2005; Nasir, McLaughlin & Jones, 2009) or gender identity, wherein some effort has been made towards integrating models. However, this work has yet to contribute to our understanding of composite identity development. Increasingly, scholars are calling for more integration of the various perspectives on identity to better support the advancement of identity research (McLean & Syed, 2015). Integrated approaches would also allow for more in-depth examinations of the relationship between identity, learning, and the use of technology enabling learning scientists to better design educational technologies that promote learning.

The modern-day conception of identity was developed by the first psychologists and sociologists to branch out from philosophy - the two most notable being George Herbert Mead and William James (Hammack, 2015). Mead's theory and its derivatives maintains that society and identity inform each other dialectically through interaction (Hammack, 2015). Identity then is a reflection of an individual's roles or positions within society. Eriksonian theories, which were inspired by William James, assert that identity development is a fluid and ongoing process of exploration, reflection, and commitment (Crocetti, Rubini & Meeus, 2008) and involves interaction between three levels of identity: ego, personal and social (McLean & Syed, 2015). Briefly, ego identity consists of basic, private beliefs and is concerned with consistency across time and space; personal identity goes beyond private beliefs to include goals and positions, and strives for congruity between beliefs, values, and roles; and social identity is the synthesis of an individual's memberships to and roles within various social groups.

By combining corresponding elements and replacing general constructs with identity-relevant conceptualizations, one possible working definition of identity development could read as such: *an iterative process wherein our values, conceptions of possible selves, and salient aspects of our self-concept influence the quality and quantity of our experiences and social interactions, which lead to new or revised commitments after a period of interpretation and reflection governed by our processing style.*

Integrating the psychological and sociological models of identity

The similarities between the Eriksonian and Mead perspective are obscured by disparate vocabulary. Also, vague definitions make it difficult to measure the process and outcome of identity development in systematic ways. The proposed definition attends to all of the main components of both perspectives and utilizes constructs for which scholars have already created reliable and valid measures. *Values* encompass both beliefs (Maio, et. al., 2003) and the internalizations of imposed positions (Hitlin, 2011). Similarly, Cheek, Smith and Tripp's (2002) *Aspects of Identity* attends to the importance of structures - which includes positions/roles and memberships - for identity development. They assert that people assign significance to their self-aspects differently and that these aspects are clustered into four levels: personal, relational, social or collective. The dialectic between structure and agency requires that the individual make sense of the structures within which they are operating so as to tailor their behavior to the situation. However, individuals process identity relevant information in three distinct and systematic ways: informational, normative, and diffuse-avoidant (Berzonsky, 2008). Individuals do not fall neatly into these categories but instead show preferences for at least two of these *Processing Styles* depending on the context (Kerpelman, Pittman & Baeder, 2008). The enactment of agency is easily observed, but to understand behavior we must have insight into motivation which is not as easily obtained/accessible. Understanding the primary style(s) with which an individual processes identity relevant information elucidates the germane aspects

of an experience for an individual and the degree to which they explore, reflect and commit which in turn determines the robustness of their resultant identity. Lastly, people call upon their experiences and understanding of the world when thinking about who they want to become (Oyserman & James, 2011). If behavior is identity in action, we can reconceptualize goals as *possible identities* which are circumscribed by an individual's perception of the world and their past experiences.

Advancing learning sciences research using the integrated model

In order for learning scientist to fully understand identity's impact on learning, we need to have a comprehensive understanding of the internal, external and interactional aspects of identity. A digital learning environment whose design employs the proposed model of identity development should aim to seamlessly evaluate the user's values, conceptions of possible selves, and salient aspects of their self-concept in order to effectively prompt exploration, reflection, interaction and commitment in relation to the learning objectives. Findings from research such as this would help design-based researchers make more informed decisions about the features they should include, mode(s) of delivery, and types of content to help foster positive identity development and promote learning. For instance, the culture of science often conflicts with that of marginalized people as evidenced by the field's lack of diversity. One possible way to address this issue is by designing and implementing an interest-based digital learning environment that aims to help participants develop positive science identities. This could be accomplished by providing users opportunities to explore the relationship between their interests and science, reflect on these new experiences (e.g., in a journal), and revise their commitments as evidenced through changes to their self-representations or career aspirations.

By embedding measures of the proposed constructs into the digital learning environment, researchers can simultaneously elucidate the unique impact that these environments have on the process and outcome of identity development and the ways in which we can improve our designs to amplify their efficacy. Additionally, these findings would allow researchers to time intervention aspects to coincide with other phases of development to enhance the final outcome.

References

Berzonsky, M. D., Cieciuch, J., Duriez, B., & Soenens, B. (2011). The how and what of identity formation: Associations between identity styles and value orientations. Personality and Individual Differences, 50(2), 295-299.

Cheek, J. M., Smith, S. M., & Tropp, L. R. (2002, February). Relational identity orientation: A fourth scale for the AIQ. In meeting of the Society for Personality and Social Psychology, Savannah, GA.

Crocetti, E., Rubini, M., & Meeus, W. (2008). Capturing the dynamics of identity formation in various ethnic groups: Development and validation of a three-dimensional model. *Journal of adolescence*, *31*, 207-222.

Hammack, P. L. (2015). Theoretical foundations of identity. The Oxford handbook of identity development, 11-30.

Hitlin, S. (2011). Values, personal identity, and the moral self. In Handbook of identity Theory and research (pp. 515-529). Springer New York.

Kerpelman, J. L., Pittman, J. F., & Adler-Baeder, F. (2008). Identity as a moderator of intervention-related change: Identity style and adolescents' responses to relationships education. Identity: An International Journal of Theory and Research, 8(2), 151-171.

Maio, G. R., Olson, J. M., Bernard, M. M., & Luke, M. A. (2003). Ideologies, values, attitudes, and behavior. In J. DeLamater (Ed.), Handbook of social psychology (pp. 283–308). New York: Plenum.

McLean, K. C., & Syed, M. (2015). The field of identity development needs an identity: An introduction to the oxford handbook of identity development. In Oxford handbook of identity development, New York: Oxford University Press.

Nasir, N. I. S., McLaughlin, M. W., & Jones, A. (2009). What does it mean to be African American? Constructions of race and academic identity in an urban public high school. *American Educational Research Journal*, *46*(1), 73-114.

Oyserman, D., & James, L. (2011). Possible identities. In Handbook of identity theory and research (pp. 117-145). Springer New York.

Sfard, A., & Prusak, A. (2005). Telling identities: In search of an analytic tool for investigating learning as a culturally shaped activity. *Educational researcher*, *34*(4), 14-22.

Steele, C. M. (1997). A threat in the air: How stereotypes shape intellectual identity and performance. American Psychologist, 52, 613-629.

Turkle, S. (1984). The second self. New York: Simon and Schuster.

Examining Productive Discourse and Knowledge Advancement in a Knowledge Building Community

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Abstract: This study examined an explicit reflection enriched knowledge building community on students' productive discourse and knowledge advancement. Knowledge advancement was analyzed using a social network analysis tool, called Knowledge Building Discourse Explorer (KBDeX) (Oshima, Oshima, & Matsuzawa, 2012). KBDeX analysis on keywords network indicated that students in the intervention class had engaged in a more cohesive discussion. Further discourse analysis clarified that students in the intervention class engaged in a more productive progressive discourse.

Introduction

This study investigated a computer-supported knowledge building (KB) community (Scardamalia & Bereiter, 2014) on students' collective knowledge advancement in the online discourse using a social network analysis tool in identifying students' progressive discourse. Substantial researches indicated that the importance of sustained inquiry and collective knowledge advancement, however, students would not spontaneously engage in a progressive discourse to advance their community knowledge (Yang, van Aalst, Chan, & Tian 2016). A challenge arises pertaining to how can we scaffold students' collective knowledge advancement in their collaborative inquiry, and more researches needed to investigate the learning environment design in fostering students' collective knowledge advancement. To address this challenge, we designed and evaluated an enriched KB environment with explicit reflection to scaffold students' progressive inquiry and collective knowledge advancement. Therefore, this study examined how students engage in collective knowledge advancement in a designed KB environment, using a social network analysis, followed by an in-depth discourse analysis.

Methods

Participants were two classes of 9th Grade students in a secondary school, among which one class was engaged in a designed discourse reflection and principle emphasized KB environment, for comparison, the other class was engaged in a regular KB environment. The key design in the enriched KB class is focusing on discourse reflection. In this paper, we focused on examining whether students engage in the productive discourse, and advanced community knowledge using their KF discourse as input data to KBDeX for social network analysis. Students notes in online discussion platform (Knowledge Forum®) were exported into KBDeX and a list of conceptual words were selected based on the curriculum guide and students' discussion. We conducted the keywords network analysis which shows how ideas are connected as indicators for detecting collective knowledge advancement (Oshima et al., 2012; Oshima, et al., 2017). The first stage of analysis focused on exploration of keywords network changed over time. Then, we conducted in-depth discourse analysis to investigate how students engaged in the productive discourse.

Results

Collective knowledge advancement between intervention and comparison class

To investigate students' collective knowledge advancement, we examined keywords network change over time. As shown in Figure 1, the network of keywords was changed from phase 1 (note 1 to 22) to 2 (note 1 to 100) to 3 (note 1 to 181). Figure 1a showed an integrated cluster of keywords which indicated that students started their KF discussion in a more cohesive way in the intervention class while the network of keywords was fragmented for the comparison class (Figure 1b), suggesting that students did not relate their ideas together in the discussion (The reason for the difference between the two classes at the initial KF discussion stage is due to the explicit reflection on ideas, students in the intervention class have a discussion and reflection on their ideas developing in the classroom before starting inquiry in KF while the comparison class start inquiry in KF directly without ideas reflection). Moreover, through the discussion, in phase 2 and 3, the keywords network also stayed fragmented for the comparison class (Figure 1d and 1f) while the keywords network continued to integrate for the intervention class (Figure 1c and 1e). Overall, the transition of keywords network change indicated that

students in the intervention class integrated their ideas with a consistently discussion and the collective knowledge was advanced through the discussion than the comparison class.
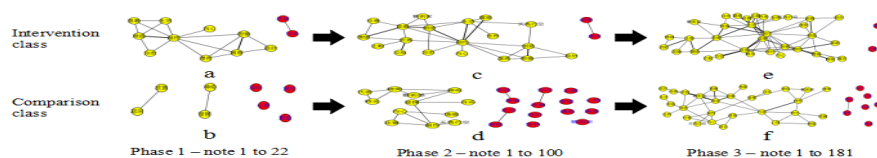
Figure 1. Keywords network change over time between intervention and comparison class.

Progressive inquiry and discourse in KF

In addition to the keywords network analysis, we also analyzed students' KF discourse to identify and explain how students engaged in productive discourse and knowledge advancement. The following excerpt is a cluster of KF discourse (under a topic on *what is art*) for the intervention class (keywords is in bold). Student A proposed a theory that arts can represent people's emotions, followed by student B's explanation that art works can be different depending on people's emotions and also proposed a new theory that art is creative, however, student C did not agree with student B's idea, followed by student B's continued build-on in explaining the various types of arts. Later, student D asked a sustained question based on previous idea on why art relate to life, followed by student E's response. Moreover, student F also asked a sustained question on the function of art to move forward the discussion. Overall, within this discourse example, different students made contributions and fully engaged in the productive discourse with ideas improvement through new questions emerged and sustained inquiry, and integrating various conceptual words to advance knowledge on *what is art*.

Student A	[My theory] … art can be a representation of **emotions**, people can **design** an artifact to represent the emotion…what kind of arts can represent emotions?
Student B	[My theory] I think art is different based on different people's ideas and **emotions**, but the common thing is the **creativity**.
Student C	[My theory] I think art works only need to be **beautiful.**
Student B	[My theory] I think art not only refers to the **drawing**…also relation to **life**…
Student D	Why do you think art works are relating to **life**?
Student E	Art can relate to **life**…art **design** can also be **unrestrained**…
Student F	…[I need to understand] what kind of social **functions** that arts have?

Conclusion and significance

In conclusion, analysis indicated the differences in the collective knowledge advancement between the intervention and comparison class. The study has theoretical value that extends the insights into scaffolding students' productive discourse and knowledge advancement focusing on explicit reflection of ideas and discourse, and for teachers, they can try to design this reflection-enriched KB environment to help students involved in progressive discourse and community knowledge advancement.

References

Oshima, J., Oshima, R., & Matsuzawa, Y. (2012). Knowledge Building Discourse Explorer: a social network analysis application for knowledge building discourse. *Educational Technology Research and Development, 60*(5), 903-921.

Oshima, J., Ohsaki, A., Yamada, Y., & Oshima, R. (2017). Collective knowledge advancement and conceptual understanding of complex scientific concepts in the Jigsaw instruction. In B. K. Smith, M. Borge, E. Mercier, & K.Y. Lim (Eds.), *Making a difference: Proceedings of the 12th International Conference on Computer Supported Collaborative Learning (CSCL) 2017*, Volume 1. Philadelphia: ISLS.

Yang, Y., van Aalst, J., Chan, C.K.K., & Tian, W. (2016). Reflective assessment in knowledge building by students with low academic achievement. *International Journal of Computer-Supported Collaborative Learning, 11*(3), 281-311.

Scardamalia, M., & Bereiter, C. (2014). Knowledge building and knowledge creation: Theory, pedagogy, and technology. In R. K. Sawyer (Eds.), *The Cambridge handbook of the learning sciences* (2nd ed., pp.397-417). New York, NY: Cambridge University Press.

Crossover Papers

Towards a Framework for Smart Classrooms that Teach Instructors to Teach

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Abstract: Teaching Assistants (TAs) play a major role in higher education; however, they receive little if any training on how to teach. Quality training requires access to grounded feedback and relevant suggestions for improvement. We developed a framework for using features of a smart classroom. This work reframes the instructor as the learner. It provides training on discursive practices with feedback based on the instructor's in-class behaviors. We built and deployed a system based on this framework to five STEM TAs as part of a larger study. This paper: discusses the action-reflection-planning framework we used, provides evidence for how the framework addresses TA learning goals, and discusses how other researchers might make use of the framework.

Introduction

Teaching Assistants (TAs) teach up to 26% of college classes (Friedman, 2017). Interestingly, most receive no pedagogical training (Ellis et al., 2016), nor do they receive regular feedback on their performance (Austin, 2002). Smart classrooms now offer many sensors that can detect various behaviors that occur during class (Blanchard et al., 2016). While this technology to date has focused mostly on students, it could also sense instructors' behaviors, recasting the instructor as a learner. Smart classrooms provide a new opportunity for training such novice instructors to teach using their own data as a form of input, creating opportunities for instructional feedback that have been difficult to achieve at scale.

We developed a framework for training instructors to teach that incorporates reflection on practice and planning for upcoming classes that is distributed over time within cycles of teaching. In addition, we prototyped a system to train instructors on discursive practices, simulated a smart classroom with research assistants logging behaviors, provided feedback in the form of data visualizations, and prompted instructors to both reflect on their performance and plan for the next class. We conducted a field trial with a small number of TAs and observed movement towards better teaching practices and some shift in beliefs around student-centered learning.

Related work

Support for TAs is rare. Many schools provide no training. When available, many TAs choose not to participate for reasons including the need to dedicate many consecutive hours to the typical workshop format of such training (Ellis et al. 2016). However, professional development (PD) research on faculty and TAs shows that they need help to notice their own poor practices (Henderson et al., 2011) and for setting goals (Brinko, 1993). Regular, data-supported feedback on teaching would address some of these needs (Brinko, 1993).

Researchers have previously offered digital feedback to instructors, typically as dashboards showing what students do or know (Jivet et al., 2017). Research on instructor feedback systems shows that instructors must have pre-existing expertise to interpret them. Currently, most TAs have no prior teaching experience nor access to feedback. Our work investigates opportunities for addressing this lack of expertise through automated feedback on what TAs actually do in the classroom combined with online training.

System design

Our socio-technical training system (STTS) is meant to simulate a future smart classroom that can provide training and feedback, and it is meant to scaffold reflection and planning. Our system aims to help TAs develop the use of discursive teaching tactics (Rocca, 2010) to reduce non-interactive lectures and shallow questioning strategies; actions which harm student attention, focus, and learning (Chi & Wylie, 2014; Freeman et al., 2014). It introduces simple research-proven strategies for eliciting student participation and describes how increased participation improves student learning (Rocca, 2010). It trains TAs on the use of discursive techniques such as asking questions, asking content questions, pausing after asking questions, and calling on students by name.

We developed a framework (Figure 1) of the TA as a learner based on our pilot studies of how TAs prepare for teaching. It is also influenced by Clark and Hollingsworth's interconnected model of professional growth (2002). This functioned as an overarching guide for the design of the STTS. The STTS directs TAs through an iterative process of reflection, planning, and acting (i.e., teaching their class).

We simulated a smart classroom by having research assistants with a logging tool capture in-class behaviors, such as the length and order of TA and student speech turns, the number and types of questions TAs asked, and the pauses between speech turns. We prototyped the training aspect of our STTS using the commercial survey service, Qualtrics. We used this to deliver training materials on discursive practices, to present data visualizations of teaching behaviors, and to scaffold reflection on recent teaching and planning for an upcoming class.

Our design organizes activities into conceptual Units that are delivered over about ten days via three subsection, called modules (M). They are M.1: training and reflecting on performance to notice teaching behaviors, M.2: planning for use of new tactics, and M.3: reviewing and reflecting on the results of attempting those tactics. M.1 provides instruction on the value of student participation and asks TAs to recall details of their most recent class. It shows them data visualizations from that class, revealing their

Figure 1. Diagram of framework for sensing and training to align with TA activities.

patterns of teaching. TAs respond to reflection prompts immediately after viewing these data. M.2 supports goal-setting and guides TAs through practical tactics (e.g., "Write questions up on the board rather than just saying them out loud"). TAs commit to trying new tactics in their next class. After the next class, M.3 reveals updated sets of visualizations comparing prior and current performance, and the outcomes of their selected strategies.

In the current field trial, we deployed two content Units, each containing these three modules. Unit A trains TAs to ask more questions and to ask questions about the course content, as opposed to simply asking if the students have "any question?". Unit B trains TAs to wait at least 3 seconds after asking a question before speaking.

Method

We conducted a qualitative study of our STTS to examine how well it promotes the features of the framework. We wanted to understand how our design might impact TAs' in-class actions, post-class reflections, and pre-class planning. We recruited 5 TAs in an American university (one undergraduate and four PhD students) who volunteered due to interest in improving their teaching. They were all male. They taught either a recitation section or a stand-alone course in math, engineering, or accounting. Average attendance per class was about 20 students. We observed a total of 80 class sessions totaling 89 hours of observation across the 5 TAs.

Before deploying our STTS, we observed a baseline of about 6 sessions per participant. Participants then interacted with the STTS seven times over the three-week trial. Each TA's interaction with the tool was short (no more than 10 minutes per session). Sessions that included class data were available within 1 hour of teaching. TAs were prompted with email messages containing links to the Qualtrics forms. TAs were prompted to plan 2 days before their next class.

Following the trial, we conducted semi-structured interviews with each TA for 1 hour, followed by a deep review of the conversation by the research team. We followed a style of contextual inquiry interviews that produces line by line segments of subject sentiments, each of which we used to produce inductive sentiment themes across participants (Beyer & Holtzblatt, 1997).

Data analysis

To assess the framework, we reviewed three data sources: interview sentiments, interactions with the STTS, and in-class behaviors. For Action, we looked at the use of suggested discursive strategies, and whether or not TAs changed behaviors following the use of the STTS. From the class logs, we calculated discursive actions at the class level (e.g., number of questions asked per session) and used exploratory data analysis to uncover behavioral trends at an individual TA level, both across sessions and between baseline and instructional sub-units. For Reflection, we reviewed STTS interactions and interview sentiments to discern whether TAs engaged in reflection, including assessments of their ability to perform critical self-evaluation. For Planning, we reviewed the strategies TAs selected to try, and we judged whether they enacted those tactics in class.

Findings

In general, the TAs all used our STTS as designed. We observed them all engage in a structured cycle of action, reflection, and planning. None abandoned the system. They typically responded to each emailed prompt to use the system within one or two days at which point they completed the module. All participants described the system as "useful" for improving their teaching. P1, P3, and P4 all exhibited positive change over the semester. P2 and P5 exhibited ineffective teaching strategies from the start, and these persisted throughout the semester. Below, we characterize the TAs' interactions with the STTS based on our Action, Reflection, and Planning framework.

Reflection (M.1 & M.3)

We designed two distinct types of reflection: *before practice* and *after practice*. *Before practice reflection* relates to module M.1, where participants received training and saw visualizations of their behavior from the previous class. *After practice reflection* relates to module M.3, where participants viewed visualizations of their performance after they had previously created a plan to try something new for their next class.

With respect to *before practice reflection*, all TAs expressed curiosity and surprise when viewing visualizations of in-class behaviors. They generally seemed to appreciate the objective nature of the data. We observed P1 and P4 rationalizing what they viewed as negative aspects of their data by explaining some challenge they faced in class. In answering the reflection prompts, P1 focused on a high number of unanswered questions. He shared that he had a "bad habit" of "chaining" several questions together, which seemed to not offer the students the time or opportunity to answer. P4 focused on his first visualization, which showed that he talked for 75% of class time and the students only talked for 5% of class time. He explained that this might be happening because he tried to "prioritize delivering all the materials on time..." He felt more pressure to cover all of the content as opposed to creating time for students to participate.

With respect to *after practice reflection*, all TAs acknowledged the validity of the data and tried to explain some aspect of it. In M.3 TAs were asked to review their attempts to enact new tactics. Some TAs expressed positive self-evaluations of themselves as instructors, pointing to increases in student participation/responses or describing their skill with a new tactic. For example, P4 shared that preparing questions before class helped him ask more content questions than he had previously been asking. In the interview, he shared that he continued this practice throughout the rest of the semester. P1 shared that he "paid more attention to what [he] was saying question-wise," as he began to notice going "on autopilot." P4 reflected on the fact that he was not able to increase the percentage of student talk. Interestingly, he gave himself credit for trying. "I set goals for myself after seeing the data, like when I saw the data where I waited too short. So, I set the goal to wait longer."

TAs did not all feel they improved. When prompted to recall their goals, neither P2 or P5 could recall the techniques they had planned to try. When asked to reflect on his goal attainment in Unit A/M.3, P5 stated he could not remember the class in question. Our system prompts TAs to review their data soon after teaching. However, in these cases, P2 waited 3 days before logging in, and P5 waited 9. Later, in Unit B, P2 reflected that waiting longer after asking questions, "Did not seem to make any particular difference, as students could not answer the question anyway." P5 reflected that he should probably wait longer in the future, despite waiting longer than the target of 3 seconds. He seemed to fail to notice a larger issue, that he asked very few questions.

Planning (M.2) and Action

We report Planning and Action together to support evaluations of TAs' attempts to use their selected tactics in class. Overall, TAs were responsive to goal-setting. When planning their upcoming class, TAs saw a list of strategies they might try in order to increase the content questions they asked, e.g., preparing questions in advance of class, or putting questions up on slides. In baseline observations, most TAs relied on lecture and shallow questioning strategies. We observed each TA select at least one improvement strategy in Unit A/M.2. Following the strategy selection, they all increased the number of content questions they asked in the following class.

P1 selected the most strategies, setting goals to slow down during question asking, ask a wider variety of question types, and wait longer before giving hints or answering a question. P4 set a more conceptual goal, describing how the questions should support the need to cover material. P3 said he planned to ask, "a few more questions than last time." After planning, P1 avoided rapidly repeating/rephrasing questions, and his students responded to a greater ratio of the questions he asked. P4 increased his use of content questions and reduced non-content questions. P3 increased his use of content questions, and this persisted for the rest of the semester.

Alternatively, P2 and P5 showed only isolated teaching improvement. P2 jumped from 1 content question at the beginning of Unit A to 19 following planning. P5 went from 6 to 15. Both then reverted to very low numbers of content questions after a single class. Goal-setting for these TAs seemed vague or disconnected from their practice. P5's only goals in Unit A/M.2 were to "Ask better questions" and "Give students more time to think about questions," (despite already averaging over 3 seconds of wait time). P5 never explained the dramatic rise and drop of content questions. Importantly, during the class where he asked 15 content questions, he averaged only 1 second of wait time after each question, and no students responded to any of the questions.

Discussion

The framework seemed to promote some reflection and planning for all TAs. Three engaged in substantive self-critique, and these instructors seemed to improve. Each TA made plans, and all of them attempted at least one new strategy. However, they did not all maintain the use of these strategies. Each TA who made concrete plans and performed more thoughtful reflection seemed to continue challenging themselves as the course progressed.

Although two of the TAs did not engage in meaningful reflection, concrete planning, or beneficial changes to their teaching, they did still engage with each stage of the STTS. Deeper analysis of their interactions with the system and possible changes in their beliefs may provide some insight into what went wrong and reveal specific needs to address to make the system more successful. Our analysis leads us to conclude that a fully deployed system would function better if it accounted for individual differences in instructors. We suspect that paying attention to beliefs in teacher-centered learning versus student-centered learning is a good place to start. A deployed system might also collect self-efficacy measures and adapt to instructors more individually.

For others attempting to operationalize this framework, we point out that it is critical to consider consistency in user engagement. Parts of the framework require specific timing constraints, such as planning before class begins and active reflection very soon after teaching. If learners fail to review their data when prompted, it will likely reduce the system's impact. Missing sessions of planning or reflection can create gaps in the training cycles where instructors lose track of their goals. Future systems should consider how the system can motivate instructors to quickly engage.

The design of this kind of teacher-as-learner system benefits from information on what drives the instructor. Instructors may embrace training due to a genuine motivation to change, or they might be compelled if this becomes a requirement of their job. They may avoid training because they are not interested in improving, do not feel it is worth the time, or because they do not believe that the strategies actually work. Future systems could use social motivations, such as connecting instructors to a community of practice. Or they could follow a more extrinsic approach, such as hinting that training could enhance the instructor's CV.

This field study of our STTS that combines smart classrooms that sense instructors' actions with personalized feedback and training shows promise, and it offers a new approach to instructional PD. Beyond producing actionable, scalable methods for TA training, we believe this data-rich approach to interacting with novice instructors may reveal interesting new insights into how people learn to teach.

References

Austin, A. E. (2002). Preparing the Next Generation of Faculty: Graduate School as Socialization to the Academic Career. *The Journal of Higher Education*, *73*(1), 94–122.

Beyer, H., & Holtzblatt, K. (1997). Contextual design: Defining customer-centered systems. Elsevier.

Blanchard, N., Donnelly, P. J., Olney, A. M., Samei, B., Ward, B., Sun, X., & D'Mello, S. K. (2016). Semi-Automatic Detection of Teacher Questions from Audio in Live Classrooms. In *Proceedings of the 9th International Conference on Educational Data Mining* (pp. 288–291).

Brinko, K. T. (1993). The Practice of Giving Feedback to Improve Teaching: What Is Effective? *The Journal of Higher Education*, *64*(5), 574.

Chi, M. T. H., & Wylie, R. (2014). The ICAP Framework: Linking Cognitive Engagement to Active Learning Outcomes. *Educational Psychologist*, *49*(4), 219–243.

Clark, D., & Hollingsworth, H. (2002). Elaborating a model of teacher professional growth. *Teaching and Teaching Education*, *18*, 947–967.

Ellis, J., Deshler, J., & Speer, N. M. (2016). Supporting instructional change: A two-pronged approach related to graduate teaching assistant professional development. *Proceedings of the 19th Annual Conference on Research in Undergraduate Mathematics Education*, (February).

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences of the United States of America*, *111*(23), 8410–5.

Friedman, J. (2017, February). *10 Universities Where TAs Teach the Most Classes*. Retrieved from http://www.usnews.com/

Henderson, C., Beach, A., & Finkelstein, N. (2011). Facilitating change in undergraduate STEM instructional practices: An analytic review of the literature. *Journal of Research in Science Teaching*, *48*(8), 952–984.

Jivet, I., Scheffel, M., Drachsler, H., & Specht, M. (2017). Awareness is not enough: Pitfalls of learning analytics dashboards in the educational practice. In *Lecture Notes in Computer Science* (Vol. 10474, pp. 82–96).

Rocca, K. A. (2010). Student Participation in the College Classroom: An Extended Multidisciplinary Literature Review. *Communication Education*, *59*(2), 185–213.

Acknowledgments

Augmenting Formative Writing Assessment With Learning Analytics: A Design Abstraction Approach

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Abstract: There is increasing interest in use of learning analytics and technologies underpinned by artificial intelligence in the support of learning. In implementing and integrating these technologies there are challenges both with regard to developing the technologies themselves, and in aligning them with existing, or transformable, practices. In this paper we argue that by 'augmenting' formative tasks with learning analytics, we can achieve impact both through the integration of the tools, and through the support of existing good practices. We exemplify our approach through its application to the design of tasks for the key skill of learning how to write effectively. The development of these designs and their abstractions holds significant potential in bridging research and practice, by supporting the sharing and interrogation of designs in a way that is intimately tied to both practice (practical applied contexts), and research (through theorized and empirically supported designs targeting particular learning outcomes).

Keywords: writing analytics, learning analytics, learning design, conjecture maps, design patterns, technology enhanced assessment, technology enhanced learning, learning sciences

Introduction

Learning how to write analytically is a core skill in higher education and professional contexts (National Commission On Writing, 2003; OECD & Statistics Canada, 2000). However, its teaching is challenging, (Ganobcsik-Williams, 2006) with students often judging their work by more superficial criteria than the analytical standards that educators apply (Andrews, 2009; Lea & Street, 1998; Lillis & Turner, 2001; Norton, 1990). This may be considered a specific case of a common misalignment between people's perceptions of their own learning and reality (Bjork, Dunlosky, & Kornell, 2013). To address this misalignment, students should be inducted into academic practice to develop 'evaluative judgement', their ability to apply normative standards to assess the quality of work, in order that they are better able to self-assess their own work and thus to improve it (Boud, 2000).

To develop this evaluative judgement, there is a need to both implement tasks that target the learning of writing, and to research the learning of writing, in classroom contexts (Graham & Harris, 2014). In their 12 recommendations for designing high quality writing intervention research, Graham and Harris (ibid) note the importance of interventions that are "well-founded and designed", "representative of the real world context", and include "a series of studies to refine and test the writing intervention" (Graham & Harris, 2014, p. 96). Task designs, and the sharing of these, that support students in learning to write are important.

In this paper, we describe an approach to 'augment' learning designs for writing pedagogy, through the addition of automated writing feedback to writing tasks. As we describe in the following section, there is growing interest in the use of techniques drawn from the fields of learning analytics, educational data mining, or artificial intelligence as applied to education. The integration and implementation of these techniques to support learning in authentic contexts is an ongoing challenge. In the section 'Empirical Case Study' we describe a set of tasks that were designed specifically to develop student writing skills. These tasks are described through the lens of design abstractions that highlight the relationship between features of the design and the theorized pedagogic intent (described in 'A Design Based Approach'). By exemplifying this 'augmentation' technique, we highlight its potential to support communities such as AIED and ISLS to develop methods that support both research and implementation.

Writing analytics to support student writing

One means through which to support the learning of writing is through the provision of feedback to students that supports them in building their evaluative judgement – i.e., feedback that helps students learn to recognize what is good, and what needs improving, particularly in their own work. Such feedback might be provided through automated means, and indeed a body of work has investigated this potential in automated essay scoring (AES), which have been successfully deployed in summative assessment contexts (see, e.g., discussions throughout Shermis & Burstein, 2013). However, these AES systems are not without detractors (Ericsson & Haswell, 2006),

and much less attention has been given to the challenge of providing formative feedback, which to be actionable by the learner, requires more than the calculation of a grade. There is a growing recognition of the potential of computational approaches and natural language processing to be applied to formative feedback on student work, to support them in understanding where to improve, and develop their writing (see, for examples, Buckingham Shum et al., 2016; Knight, Allen, Gibson, McNamara, & Buckingham Shum, 2017; Passonneau, McNamara, Muresan, & Perin, 2017; Zhang, Hwa, Litman, & Hashemi, 2016).

However, the design and implementation of such systems should be conducted with regard to their potential as tools for intervention, and as Graham and Harris note, that has implications for design. Specifically, in developing learning analytics as a form of formative assessment (Knight, Buckingham Shum, & Littleton, 2014) on writing, they should be tested in real world contexts that provide for incremental improvement of the tool alongside impact on learning. To deploy such emerging technologies in formative contexts, we can conceive of two approaches. One approach would use technology to shift the focus of assessment to new kinds of process and product, for example towards choice based assessments (Schwartz & Arena, 2013) or 'performance assessment' (Linn, Baker, & Dunbar, 1991) that investigate the decisions students make in completing tasks. An alternative approach would investigate how existing systems might be 'augmented' by learning analytics, to provide novel feedback in existing high quality pedagogy (Knight, Forthcoming). While the potential of the former is transformative, its challenges include: the need to gather new data types, possibly using novel technology; and the expense and research required in order to develop new kinds of assessments. As Baker (2016) noted with regard to intelligent tutoring systems, adoption of artificial intelligence technologies has not been widespread, and thus our attention may be best focused on how to better use such intelligent systems *alongside* educators and students in flexible ways. Indeed, the need for pedagogically aligned learning analytics intervention designs has been highlighted as key in incorporating learning analytics within educational systems to improve existing teaching and learning practices (Wise, 2014). Given that for innovations to be taken up by educators, their distance from existing culture, practice, and technologies must be considered (Ferguson et al., 2014; Zhao, Pugh, Sheldon, & Byers, 2002), a focus on augmenting (rather than revolutionizing) existing practice may both support and enhance that practice, alongside raising awareness regarding – and implementation of – the role of these technologies for learning.

A design based approach

This paper, then, adopts a perspective of 'augmentation', by taking a design approach to analyzing teaching and learning contexts, to investigate where existing good practice might be augmented by learning analytics, further strengthening that practice. In our view, this approach is likely to increase adoption both of the analytics, and of the underlying practices, thus driving forward implementation of such learning designs, and the potential to research them. A similar call has been made in learning analytics applications for researchers to capture their pedagogical intents by aligning learning analytics to learning design. In this way, Learning Analytics can help to test the assumptions of learning designs by providing the necessary data, methodologies and tools to support the learning design in lieu of self-reported measures (Lockyer, Heathcote, & Dawson, 2013). In turn, knowledge of the pedagogical context that gives rise to the data is critical to its interpretation. The use of design abstractions can support this alignment, as we outline in this paper.

In taking a design approach, we specifically focus on a particular set of goal oriented design representations to support learning (Goodyear, 2005). Design abstractions that represent features of the design for learning thus aim to bring into alignment theory and practice to improve both (for example, Goodyear, de Laat, & Lally, 2006; Sandoval, 2014). These representations aim to share the general principles of a task design and purpose, specifics of a practical implementation, and design configurations targeted at particular outcomes. For example, 'design patterns' are abstractions that help in sharing existing practice in a way that supports its adoption across an array of learning tasks and contexts (Goodyear & Retalis, 2010). Good patterns foster research and adoption by: capturing existing practices that solve existing, complex, problems; abstract at the right level, neither too concrete or specific, or too general and divorced from context; gives insight into how it works, making clear why we should value it as a solution to the problem; links to other patterns in a structured way; and follows a generalized representation: a problem statement, the solution pattern, and a rationale for how the solution addresses the problem (Goodyear et al., 2006).

With a similar aim, conjecture mapping (Sandoval, 2014) involves understanding the ways that learning tasks make conjectures about how the learning should happen; these become testable, improvable, conjectures and designs (Sandoval, 2014).Tasks are thus analyzed for the *design* and *theoretical* conjectures they are based in. In common across conjecture mapping and design patterns is the desire to flag a key, high-level problem being addressed (a learning need). Across both, particular designs then embody or manifest the principles. Thus, a section of a pattern describes empirical background or evidence, and examples of the pattern's manifestations,

while conjecture maps describe a design's embodiment through tools and materials, task structure, participant structures, and discursive practices into mediating processes of observable interactions and participant artefacts; these mediating processes are then mapped to learning outcomes. *Design* conjectures thus describe assumptions about "how embodied elements of the design generate mediating processes," such that, "if learners engage in this activity (task + participant) structure with these tools, through this discursive practice, then this mediating process will emerge" (Sandoval, 2014, p. 22). *Theoretical* conjectures, then, describe "how those mediating processes produce desired outcomes"…in the form "if this mediating process occurs it will lead to…".

In the work described in this paper, we have undertaken a design process to:

1. Understand existing patterns of writing support in a particular institutional context, and develop abstractions of these

2. Augment these abstractions with additional – learning analytics based – abstractions (in this case, patterns) that complement the original designs

3. Evaluate the implementation of these patterns, to understand relations among them and the development of a larger pattern-set that can be augmented with learning analytics (that are described by patterns in their own right)

Empirical case study

In this section, we explain an empirical case study of our approach in the context of a design for writing instruction. The key components of the design are represented in a conjecture map shown in *Figure 1*. The specific sections of the task design which were augmented by analytics are displayed with a 'gear' icon. The elements of the design and the augmentation will be explained in detail below.
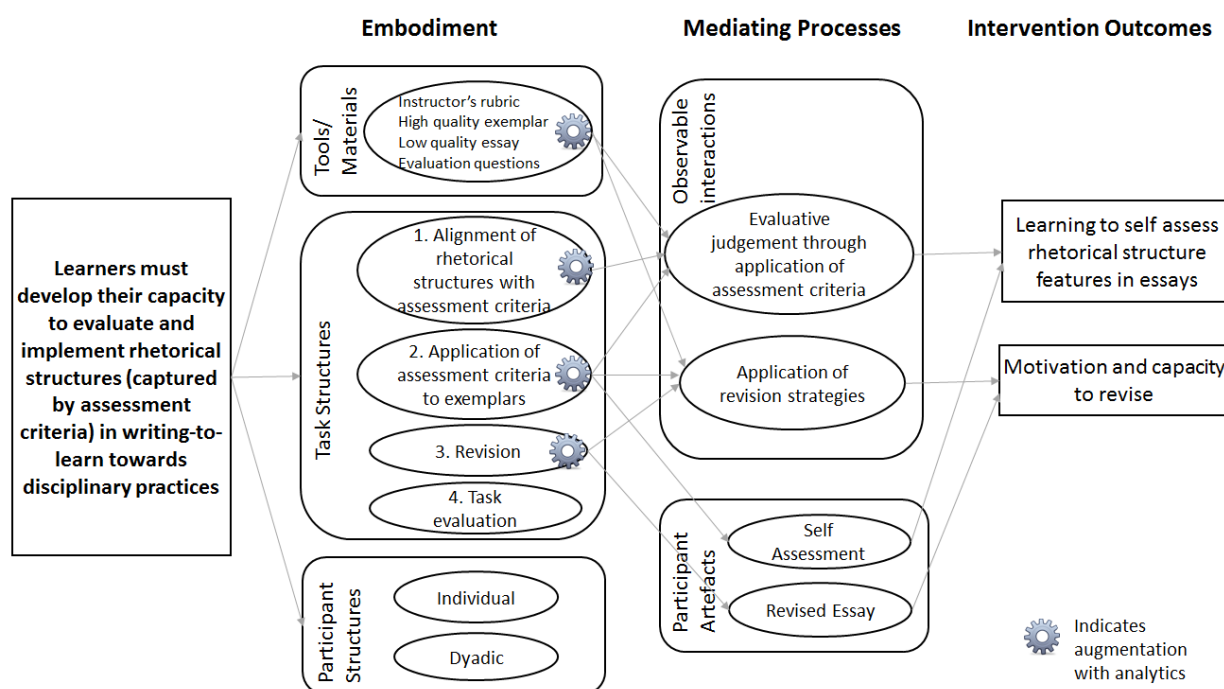
Figure 1. Conjecture map of a learning design for writing instruction, augmented by analytics.

The box on the left conveys the theoretically principled high-level conjecture, specifically, that in order to induct students into disciplinary practice, they must learn to write using the rhetorical structures that make up argumentative forms. This conjecture is then applied through its embodiment within a designed learning environment that uses three main elements: Tools/Materials, Task Structures and Participant Structures. The writing instruction is driven by the materials defined by the instructor (in tools/materials) and tasks described in the task structures, listed in the order that students complete them.

The current design was developed over three design iterations, described below. These iterations introduced changes around the use of analytics (tools/materials), and a dyadic task design (participant structures). Conjecture maps developed for each iteration can help in tracking the trajectory of the research by capturing the rationale behind the changes made to the design over the iterations. A key feature of the conjecture map is that it

separates the logic of the design from the specific instantiations, and provides a clear perspective on pedagogic sites at which learning analytics can *augment* the design towards the conjecture. In this case, a tool called AWA-Tutor (the Academic Writing Analytics Tutor) was developed that guided students through the tasks, and collected data for research, by integrating Writing Analytics in pedagogic contexts (Shibani, 2018; Shibani, Knight, Buckingham Shum, & Ryan, 2017). This tool provides an example case for the use of abstraction to develop research and implementation understanding of a learning context.

Writing analytics tools that make use of computational techniques produce feedback which is almost immediate. One such tool – "Academic Writing Analytics" (AWA) – uses natural language processing techniques, and has been embedded in an AWA-Tutor tool which allows students to submit their drafts and receive immediate feedback to make further revision in their texts. This enables students to assess their revisions based on the feedback and encourage further revisions upon assessment. This immediate feedback, made possible by analytics, can aid reflection and encourage improvement in student revisions on their drafts. While the current design is based on an automated tool which provides feedback on rhetorical structures in the text, the design can also be extended for tools that provide feedback on other text features.

Because the tasks were developed within an online tool, a separate evaluation question was also built into the structures, as indicated in the conjecture map. The artifacts highlighted in this conjecture map include specifically those artefacts about which learning conjectures were made. Since the artifacts from observable student interactions in the tasks could be useful proxies for students' learning, they are of interest to researchers and practitioners. Indeed, the artificial intelligence in education (AIED), learning analytics, and other communities have strong interest in analysis of such data. In the context of our design iterations, this interest is further developed in not only describing how conjectures may be made regarding the trace obtained through use of an online tool designed with pedagogic principles in mind, but also how learning analytics may *augment* these task designs. Here, we describe the final map with reference to its development, describing each design, and its analysis for research and implementation purposes. Drawing on (though not directly using) Alexandrian design pattern principles, here we highlight the core evolution of the tasks, in relation to the conjectures made, including through the use of computer aided augmentation.

DESIGN 1: Benchmarking and Automated Writing Analytics

Problem: We wanted students to engage with exemplars and their assessment, in order that they have an activity that (1) prompts them to critically apply the assessment criteria, (2) prompts them to engage actively with exemplars, (3) provides us as researchers with information regarding their ability to appropriately assess texts.

Task: The initial base task (task 2) consisted of a task in which students were provided with three exemplars of varying quality, and asked to assess those exemplars using the assessment criteria. The application of the assessment criteria involves a mediating process of evaluative judgement in the application of assessment criteria, which in turn should produce the outcome of improved self-assessment ability.

Tools/materials and participant structures: This task was designed for individual completion, making use of the instructor's rubric, and both high and low quality exemplars.

Iterations and Augmentation: The task design was modeled on an existing common practice at the institution. To augment this with writing feedback, in the initial iteration of the task, students were provided with texts that had been marked up using writing feedback (from either a tool for feedback on rhetorical structures in writing, or one focusing on spelling and grammar, or from the instructor). With the intent of foregrounding salient features of the texts through the provision of NLP-derived feedback in the form of

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Analysis (unpublished) of this activity indicated that – as in previous iterations of the task design – the students appreciated access to the exemplars, and criteria. However, there were no clear differences between the ability of students to appropriately apply the criteria in the group with, or without, the automated feedback. In addition, the mode of interaction with both the exemplars (in the original task), and the automated feedback (in the 'augmented' version) is rather shallow. Thus, we sought to develop the task to provide opportunity for deeper interaction.

DESIGN 2: Benchmarking, Text-Revision, and Automated Writing Analytics

Problem: We wanted students to critically consider how specific features in the text instantiate responses to the assessment criteria, and to develop the student's interaction with the application of the criteria for building their understanding of how to – practically – improve a text.

Task: The initial task (task 2) was amended, and an additional task was added (task 1). Task 1 consisted of a task in which the students were asked to match excerpts from a text to the criteria that they addressed (for example, a sentence providing background information aligns with the criterion "Identification of relevant issues", while a sentence providing evaluation or analysis of a claim or piece of evidence aligns with the criterion "Critical analysis, evaluation, original insight". The revised task 2 involved students assessing a single exemplar text using the assessment criteria, and being specifically asked how they would suggest improving the text. In task 3, then, the students were asked to edit the text they were provided with (in an editable window, see *Figure 2*), and (task 4) to evaluate the improvements that they had made (i.e., to provide a new assessment of the quality of the text). Following task 4 the students were provided with their own text revisions, and those of an instructor on the same text, providing a 'good' exemplar to demonstrate the improvements made. While the original task (above) was intended to produce a mediating process of evaluative judgement, the revision task was – in addition – designed to produce a mediating process of revision strategy application, to produce the outcome of increased capacity and motivation to revise, and improved self-assessment ability. The first task was specifically designed to develop evaluative judgement through understanding of the assessment criteria, and thus to improve self-assessment through understanding of rhetorical structures.

Tools/materials and participant structures: As in design 1, this task was designed for individual completion, making use of the instructor's rubric, and in task 2 a lower quality exemplar, with task 4 providing the higher quality comparator. The instructor's rubric and the lower-quality exemplar drive the first and second-to-fourth tasks from the task structures list respectively.

Iterations and Augmentation: This task design developed from that described in design 1. As in that case, a between-subjects design was used to provide some students with instructor-based (static) feedback, others with dynamic feedback from AWA, and others with no feedback. Prior work has been conducted to establish conceptual relations between the instructor's criteria, rhetorical structures, and their specific instantiation in AWA (Knight, Buckingham Shum, Ryan, Sándor, & Wang, 2017). These relationships were foregrounded to the AWA group through static highlights flagging the AWA moves on the sentences to be aligned with the criteria. Then, the revision task was also augmented by AWA, with feedback provided on-request (via a button) to students as they revised the draft they were provided with.

Figure 2. Sample screenshot from the revision task with an editable text (left) and automated feedback (right).

Analysis of this activity (preliminarily reported in, Shibani et al., 2017) indicated that across groups (with and without augmentation) the students generally found the tasks useful, and performed at equivalent levels when their text revisions were assessed. Feedback in places indicated that students would find it helpful to gain multiple perspectives on the texts and their revisions. Indeed, in conducting the work, it was observed that in some groups

students engaged in peer discussion as a part of the process. Moreover, prior research has indicated the benefits of peer discussion of assessment criteria and exemplars (Hendry, Armstrong, & Bromberger, 2012; Hendry & Jukic, 2014; Payne & Brown, 2011). Thus, peer discussion may provide a further mediating process. In addition, it provides a further site for possible augmentation (of the peer discussion), and – in contexts where feedback is provided on the exemplars and revisions – a site to investigate how that feedback is understood and discussed in application.

DESIGN 3: Benchmarking, Text-Revision, Peer-Discussion, and Automated Writing Analytics
Problem: Building on the previous designs, we additionally wanted students to engage with each other around the application of assessment criteria, to further develop their evaluative judgement, and ability to explain and justify their judgements of texts and their revisions.
Task: The initial base tasks in design 2 were adapted, such that in in one group of students they were asked to work as dyads, submitting a single revised text, and in the other group they worked individually.
Tools/materials and participant structures: In this design, the participant structure varied by group, with some working in pairs and others individually. When students work in dyads, they involve in discussion consisting of reflection and critique on the structure of essays and the application of automated feedback. The materials and tool for this design are the same as those in design 2.
Iterations and Augmentation: This task design developed from that described in design 2. A key concern in this design was that peer discussion may mediate the understanding and use of the augmented feedback provided by AWA; that is, this task may develop students' abilities to – critically – use such feedback, and that through observation of this dialogue research and implementation data is obtained. A further alternative design iteration (to be implemented in 2018) consists of asking students to work individually first (with, or without, augmentation), and then to work in dyads (or not) to create a hybrid revised text to submit.

Preliminary analysis of a pilot of this task indicated that across the paired vs individual and AWA vs instructor groups there were no differences in their reported 'usefulness' of the task, or quantity of revisions made (although no analysis of the quality of text revisions has yet been conducted). The instructor has reported a preference for peer discussion in the revision as an authentic practice. Further research is being developed to analyse both the outputs of the paired tasks, and the dialogue that students engage in and how it might mediate the automated feedback received (and vice-versa).

Conclusions and implications

Artificial intelligence and learning analytics hold unmet potential to address learning challenges. One means through which to increase their impact is through the *augmentation* of tasks grounded in practice, supported by research. Design abstractions, such as design patterns and conjecture maps, can support such augmentation. In this paper we have exemplified this approach by using abstractions to (1) understand the existing design of practices to support writing within a particular institutional context; (2) support the augmentation of these existing designs with additional – learning analytics based – design features that complement the original designs; (3) describe and develop the evaluation of the implementation of these patterns, in order to understand relations among the design features. In doing so, we indicate how larger task designs can be developed that augment formative tasks with learning analytics. This approach makes effective use of practitioner strategies for addressing pedagogic problems, thus grounding the use of learning analytics in tasks that are well established, and theoretically grounded. While this paper focuses on one example – writing instruction – the approach described has broad application. The approach described, then, addresses the general concern that innovation must address the needs of existing practice (Ferguson et al., 2014; Zhao et al., 2002), and the specific concern that writing interventions must be "well-founded and designed", "representative of the real world context", and include "a series of studies to refine and test the writing intervention" (Graham & Harris, 2014, p. 96).

By taking this approach, we intend to support existing good practice, develop implementation models for analytics, and provide opportunities for research that are grounded in practice and theory. The technologies developed for this particular task are used not only to engage students in those tasks, but also to gather data regarding student interaction with the tools, and provide opportunity for exploring how students engage with different kinds of (automated) feedback. By developing further design patterns, we can extend this work. For example, further patterns might augment the student text-revision with feedback on the revisions that they make, automate the allocation of peers based on ability or topical interest, or provide feedback to students on how well

they assess texts that they are provided with in the benchmarking. Each of these builds on a practice that can be described in terms of design patterns, each of which could be augmented with learning analytics designs.

In this paper, conjecture maps provide the 'argumentative grammar' that shows the broad design logic. However, these maps omit contextualized features of the designs across contexts, and detailed descriptions of task specifics and their relationships to design conjectures. Design patterns can address this concern by setting out in detail specific elements of a design, in such a way that the pattern may be adapted across contexts. By using these approaches we bridge the gap between research and practice, to represent and share designs in a way that is useful for both audiences.

References

Andrews, R. (2009). *Argumentation in Higher Education: Improving practice through theory and research*. Routledge.

Baker, R. S. (2016). Stupid tutoring systems, intelligent humans. *International Journal of Artificial Intelligence in Education*, *26*(2), 600–614. Retrieved from http://link.springer.com/article/10.1007/s40593-016-0105-0

Bjork, R. A., Dunlosky, J., & Kornell, N. (2013). Self-regulated learning: Beliefs, techniques, and illusions. *Annual Review of Psychology*, *64*, 417–444. Retrieved from http://www.annualreviews.org/doi/abs/10.1146/annurev-psych-113011-143823

Boud, D. (2000). Sustainable assessment: rethinking assessment for the learning society. *Studies in Continuing Education*, *22*(2), 151–167. https://doi.org/10.1080/713695728

Buckingham Shum, S., Knight, S., McNamara, D., Allen, L., K. ., Betik, D., & Crossley, S. (2016). Critical Perspectives on Writing Analytics (pp. 481–483). Presented at the 6th ACM Learning Analytics and Knowledge Conference, Edinburgh, UK: ACM. https://doi.org/10.1145/2883851.2883854

Ericsson, P. F., & Haswell, R. H. (2006). Machine scoring of student essays: Truth and consequences. Utah State University Press.

Ferguson, R., Clow, D., Macfadyen, L., Essa, A., Dawson, S., & Alexander, S. (2014). Setting learning analytics in context: overcoming the barriers to large-scale adoption. In *Proceedings of the Fourth International Conference on Learning Analytics And Knowledge* (pp. 251–253). ACM. Retrieved from http://dl.acm.org/citation.cfm?id=2567592

Ganobcsik-Williams, L. (Ed.). (2006). *Teaching Academic Writing in UK Higher Education*. Basingstoke, UK: Palgrave Macmillan.

Goodyear, P. (2005). Educational design and networked learning: Patterns, pattern languages and design practice. *Australasian Journal of Educational Technology*, *21*(1). Retrieved from http://ascilite.org.au/ajet/submission/index.php/AJET/article/view/1344

Goodyear, P., de Laat, M., & Lally, V. (2006). *Using pattern languages to mediate theory–praxis conversations in design for networked learning*. Taylor & Francis. Retrieved from http://www.tandfonline.com/doi/full/10.1080/09687760600836977

Goodyear, P., & Retalis, S. (2010). Technology-enhanced learning. *Rotterdam: Sense Publishers*. Retrieved from https://www.sensepublishers.com/media/1037-technology-enhanced-learning.pdf

Graham, S., & Harris, K. (2014). Conducting High Quality Writing Intervention Research: Twelve Recommendations. *Journal of Writing Research*, *6*(2), 89–123. https://doi.org/10.17239/jowr-2014.06.02.1

Hendry, G. D., Armstrong, S., & Bromberger, N. (2012). Implementing standards-based assessment effectively: Incorporating discussion of exemplars into classroom teaching. *Assessment & Evaluation in Higher Education*, *37*(2), 149–161. Retrieved from http://www.tandfonline.com/doi/abs/10.1080/02602938.2010.515014

Hendry, G. D., & Jukic, K. (2014). Learning about the Quality of Work That Teachers Expect: Students' Perceptions of Exemplar Marking versus Teacher Explanation. *Journal of University Teaching and Learning Practice*, *11*(2), 5. Retrieved from http://eric.ed.gov/?id=EJ1040741

Knight, S. (Forthcoming). Augmenting Assessment with Learning Analytics. In P. Dawson, D. Boud, & M. Bearman (Eds.), *Re-imagining Assessment in a Digital World*. Springer.

Knight, S., Allen, L. K., Gibson, A., McNamara, D., & Buckingham Shum, S. (2017). Writing analytics Literacy - Bridging from Research to Practice. Presented at the 7th ACM Learning Analytics and Knowledge Conference, Edinburgh, UK: ACM.

Knight, S., Buckingham Shum, S., & Littleton, K. (2014). Epistemology, assessment, pedagogy: where learning meets analytics in the middle space. *Journal of Learning Analytics*, *1*(2), 23–47. http://dx.doi.org/10.18608/jla.2014.12.3

Lea, M. R., & Street, B. V. (1998). Student writing in higher education: An academic literacies approach. *Studies in Higher Education*, *23*(2), 157–172. Retrieved from http://www.tandfonline.com/doi/abs/10.1080/03075079812331380364

Lillis, T., & Turner, J. (2001). Student writing in higher education: contemporary confusion, traditional concerns. *Teaching in Higher Education*, *6*(1), 57–68. Retrieved from http://www.tandfonline.com/doi/abs/10.1080/13562510020029608

Linn, R. L., Baker, E. L., & Dunbar, S. B. (1991). Complex, Performance-Based Assessment: Expectations and Validation Criteria. *Educational Researcher*, *20*(8), 15–21. https://doi.org/10.3102/0013189X020008015

Lockyer, L., Heathcote, E., & Dawson, S. (2013). Informing Pedagogical Action: Aligning Learning Analytics With Learning Design. *American Behavioral Scientist*, 0002764213479367. https://doi.org/10.1177/0002764213479367

National Commission On Writing. (2003). *Report of the National Commission on Writing in America's Schools and Colleges: The Neglected "R," The Need for a Writing Revolution*. College Board. Retrieved from http://www.collegeboard.com/prod_downloads/writingcom/neglectedr.pdf

Norton, L. S. (1990). Essay-writing: what really counts? *Higher Education*, *20*(4), 411–442. Retrieved from http://link.springer.com/article/10.1007/BF00136221

OECD, & Statistics Canada. (2000). Literacy in the Information Age - Final Report of the International Adult Literacy Survey. OECD. Retrieved from http://www.oecd.org/edu/skills-beyond-school/41529765.pdf

Passonneau, R. J., McNamara, D., Muresan, S., & Perin, D. (2017). Preface: Special Issue on Multidisciplinary Approaches to AI and Education for Reading and Writing. *International Journal of Artificial Intelligence in Education*, *27*(4), 665–670. https://doi.org/10.1007/s40593-017-0158-8

Payne, E., & Brown, G. (2011). Communication and practice with examination criteria. Does this influence performance in examinations? *Assessment & Evaluation in Higher Education*, *36*(6), 619–626. Retrieved from http://www.tandfonline.com/doi/abs/10.1080/02602931003632373

Sandoval, W. (2014). Conjecture Mapping: An Approach to Systematic Educational Design Research. *Journal of the Learning Sciences*, *23*(1), 18–36. https://doi.org/10.1080/10508406.2013.778204

Schwartz, D. L., & Arena, D. (2013). *Measuring what matters most: Choice-based assessments for the digital age*. Boston Massachusetts: MIT Press.

Shermis, M. D., & Burstein, J. (2013). *Handbook of Automated Essay Evaluation: Current Applications and New Directions*. Routledge.

Shibani, A. (2018). AWA-Tutor: A Platform to Ground Automated Writing Feedback in Robust Learning Design. In *8th International Learning Analytics and Knowledge Conference*. Sydney, Australia: Society for Learning Analytics Research (SoLAR) Companion Proceedings.

Shibani, A., Knight, S., Buckingham Shum, S., & Ryan, P. (2017). Design and Implementation of a Pedagogic Intervention Using Writing Analytics. In W. Chen, J.-C. Yang, A. F. Mohd Ayub, S. L. Wong, & A. Mitrovic (Eds.), *25th International Conference on Computers in Education* (pp. 306–315). Christchurch, New Zealand: Asia-Pacific Society for Computers in Education.

Wise, A. F. (2014). Designing Pedagogical Interventions to Support Student Use of Learning Analytics. In *Proceedings of the Fourth International Conference on Learning Analytics And Knowledge* (pp. 203–211). New York, NY, USA: ACM. https://doi.org/10.1145/2567574.2567588

Zhang, F., Hwa, R., Litman, D., & Hashemi, H. B. (2016). Argrewrite: A web-based revision assistant for argumentative writings. In *Proceedings of the 2016 Conference of the North American Chapter of the Association for Computational Linguistics: Demonstrations* (pp. 37–41). San Diego, California: Association for Computational Linguistics. Retrieved from http://www.aclweb.org/anthology/N16-3008

Zhao, Y., Pugh, K., Sheldon, S., & Byers, J. L. (2002). Conditions for classroom technology innovations. *Teachers College Record*, *104*(3), 482–515. Retrieved from http://crcsalon.pbworks.com/f/Conditions+for+Classroom+Technology+Innovations.pdf

Acknowledgments

Distributed Representation of Misconceptions

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Abstract: Tutoring systems deployed at scale present an opportunity to reinvigorate the study of how misconceptions or partial understanding develops in a wide range of STEM domains by connecting to critical pedagogical theories from the learning sciences by way of a distributed representation of the learner. Using answer sequence data from three Khan Academy exercises, we generate high-dimensional vector representations of incorrect student answers using a model of distributed representation more commonly applied to natural language. After clustering wrong answers in the learned vector space, we use these clusters as the basis for analysis of student misconceptions with a quantitative comparison to manual coding and a deeper qualitative discussion based on a constructivist framework. The result is a demonstration of how big data from conventional tutoring systems can act as a bridge to more critical pedagogies from the learning sciences via a distributed, connectionist model of student concept formation.

Keywords: misconception analysis, distributed representation, big data, tutoring systems

Introduction

The computational cognitive sciences and learning sciences have come from different pedagogical points of view on the framing and intervening on misconceptions (Anderson, 1993; Piaget, 1952; Smith, DiSessa, & Roschelle, 1994). Big data from tutoring systems paired with rich models of representation can serve as a bridge between the two, demonstrating the utility of scale while being more amenable to representing theories from the learning sciences and empirically testing them. In this paper, we present an approach to algorithmically cull together common wrong answers that share a misconception across instances of variablized problems. The intuition is that a misconception, exhibited by a particular answer on a problem, can distinguish itself by the answers given by a student to problems immediately before and after that particular answer. Those adjacent answers may themselves belong to their own misconception groups. This distribution of groups possibly comprises the signature of a misconception. A skip-gram model, which creates vector representations that capture a contextual distribution, is used to position problem instantiations into a vector space in which we find that common wrong answers of the same misconception are clustered together with considerable fidelity. We present an algorithm aided misconception analysis of three fraction arithmetic exercises in Khan Academy (www.khanacademy.org) and provide a discussion of the results and designs for potential future interventions.

The manual process of diagnosing the misconception associated with a common wrong answer is a laborious one and can be made more difficult if several hypotheses exist for how an answer was generated. Adding to the challenge of misconception analysis in tutoring systems is the use of templatized or variablized problems. This variablization, where a single problem template can create hundreds of instances with different numbers filled in, is often used to (1) allow students to continue to practice a particular skill without exhausting the available item pool and (2) reduce the possibility for cheating to occur in certain contexts. The challenge this poses to misconception analysis is that instead of having all students contribute to a single distribution of common wrong answers for a problem, that distribution is split across the hundreds of instantiations of the now variablized problem, potentially negating the benefit of the scale of data afforded by a widely used tutoring platform. Additionally, the differences in the numbers used in each instantiation changes the distribution of common wrong answers, such that the proportion of each misconception is not equal across instances. Having the ability to cluster together common wrong answers of a shared misconception across different instantiations of a problem would address these challenges. Furthermore, it would allow a tutoring platform to adapt instruction to each cluster as opposed to each individual answer. Without this ability, a platform is limited to addressing the misconceptions, and their respective common wrong answers, that teachers and instructional designers can anticipate and proceduralize help for.

Related work

Misconception research has roots in the cognitive development theories of Piaget (1952, 1962), which argue all

persons' continual adaptations to new knowledge can produce "systematic errors". The person may assimilate and accommodate new information that develops a conception sufficient for their current needs yet is inconsistent with more advanced knowledge from the mathematical community. Erlwanger's (1973) case study on a student developing a partially consistent-- yet incorrect-- set of mathematical knowledge highlighted the fact that misconceptions are durable even in the face of repeated negative reinforcement from an individualized and automatic instructional system.

From the disciplinary angle of the computational cognitive sciences, misconceptions have been cast as *buggy rules*, and have been foundational to modern Intelligent Tutoring Systems (Anderson, Corbett, Koedinger, & Pelletier, 1995; Zinn, 2006). In this field buggy rules represent incorrect variations of the correct reasoning processes in the ideal model (Brown & Burton, 1978; Sleeman & Brown, 1982). Previous studies of buggy rules largely revolved around student learning processes in programming (Putnam, Sleeman, Baxter, & Kuspa, 1986; Reiser, Anderson, & Farrell, 1985) and mathematics (Jurkovic, 2001; Milson, Lewis, & Anderson, 1990). In programming problems, a buggy rule may represent various student misconceptions such as semantic confusions between functions (VanLehn, 1990). In a similar fashion, buggy rules have also been studied in mathematical problems (Star, 2005) such as signed subtraction (Tatsuoka, 1985) and basic algebra (Milson et al., 1990).

Tutoring systems assume a set of ideal rules that produce correct and consistent answers, and efforts have been made towards cataloguing collections of buggy rules that could explain incorrect answers. These buggy rules could represent misconceptions that students often have during the learning process (Brown & VanLehn, 1980). This large collection of buggy rules has been referred to as a bug catalogue (Johnson & Soloway, 1984). The bug catalogue enables tutoring systems, such as ASSISTments (Razzaq et al., 2009), to model a student's path through a problem, which enables it to respond to common wrong answers that student may express with their answer. In the spirit of exploring methodologies for improving this catalogue and its association with answers and with skills (Birenbaum, Kelly, & Tatsuoka, 1992) or knowledge components (Barnes, 2005) through the analysis of big data, Liu, Patel & Koedinger (2016) explored how the incorporation of buggy rules could improve model fit to dichotomous response data in an algebra tutor.

Smith, DiSessa, & Roschelle (1994), in contrast, made an explicit call to shift attention away from only cataloguing misconceptions, as education theorists noted conflicts between the learning theory of constructivism and the assumptions of misconceptions as thoughts to be replaced (Sfard & Cobb, 2014). Smith et al. argue that misconceptions should not be seen as knowledge to be confronted and replaced but rather as knowledge to be appreciated and developed in the student. "Persistent misconceptions, if studied in an evenhanded way, can be seen as novices' efforts to extend their existing useful conceptions to instructional contexts in which they turn out to be inadequate." For example, learners may *productively* order integers (125 > 99) in such a way that their strategy produces a correct answer. However, the same strategy may produce an incorrect answer in another setting (1.25 > 9.9), leaving the learner confused about keeping or discarding their conception of ordering. Instead of a *confrontation* between keeping and discarding a conception, Smith et al. (1994) pressed for the importance of *developing* and refining the student's conceptions through reflection and discussion. Teachers have increasingly incorporated misconception-based strategies in their classrooms from the 1980s to present day (Franke et al., 2015; Sfard & Cobb, 2014; Watkins, Hammer, Radoff, Jaber, & Phillips, 2017).

An assessment-driven approach in most tutoring systems have struggled to represent partial understanding to substantial effect (Ostrow, Donnelly, Adjei, & Heffernan, 2015). With the advent of big data and reemergence of the application of connectionist models (Pardos, 2017), progress has been made towards a more relational and structural representation of students' cognitive (Piech et al., 2015) and behavioral (Tang, Peterson, & Pardos, 2017) states during the learning process. Berland, Baker, & Blikstein (2014) allude to a bridge, asserting that assessment has much to gain from interdisciplinary cooperation.

Methodology

Selecting exercises from the Khan Academy dataset

We develop our representation learning approach to misconceptions using anonymized data granted from Khan Academy. Subjects on Khan Academy are broken into groups of *exercises*, each of which contain questions on a specific concept for students to master, loosely analogous to knowledge components (Piech et al., 2015).

Our work involves analysis of three exercises chosen based on the criteria that (1) answers to questions in these exercises could be reliably parsed from the data logs and (2) that the exercises represented topics in which misconceptions had been studied by past learning sciences work. The exercises were, "*Adding and Subtracting Fractions with Unlike Denominators*", "*Understanding Multiplying Fractions with Whole Numbers*", and "*Multiplying Unit Fractions and Whole Numbers*" (see Table 1 for descriptive stats). Within each exercise, instructional designers create several problem templates, dubbed *problem types*. These are questions with generic

parameters that are instantiated based on a random *seed*. Khan Academy randomly selects problems from different problem types and seeds within an exercise to present to students as they interact with the system.

Table 1: Khan Academy Dataset Statistics

-	Adding and Subtracting Fractions with Unlike Denominators	Multiplying Unit Fractions and Whole Numbers	Understanding Multiplying Fractions and Whole Numbers
# Student Answers	103,873	78,369	134,590
# Users	24,411	21,923	36,968
# Problem Types	4	3	5
# Seeds	23	19	18

Skip-gram model

The skip-gram (more popularly known as "word2vec") was initially developed to model language (Mikolov, Sutskever, Chen, Corrado, & Dean, 2013), vectorizing words and learning syntactic and semantic relationships among them automatically from a large corpus of text. In this work, we apply the technique not to textual sequences of words but rather to chronological sequences of student answers, reasoning that regularities in student answer patterns can surface insights about each answer, much like a traditional application of skip-grams to natural language surfaces insights about words and their relationships to one another. A skip-gram is a simple neural network, or "connectionist" model (Hinton, 1990), taking an element in a sequence as an input and predicting which elements occurred adjacent to that element in the sequence (or within a specified context window length). It is similar in topology to a multinomial logistic regression (or softmax regression), but with a single hidden layer (the vector space) serving to featurize the input and outputs. In our case, this input is a wrong answer and we posit that the featurization may encode misconceptions shared among several wrong answer inputs. Ideally, two student wrong answers stemming from the same misconception but different problem seeds would be near to one another in the vector space, similar to how synonymous words cluster together in a word vector space as a result of the similar contexts in which they are used, linguistically.

We represent each answer as the concatenation of the problem type, the randomly generated seed that was used to instantiate the question, and the frequency rank of the student's answer within that seed. For example, a student submits the answer "3/4" to a question seed "ef2" that was instantiated from the problem type "adding." The answer "3/4" is the third most common answer so we encode this within the skip-gram model as the token "adding_ef2_3". We assemble a chronologically ordered sequence of answers submitted to Khan Academy for each unique student represented in each exercise's dataset.

Once a model is trained, we iterate through each student answer as a "main answer" and find its ten nearest neighbors (i.e. the ten most similar answers based on Euclidean distance within the vector space). We sort a list of these groupings by the average distance of the neighbors to the main, then proceed to select the groupings with the smallest distance for subsequent manual analysis. We enforce a certain degree of diversity in the groupings by not passing on any grouping that has greater than 50% overlap with a previously selected grouping. This style of grouping assumes that common misconceptions are clustered near one another, as opposed to manifesting as a common vector offset. The skip-gram model involves several hyperparameters: vector size (dimensionality of the vector space), window size (number of adjacent student answers in a sequence to consider when processing a given student answer), a minimum occurrence count for a token to be included in the model, and the number of training iterations. We chose a vector size of 35, a window size of 5, a minimum occurrence threshold of 25, and 40 training iterations for all our models based on the magnitude of our data and the parameters of a past study whereby a skip-gram was used to associate problems with skills based on the order of items answered (Pardos & Dadu, 2017). We leave the optimization of these hyperparameters to this context for future work.

Manual misconception labeling

After producing vectors for student answers through the skip-gram approach and identifying the ten most similar answers based on Euclidean distance to create an answer grouping, we manually verified the extent to which each of these groupings corresponds to an underlying misconception. Ideally, a single misconception label would explain all of the answers contained in the grouping. Due to the large number of answers, we focused our manual labeling on the ten groupings with the lowest average distance between the original answer and its ten neighbors. Overall, we inspected ten groupings containing 11 student answers each. Hence, we labeled 110 answers per exercise, yielding 330 total answers across the three exercises.

To determine how well each grouping identified by the skip-gram process reflects a misconception shared among its constituent student answers, we manually attribute each student answer to a misconception. Table 2 shows an example of answers assigned to misconceptions. The first row is the *main answer* generating the cluster, and the subsequent ten rows are its ten nearest neighbors in increasing order by Euclidean distance.

Table 2: Answer grouping with its main answer and two nearest neighbors labeled with misconceptions

Generating ("Main") Seed	Student Answer	Seed	Similarity Rank	Misconception Index
xe29d6ce8acbcc688	2	xe29d6ce8acbcc688	0	2
xe29d6ce8acbcc688	3	x0ac68cd06ed51fc6	1	2
…	…	…	…	…
xe29d6ce8acbcc688	2/6	x3f10fca965656d09	10	3

The Main Seed column value shared across all rows represents the answer that the group was based around. The Seed and Student Answer column values differ because they pertain to individual neighboring answers. The explanations for Similarity Rank and Misconception Index column values are outlined in the next section.

Complete the equation.

$$\frac{2}{5} + \frac{2}{5} + \frac{2}{5} + \frac{2}{5} = \boxed{} \times \frac{1}{5}$$

Figure 1. The main seed from Table 2.

In labeling the misconceptions for student answers in Table 2, we access each problem through a Khan Academy problem preview link (https://www.khanacademy.org/ preview/content/items/SEED). Figure 1 shows the table's first problem. Here, the correct answer is 8, but the student's answer was 2. We hypothesize that the student misunderstood the problem as simply multiplying a numeric factor, in this case: 2, to match the unit fraction 2/5 apparent in the problem. We create and add this misconception label to an indexed catalogue and label the student answer as misconception 2. We extend this process to all the neighboring answers within this group, and to all the groupings within an exercise, and lastly to all three exercises we analyzed. We generated separate misconception labels for the three exercises.

Results

We evaluated the degree to which our hypothesis held true; that answers sharing the same misconception would cluster together in a vector space produced by the model. We used homogeneity of answer misconception labels in a cluster as an evaluation metric, as well as agreement between the main answer's label with the most common label of its cluster. If the method successfully clustered answers with shared misconceptions together, then the homogeneity and agreement measures should be high. Our manual labeling process was performed on the ten main answers with the smallest average distances to their own ten nearest neighbors. This was repeated for each of the three exercises for a total of 30 main answers and 300 nearest neighbor answers. Our analysis produced nine misconception labels for "*Adding and Subtracting Fractions with Unlike Denominators*", nine for "*Understanding Multiplying Fractions with Whole Numbers*", and fourteen for "*Multiplying Unit Fractions and Whole Numbers.*"

Figure 2. Proportion of answers with the main answer's misconception vs. average distance of the grouping.

With the 330 answers manually labeled, we calculated metrics for each of the 30 clusters of answers. The most common misconception of a cluster was shared, on average, by 46% of the answers in that cluster. Further, in 63.33% of the clusters, the most common misconception matched the misconception of the main answer. Finally, we found a weak negative correlation (p = -0.35) between the average Euclidean distance of answers in a cluster to their main answer and their misconception agreement. As seen in Figure 2, besides the outlier, there is a weak inverse relationship between the proportion of neighboring answers with the main answer's misconception and the average distance between the main answer and the other answers in the cluster.

Discussion

In this paper, we combine modern machine learning techniques with manual misconception labeling, providing an illustration of how the communities of learning analytics and learning sciences may benefit from combined efforts. While our experiment showed promise in the ability of algorithms to aid manual analysis, we became further interested in how methods like ours may allow conceptions to be studied in a distributed representation framework. In this discussion we give a brief evaluation of this paper's results followed by a deeper analysis of the clusters with potential future applications inspired by ideas from the learning sciences.

Evaluation of results

Though we examined only a small subset of the entire Khan Academy dataset, our analysis of student answers helped identify the most frequent misconceptions and how they differed across exercises, even when two exercises may have had the same mathematical concept behind them. We found that only a handful of misconceptions were present in each exercise – leading us to evaluate quantitatively how the skip-gram clustered student answers associated with these misconceptions. Grouping the skip-gram produced wrong answer vectors by nearest neighbors showed mixed results. Generally, the process did cluster student answers sharing a common misconception within each main student answer cluster. However, the most common misconception in an answer cluster was not necessarily the misconception evidenced in the main answer that the cluster was based on. We did verify that the more similar neighboring-answers were to the main answer (determined by Euclidean distance), the higher proportion of them shared the main answer's misconception. This observation implies that our model did cluster neighboring answers based on common misconceptions, though some may not be due to the exact same manual label. Future research can work to compare clusters with more robust misconception frameworks, and may better test validity by blinding the manual analysis. Overall, the combination of the qualitative manual misconception analysis and the quantitative evaluation of our model showed potential in clustering and identifying student answers based on shared misconceptions.

Ideas from Learning Sciences

Templated exercises aim to enable variety by parameterizing elements of the question, while remaining true to the nature of the problem. However, parameterization can produce different misconceptions across instances. Models like the one in this paper, may support a latent space of intertwined conceptions, with templated (or not) exercises shining light on traces of evidence supporting a larger distributed theory of knowledge. This dovetails with research interests from the learning sciences, providing an opportunity to draw upon teacher knowledge and education theory.

Latent conceptions and productive strategies

The answer groupings given by this model may help reveal latent student misconceptions that are more apparent when viewed across instances of a template. The specific parameters of a problem may prime differing solution strategies. Thus, one instance may conceal a misconception that another instance reveals.

If a student answers ¼ of 8 as "4", (Figure 3b) they may have performed 8-4 (trying a familiar operation), or they may have confused fourths with the more familiar halves, due to the 8/4 interaction with doubling/halving concepts. Our model clustered the response of 4 with the group centered around a different instance of the problem template (Figure 3a). These possible misconceptions may be the type expected by our analysis: a description of a student's mathematical reasoning. However, this main answer and its nearest neighbors inform new hypotheses on the students' thinking:

We offer a new hypothesis that the students are using the pictorial clues. For question (a), "15" is the entire set, for question (c), "2" is the size of the partitions portrayed of 10. In this context, the answer "4" to the question (b) may be giving the number of partitions displayed of "8". The misconception displayed by students giving these answers may be less specific than our labeling process performed in this paper. Instead, the answer grouping generated may represent a more general student solution strategy of picking out properties of a graphical hint as answer candidates. The result is that answers identifying different properties of the image (total, group size, count of groups) are grouped by the skip-gram model. A diagnosis of the single answer ¼ of 8 = "4" (above) could be augmented to consider that 4 represents one instance of a heuristic for this kind of question.

Further research will need to establish the degree to which such algorithmically generated groupings are meaningful; but if they are, tutoring systems may have a new lens on student conceptions. Consider an answer grouping from the *Multiplying Unit Fractions with Whole Numbers* exercise (Figure 4). Most (six) of the group's answers are extremely similar to the main answer (a): each of their inputs is the numerator of the repeated addends. The remaining grouped answers appear different: Figure 4 (b, c) do not match the numerator pattern, Figure 4 (d, e) even come from a different prompt structure in which the correct input is a fraction rather than a whole number. It may be that the later elements of the group are not significantly linked to the main, (a), but if they are linked,
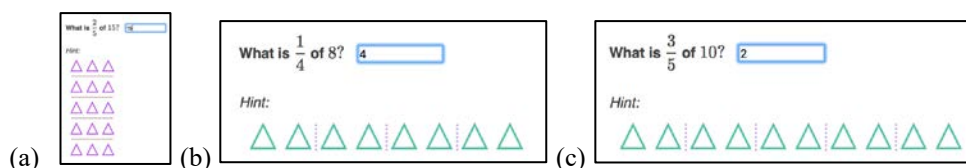
Figure 3. Selected elements (b,c) of the answer grouping around the main answer (a): 2/5 of 15 = 15. Despite the word "hint," these clues are given as part of the problem statement for this Khan Academy exercise.
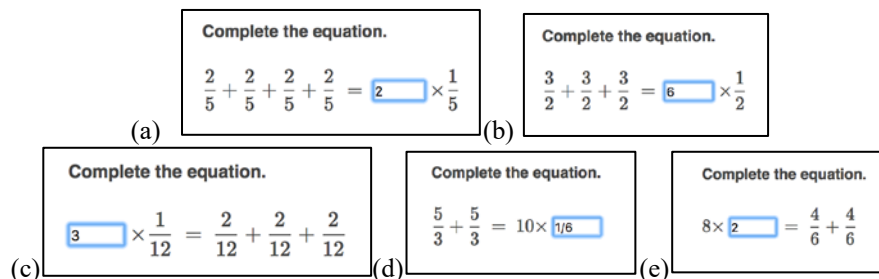
Figure 4. An answer grouping from Multiplying Unit Fractions with Whole Numbers.

we offer a hypothesis that these inputs are the partial results of student thinking, perhaps impatiently entered. In the process of doing each problem a student may arrive at statements such as: (a) $2/5 = \mathbf{2} * 1/5$, (b) $3/2 + 3/2 = 6/2 = \mathbf{6} * 1/2$, (c) $2/12 + 2/12 + 2/12 = \mathbf{3} * 2/12$, (d) $5/3 + 5/3 = 10/6 = 10 * \mathbf{1/6}$, (e) $4/6 + 4/6 = \mathbf{2} * 4/6$. In each case, the student may consider the expression similar enough to the prompt to try to input it. Note, all but statement (d) are true statements, similar but not equivalent to the question being asked. Statement (d) contains a hypothesized false statement from a common error. We note the connection of this analysis to that of Figure 3. Students may have picked out true properties or statements from the given information, and then used that initial idea to input their answer. The search for mathematical misconceptions may be concealed by the student's conceptions of how to succeed in the tutoring system. With online tutoring often given instant feedback, the students may feel they can work quickly and productively via this method, overcoming negative consequences for wrong answers if the strategy produces enough correct answers along the way. Future work may investigate the degree to which mathematical misconceptions are hidden behind the student's mental model of the software and its incentives.

Developing conceptions with positioning

If a system knows more about student thinking, the system is posed to give better feedback. The modern expert teacher carefully interprets representations of student thought to supply that student with challenges appropriate to the student's internal model (Franke et al., 2015). One method involves prompting students to reflect upon their thinking. Another, *positioning*, places a student in a situation set up for them to make productive engagement with their own work or the work of another learner. In Watkins et al. (2017), the teacher encourages student voicing of uncertainty as a mechanism to provide peer feedback to address incomplete understanding in a way that fosters co-construction. Our system of representation of misconceptions could aid in the orchestration of this positioning online, matching students up with peers with complimentary constructions.

We may avoid directly confronting a student's misconception with a "wrong" message. The instant feedback may encourage gaming the system, but more importantly the feedback is imprecise: leaving the student in a difficult position of not knowing which ideas to prune and which to keep. Instead, we may more gently give feedback by leveraging a machine learned similar question-answer to better respond to the student's actual input. In a normal interaction on Khan Academy, the student answering in the way shown in Figure 5(a) would be alerted that their response is wrong as soon as they submitted.

We propose an alternative that delays communicating right/wrong for the student's *own* response. Instead, we position their thinking next to a similar answer, Figure 5(b), pulled as a nearest neighbor from 5(a)'s answer grouping. The system asks the student to find the error in this other student's work. **"Another student answered a question like this but made a mistake. See if you can find the mistake and fix their answer for them."** Upon submitting this answer, the student could be shown their own question-answer again and could be asked if they'd like to keep or change their answer. Upon submitting, the normal right/wrong flow resumes. This intervention may need only happen sparingly and may also act on correct answers. We notice 4/3 is the sum 5/6+1/2 from the first exercise item. This could be naïve adding of the two fractions, or a confusion of balancing the equation. But in either case, 4/3 may indicate a partial understanding, not to be harshly rejected. The student is asked to interpret the answer of a different question, but because this answer is selected via the algorithm it has

a high chance of containing similar thinking. We notice the same procedure 5/2+1/3 yielding the answer 17/6. The goal of the intervention is to direct the student to analyze their own thinking. We note also that this intervention asks a new task of the student (analysis) while staying focused on the same skill.

Figure 5. a student answer (a) and a similar question-answer (b) found via algorithm.

Limitations

The methods utilized to produce our results involved a selection of exercises and a limited focus on answer groupings, both for ease of manual analysis. In addition, the "long tail" of potentially interesting student responses with low frequency were lumped into a miscellaneous category and we did not have the skip-gram model create groupings across problem types both to allow the model to focus on common answers within one problem type. Consequently, we acknowledge that the results were produced in a very controlled setting which may not reflect the entirety of Khan Academy exercises. Finally, the manual analysis was not performed blindly, rather the answers were analyzed after being grouped by the model, thus researcher bias may exist. Despite the limitations we believe we offer a novel prototypical approach to identifying conceptions through a distributed, algorithmic perspective.

Conclusion

In this work, we conducted an analysis of misconceptions among the common wrong answers in three exercises chosen from Khan Academy. Through a novel application of a representation learning model, we observed that answers exhibiting common misconceptions tended to group together in the vector space, combining traces of a common misconception across answers to different numeric instantiations, or templates, of a problem. This paper contributes to theory in the parallels it draws between representation learning and the theories and best practices arrived at in the learning sciences.

There are several steps we can take as future work, starting with an improvement to the accuracy of the model by tuning its various hyper parameters. Next, we can connect to the STEM teaching community to assist in the characterization of student wrong answers and ultimately in the validation of our model representations. Finally, we can deploy pilot online interventions based on peer co-construction of understanding based on inferences about the misconceptions and partial understanding inferred to be held by each student. The learning sciences have had a strong pedagogical voice over the past decades and it is our belief that student models based on distributed representation using big data are an appropriate vehicle to empirically test and scale its impact.

References

Anderson, J. R. (1993) *Rules of the mind*. Psychology Press.

Anderson, J. R., Corbett, A. T., Koedinger, K. R., & Pelletier, R. (1995) Cognitive tutors: lessons learned. *The Journal of the Learning Sciences*, *4*(2), 167–207.

Barnes, T. (2005) The q-matrix method: mining student response data for knowledge. In *American Association for Artificial Intelligence 2005 Educational Data Mining Workshop* (pp. 1–8).

Berland, M., Baker, R. S., & Blikstein, P. (2014) Educational Data Mining and Learning Analytics: Applications to Constructionist Research. *Technology, Knowledge and Learning*, *19*(1–2), 205–220.

Birenbaum, M., Kelly, A. E., & Tatsuoka, K. K. (1992) Diagnosing knowledge states in algebra using the rule space model. *ETS Research Report Series*, *1992*(2).

Brown, J. S., & Burton, R. R. (1978) Diagnostic models for procedural bugs in basic mathematical skills. *Cognitive Science*, *2*(2), 155–192.

Brown, J. S., & VanLehn, K. (1980) Repair theory: a generative theory of bugs in procedural skills. *Cognitive Science*, *4*(4), 379–426.

Erlwanger, S. H. (1973) Benny's conception of rules and answers in IPI mathematics. *Journal of Children's Mathematical Behavior*, *1*(2), 7–26.

Franke, M. L., Turrou, A. C., Webb, N. M., Ing, M., Wong, J., Shin, N., & Fernandez, C. (2015) Student engagement with others' mathematical ideas: the role of teacher invitation and support moves. *The Elementary School Journal*, *116*(1), 126–148. https://doi.org/10.1086/683174

Hinton, G. E. (1990). Connectionist learning procedures. In *Machine Learning, Volume III* (pp. 555-610).

Johnson, W. L., & Soloway, E. (1984) Intention-based diagnosis of programming errors. In *Proceedings of the 5th national conference on artificial intelligence, austin, tx* (pp. 162–168).

Jurkovic, N. (2001) Diagnosing and correcting student's misconceptions in an educational computer algebra system. In *Proceedings of the 2001 international symposium on Symbolic and algebraic computation* (pp. 195–200). ACM.

Liu, R., Patel, R., & Koedinger, K. R. (2016) Modeling common misconceptions in learning process data. In *Proceedings of the Sixth International Conference on Learning Analytics & Knowledge* (pp. 369–377). ACM.

Mikolov, T., Sutskever, I., Chen, K., Corrado, G. S., & Dean, J. (2013) Distributed representations of words and phrases and their compositionality. In *Advances in neural information processing systems* (pp. 3111–3119).

Milson, R., Lewis, M. W., & Anderson, J. R. (1990) The teacher's apprentice project: building an algebra tutor. *Artificial Intelligence and the Future of Testing*, 53–71.

Ostrow, K., Donnelly, C., Adjei, S., & Heffernan, N. (2015) Improving student modeling through partial credit and problem difficulty. In *Proceedings of the Second (2015) ACM Conference on Learning@ Scale* (pp. 11–20). ACM.

Pardos, Z. A. (2017) Big data in education and the models that love them. *Current Opinion in Behavioral Sciences*, *18*, 107–113.

Pardos, Z. A. & Dadu, A. (2017) Imputing KCs with Representations of Problem Content and Context. In *Proceedings of the 25th Conference on User Modeling, Adaptation and Personalization* (UMAP). Bratislava, Slovakia. ACM. Pages 148-155.

Piaget, J. (1952) *The child's concept of number*. New York.

Piaget, J. (1962) Commentary on Vygotsky's criticisms of Language and thought of the child and judgment and reasoning in the child. *Lev Vygotsky, Critical Assessments*, *1*, 241–260.

Piech, C., Bassen, J., Huang, J., Ganguli, S., Sahami, M., Guibas, L. J., & Sohl-Dickstein, J. (2015) Deep knowledge tracing. In *Advances in Neural Information Processing Systems* (pp. 505–513).

Putnam, R. T., Sleeman, D., Baxter, J. A., & Kuspa, L. K. (1986).A summary of misconceptions of high school Basic programmers. *Journal of Educational Computing Research*, *2*(4), 459–472.

Razzaq, L., Patvarczki, J., Almeida, S. F., Vartak, M., Feng, M., Heffernan, N. T., & Koedinger, K. R. (2009) The ASSISTment Builder: supporting the life cycle of tutoring system content creation. *IEEE Transactions on Learning Technologies*, *2*(2), 157–166.

Reiser, B. J., Anderson, J. R., & Farrell, R. G. (1985) Dynamic student modelling in an intelligent tutor for LISP programming. In *IJCAI* (Vol. 85, pp. 8–14).

Sfard, A., & Cobb, P. (2014) Research in mathematics education: what can it teach us about human learning. *The Cambridge Handbook of the Learning Sciences*, 545–63.

Sleeman, D., & Brown, J. S. (1982) *Intelligent tutoring systems*. London: Academic Press.

Smith, J. P., DiSessa, A. A., & Roschelle, J. (1994) Misconceptions reconceived: a constructivist analysis of knowledge in transition. *The Journal of the Learning Sciences*, *3*(2), 115–163.

Star, J. R. (2005) Reconceptualizing procedural knowledge. *Journal for Research in Mathematics Education*, 404–411.

Tang, S., Peterson, J., & Pardos, Z. (2017) Predictive modelling of student behaviour using granular large-scale action data. *The Handbook of Learning Analytics*, 223–233.

Tatsuoka, K. K. (1985) A probabilistic model for diagnosing misconceptions by the pattern classification approach. *Journal of Educational Statistics*, *10*(1), 55–73.

VanLehn, K. (1990) *Mind bugs: The origins of procedural misconceptions*. MIT press.

Watkins, J., Hammer, D., Radoff, J., Jaber, L. Z., & Phillips, A. M. (2017). Positioning as not-understanding: The value of showing uncertainty for engaging in science. *Journal of Research in Science Teaching*, n/a-n/a.

Zinn, C. (2006) Supporting tutorial feedback to student help requests and errors in symbolic differentiation. In *Intelligent Tutoring Systems* (pp. 349–359). Springer.

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Envisioning a Learning Analytics for the Learning Sciences

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Abstract: There is both great excitement and substantial concern within the learning sciences about what educational data science and learning analytics (EDS/LA) have to offer our understanding of learning and ability to support it. This paper lays out three concerns often raised about the use of EDS/LA approaches in learning sciences work: reliance on algorithmic processing over human insight, attention to generalized structures over contextualized processes, and emphasis on empirical findings over theory building. Through an overview of work conducted on the MOOCeology project it then shows specific ways that such concerns can be meaningfully addressed. The paper concludes by elucidating a set of seven initial principles for "learning sciences aware" EDS/LA work and opening the question of to what extent these principles might be appropriate to guide EDS/LA work more broadly.

Introduction

There is both great excitement and substantial concern within the learning sciences (LS) about what educational data science and learning analytics (EDS/LA) methods have to offer our understanding of learning and ability to support it (Wise & Schwarz, 2017). On the enthusiastic front, proponents see these new techniques as offering powerful ways to find patterns in and made sense of the large amounts of data that technological learning environments (and technological data captured in physical learning environments) can now produce. From a more cautious perspective, doubts have been raised about the appropriateness and ultimate usefulness of these methods for generating deep insight into the complex cognitive and interpersonal processes of learning. While there are important issues raised on both sides of this debate, the simplistic discourse of "should we or shouldn't we (embrace EDS/LA as part of the methodological repertoire of LS)" misses the point and distracts us from the real conversation we should be having. Certainly there is research within EDS/LA that may be at odds with some of the core tenets of LS (for example learning theory plays a central role in LS research while it may or may not be central to an EDS/LA study; there are also questions of how theory is mobilized see Wise & Shaffer, 2015). But to declare EDS/LA approaches as fundamentally incompatible with the learning sciences unwisely ignores the exciting new avenues to understanding learning it offers (for example extending manual content analysis to examine learning processes across many more contexts than is currently possible, generating in-the-moment feedback tailored to the learning activities of individuals and small groups), and closes any conversation of how it could thoughtfully be put to use. In other words, the discussion that needs to occur is not one of *if* EDS/LA approaches are appropriate for LS, but *how* we can develop such approaches, as well as norms and practices surrounding their use, in ways that can make valuable contributions to the field.

This paper takes a first step in that direction by laying out three concerns often raised about the use of EDS/LA approaches in LS work. In doing so, it is important to note that EDS/LA is still very much an emerging area. Thus, to the extent that these concerns represent critiques of the actual body of current work (as opposed to worries of a more abstract nature), it does not imply that such characteristics are unchangeable. To the contrary, EDS/LA are undergoing rapid processes of development and maturation which LS can help inform. With this in mind, the paper then shows, through an overview of one particular research project, ways that such concerns can be meaningfully addressed through specific decisions about how the work is conducted. The paper concludes by elucidating a set of seven initial principles for "learning sciences aware" EDS/LA work and opening the question of to what extent these principles might be appropriate to guide EDS/LA work more broadly.

Concerns for the learning sciences in embracing learning analytics

Concern I: Reliance on algorithmic processing over human insight

A core concern for LS in the adoption of EDS/LA approaches relates to the relative balance of the roles of human and machine in the generation of knowledge; specifically that computational processing will supersede the role of human intellect (Wise & Schwarz, 2017). This concern can be elaborated at two levels. From a basic perspective, the application of EDS/LA relies greatly on the computer's ability to apply sophisticated algorithms to relatively large quantities of data; thus the bulk of the responsibility for knowledge generation falls to the computer. The counterargument to this points to the many important decisions made by humans about which overall class of computational methods to apply, which specific algorithm(s) to use, what features to include,

and how to set the hyperparameters of the model. While advances in "deep learning" techniques can shift responsibility for some of these decision to computers (e.g. the multiple layers used in neural networks can build up features based on patterns that occur in the data rather than having them determined a priori), there are still numerous other judgments to be made. For example, there are important choices about the architecture of the network with respect to the size and number of layers included, the way the initial data inputs are represented, and even the appropriateness of adopting a neural network in the first place. It is important to be transparent about such decisions both to support algorithmic accountability (Buckingham Shum, 2016) and to acknowledge the role of human input in the modeling process. A key point here is that there are many different ways that humans and machines can "collaborate" in EDS/LA. For example, human judgement may be more efficiently used to verify or correct machine-generated coding than to manually apply codes to data from scratch (Cui, Jin, & Wise, 2017). A similar notion underlies work on open learner models that allows students to not only inspect the model but also edit or negotiate it with the system (Bull & Kay, 2016). It is also important to remember that computational outputs do not themselves represent a contribution to knowledge; human intellect is required to make sense of analytic results in light of the existing knowledge base. Thus, computational approaches to studying learning processes can be thought of as providing new kinds of support for generating human understanding rather than attempting to replace or automate it. Similarly, humans and computers offer different capabilities to provide support for learning based on EDS/LA; thus we should replace the false question of which support is better overall with exciting questions about how responsive scaffolding should be distributed across humans and computers over time. The second level of elaboration of the computational critique of EDS/LA acknowledges the role of humans in setting up analyses, but suggests that such high-level methodological decisions play a fundamentally different role in knowledge-generation than when the researchers themselves are the instruments through which meaning is extracted from data. This latter concern is connected to larger questions about valued knowledge claims and how they are best generated.

Concern II: Attention to generalized structures over contextualized processes

Another concern for LS in incorporating EDS/LA approaches emanates from existing tensions between quantitative and qualitative methodologies and their associated sets of epistemological assumptions. Stated (over)simply, quantitative approaches are often concerned with identifying generalizable regularities in learning while qualitative approaches tend to focus on understanding the particularities tied to specific contexts. While there is a place for well-conceived quantitative work as one of many sources of useful knowledge contributions within LS, the concern is that computational approaches exacerbate existing concerns about work that focuses on structural relations over nuanced processes, and on generalizability over contextualization. However, there are important differences to note between EDS/LA and traditional quantitative methodologies. First, as a field, EDS/LA is explicitly devoted to the study of learning processes. While these processes may be indexed and studied in a quantitative way, the importance of probing mechanisms for learning is built in to the core of the field. The unwillingness to accept black-box relations between treatments and outcomes as a satisfactory account of learning thus represents an area of commonality between LS and EDS/LA that is not always present in all quantitatively oriented work. Second, EDS/LA offers tools for pattern recognition that can be applied to look across large quantities of data collected from many different contexts. This offers the potential for insight into regularities with much greater actual support for generalizability than statistical inference based on data from just a handful of classrooms. Third, EDS/LA is also concerned with building models based on fine-grained patterns of data within individuals to develop personalized insights for students or subpopulations of students. This is quite a different enterprise than aiming to develop generalized knowledge, and one which presents better potential for alignment with LS, especially when such models are used to help students self-regulate their learning (for an elaborated critique of the problems with RCTs and how EDS/LA can help see Winne, 2017). Finally, computational approaches are often less pre-constrained in examining variables and the relationships between them compared with traditional statistical methods in which these must be hypothesized in advance.

Concern III: Emphasis on empirical findings over theory building

A final concern that has been raised about the use of EDS/LA approaches in LS is an outstated focus solely on documenting empirical patterns without sufficient attention to simultaneously developing and testing theories that can explain and cohere patterns seen in the data (Wise & Schwarz, 2017). This is a valid critique of some early work in the field; however other efforts, particularly those focused on developing intelligent agents, have worked closely with theory, developing conceptual models of learning and interactional processes which are then made computational (e.g. Zhao, Papangelis, & Cassell, 2014). Such use of computational models to instantiate, test, and refine theoretical models offers a powerful tool for the process of theory building. Currently, the importance of and need for increased attention to theory is well-acknowledged among many EDS/LA

researchers (Wise & Shaffer, 2015), and it has also been noted that the introduction of new analytic methods can create new needs for theorization (for example, with regards to temporality, see Knight, Wise, & Chen, 2017). However, efforts are still required to develop the expertise and processes to do so. This actually represents an opportunity for LS to bring its long history of theorizing learning processes and multidisciplinary scholarly collaboration to bear productively in conversation with EDS/LA researchers.

Addressing the concerns: Examples from the MOOCeology project

The prior section laid out three of the key concerns for the learning sciences related to the adoption of EDS/LA approaches and demonstrated that they relate to characteristics that are neither inherent nor intractable. This section concretizes the argument by detailing the specific ways these concerns were addressed in the course of our work over the last three years on the MOOCeology project. This serves as an intermediary step towards generating a set of principles for conducting "learning sciences aware" EDS/LA work. The project originated from the premise that while *all* interactions in large-scale open online learning environments do not necessarily represent rich collaborative learning, that does not mean that *no* such learning takes place. Furthermore, we had a hypothesis that a lack of attention to differentiating among such interactions might explain some of the divergence found in the literature as to the roles and importance of discussion forums to MOOC learning.

Part 1: Seeking to differentiate "content-related" and "non-content" interactions

Research need: Identify learning-related interactions in large-scale discussion forums

Massive Open Online Courses (MOOCs) provide accessible learning opportunities, attract learners with diverse backgrounds and perspectives, and have the potential to support learning across the globe (Dillahunt, Wang, & Teasley, 2014). Discussion forums in MOOCs are important venues for interpersonal interactions, generally populated with numerous potential learning partners, but often flooded with a variety of topics not directly related to learning (Stump, DeBoer, Whittinghill, & Breslow, 2013). This creates a problem of practice (it is hard for forum participants to find learning opportunities and support) and a problem of research (analyses of very different kinds of interactions that play different roles in learning are considered together).

Prior to computation: Conceptualizing the role of MOOC discussions in learning

Discussion forums can play a variety of roles in the learning process, being designed as sites for collaborative knowledge building, community development, or a place to ask questions and seek answers. In the majority of MOOCs, discussion forums are offered as a supplemental form of support, with use for learning not prescribed. Based on this aspect of MOOC pedagogy, we chose to define "learning-related" very broadly as any discussions that relate to the course content. This included seeking/providing help, information, or resources on the course topic, whether specifically about content mentioned in the course materials or not. The remainder of discussions were considered "non-content" and tended to include technical / logistical issues or socializing (though they might serve other purposes). A second important decision was to categorize discussions at the level of the thread, rather than individual post. As MOOC discussions happen in threaded conversations, categorizing them at this level allowed us to understand interactions in the intact conversation context.

Computation: Building a supervised model using NLP to extend human content-analysis

Prior research has shown that even when MOOC discussions are designed to be segregated by topic, substantial cross-posting occurs, making this a poor indicator of discussion content (Rossi & Gnawali, 2014). A more accurate approach is to assess the content of discussion posts directly; however manual content analysis is extremely time-consuming given the quantity of posting in MOOCs. This creates an exciting research agenda and interesting questions around the extent to which computational models can be created to scale-up the work of human judgement, based on linguistic features of the posts. This study (Wise, Cui, Jin, & Vytasek, 2017) investigated these issues by first looking at whether starting posts of content-related threads in a statistics MOOC discussion (manually identified by humans with $\alpha >= .75$ reliability) had linguistic features that distinguished them from those starting non-content threads. (Starting posts set the frame for a discussion and thus are a reasonable first approximation of thread topic; the DIPTiC approach including reply posts was later developed to make a more refined characterization of thread topic [see Part 1 coda]). Once linguistic features distinguishing content and non-content starters were identified, we then asked if they could be used to create a model that reliably classified the content-related ones. Results showed that a binary L2 regularized logistic regression classification model based on unigrams and bigrams from the discussion posts showed good results on the original statistics course as evaluated by ten-fold cross-validation (accuracy = .80, kappa = .61, recall and precision both = .79). Generalizability was good to another offering of the same course and a different MOOC

on the same topic (statistics), with negligible differences in accuracy. Exploring generalizability to two courses on progressively more distal topics (psychology and physiology) showed expected decreases in accuracy.

<u>After computation: Unpacking the model to understand its relevance to different contexts</u>
Following model creation and testing, we unpacked key linguistic features used to make the predictions to better understand the ways in which learners were starting content-related threads across the different courses. The top 30 features (ranked by kappa) from content and non-content starting posts in the five courses were extracted. Researchers then went back to the actual discussion text to examine how these features (words and pair of words) were used in context. This was important because the same word could have different meanings in different contexts of use that would not be detected by the model (e.g. "I have a *question* about transforming data" versus "Is the answer to *question* 2 choice B?"). Based on this examination, the features were organized into categories of word types. Top features of content-related starting posts were primarily terms related to the process of learning (e.g. understand), question words (e.g. why or what), and terms that connected ideas (e.g. but). In contrast, top features of non-content starting posts were terms related to the course tasks and platform (e.g. videos), effort / action (e.g. do), appreciation (e.g. great), and first person singular pronouns (e.g. my). Words related to the course domain (e.g. probability) were also present, but notably (and unexpectedly) these represented less than 20% of the top features across both classes. While somewhat counterintuitive (c.f. Rossi & Gnawali, 2014), given the diversity of specific course topics, this suggests that it is the language that surrounds the varied particular domain-specific words (e.g. interrogatives, learning process words, connectors) used again and again that are most important for identification. This finding can contribute to theories of learning through discussion by directing attention to how questions are asked as an important element leading to the discussion that results (i.e. a question on the same topic asked slightly differently might elicit vastly different replies, e.g. "Is the answer I should put 'scale the data'?" versus "How will scaling the data fix the distribution"). This focus on question form also helps make sense of the model's generalizability, not in terms of topic specific vocabulary, but in the discourse practices of a discipline and the pedagogical approach of the course (the physiology course differed from the others in connecting its topics to learners' daily lives, leading to more personal conversations).

Part 1 coda: Better differentiation via hybrid human-machine categorization

As a follow-up to the first study, we sought to examine whether we could combine the contributions of nuanced human insight and algorithmic processing power to increase the accuracy of categorization. In this work (Cui et al., 2017) we labeled discussion threads twice: once based on the content/non-content classification of their starting post via the model described in Part 1 and once based on a threshold proportion of content/non-content replies (application of the model to reply posts was first validated with accuracy = .85, kappa = .68). We could then automatically compare the two results, accepting the categorizations when they converged and using human judgment to resolve discrepancies. Compared to starter-only thread categorization, this method improved classification performance (estimated accuracy = .88 [vs .81 for starter-only]; estimated kappa = .76 [vs .62 for starter-only]) with the addition of 16 person-hours (using two humans to examine discrepancies). We refer to this process as Dynamic Interrelated Post and Thread Categorization (DIPTiC) and see it as one powerful way to position human and computer contributions to analysis in support of one and other, rather than in competition.

Part 2: Examining learning interactional processes in MOOCS

<u>Research need: Deepen understanding of interaction in MOOC discussion forums</u>
Understanding interactions in MOOC discussion forums can be challenging given the scale of activities and diversity of participation patterns. SNA can be useful for this purpose due to its strengths in identifying interaction patterns from complex activities (Scott & Carrington, 2011), but it alone may not be sufficient when understanding learning in discussion is the primary goal. As MOOC forum interactions consist of both content and non-content discussions, this raises the question of whether it is necessary to differentiate social relationships formed in different types of discussions. The literature indicates good reasons for doing so. First, academically-related and unrelated social interactions were found to impact college retention differently (Kuh, 2002). It is possible that social relationships develop in distinct patterns when the content and contexts of interactions differ. Second, MOOC learners engage with the courses in distinct patterns associated with different motivations (Kizilcec, Piech, & Schneider, 2013). It is possible that learners with interest in learning the course content and those who participate for social experiences take part in different types of discussions, and thus develop social relationships with distinct groups of people. These considerations substantiate the quest to understand social interactions and relationships in context, and the need to address this quest using SNA and content analysis methods in combination.

Prior to computation: What counts as "interaction" and "relationship"? How to operationalize them?

Constructing social networks involves critical conceptual and operational decisions. For instance, the stance on what activities (posting, reading, or both) reflect / associate with learning determines what tie definition is appropriate for network construction. Specifically, reply-based tie definitions (e.g. Direct Reply) construct networks for posting and are based strictly on the reply relationship between discussion contributors; copresence-based definitions (e.g. Total Copresence) construct networks for both posting and reading, and are based on coparticipation relationship among learners. Different tie definitions (even from the same category) can produce dramatically different social networks and substantially influence how the observed patterns should be interpreted (Wise, Cui, & Jin, 2017). These decisions need to be made by human researchers with careful consideration and in-depth understanding of many factors, such as the nature of learning being examined, the learning context, and the characteristics of the chosen tie definition.

Computation: What can we learn about social relationships through social properties at network, community, and individual levels?

Based on the characterization of content and non-content discussion threads, we can investigate the social relationships in these two types of interactions through examining the structural characteristics of the social networks. The study was conducted on discussion forums in a statistics MOOC. The forums were provided for optional interactions. Two instructors and 565 learners participated in the forums. The discussions were categorized using the methods introduced in Part 1 and social networks were constructed separately for the content and non-content discussions. As reading constitutes a substantial proportion of learning activities in online discussion (Wise, Speer, Marbouti, & Hsiao, 2013), social networks were constructed using the Limited Copresence definition, which constructs ties based on either thread coparticipation (for threads with a smaller number of replies) or subthread coparticipation (for bigger threads, see Wise, Cui, & Jin, 2017). Content and non-content social networks were found to have distinct characteristics at network, community (detected using the Louvain method), and individual levels. For instance, comparison of structural network properties (average node degree and average edge weight) showed learners interacted with more people and had more repeated interactions with the same people in content discussions than in non-content discussions. Moreover, the two networks were participated by substantially distinct people, with only 28% of all forum participants contributed to both kinds of threads; for learners who contributed to both content and non-content threads, those who were highly connected in one network were not necessarily highly connected in the other. Furthermore, examination of the major communities (containing > 5% of the network populations) from the two networks yielded two additional findings that expanded our understanding of forum interactions. First, a learner-only community in the content network had a web structure with a distributed core consisting of multiple central learners connected via strong ties, which was dramatically distinct from the wheel or elongated structures in other communities; the community members interacted with substantially more people and had more repeated interactions with the same people. Second, in the content network, learners in the community around one instructor showed stronger ties with a greater number of peers than those around the other instructor.

After computation: Probe where the computation flags to get in-depth understanding of interaction

Comparing structural properties of content and non-content social networks led to improved understanding of interaction and relationship patterns in the two types of discussions. These results also flagged areas that worth to investigate in ways that humans can do better than machines. We conducted inductive analysis on threads contributing to major communities in the two networks following the constant comparative method (Auerbach & Silverstein, 2003), to identify emergent themes and patterns through probing the characteristics, similarities and differences between interactions in the communities. It was found that interactions in the content and non-content networks involved different communication purposes. Non-content interactions often involved straightforward factual information exchanges and did not evolve into extended conversation; content interactions commonly involved problem-solving or understanding complicated concepts, which required multiple rounds of back-and-forth comments to resolve. In the content interactions, it was common for participants to use diverse interaction techniques such as paraphrasing, giving examples, and asking leading questions and follow-up questions. Moreover, conversation structures in content and non-content communities showed differences. Content conversations often developed into complicated structures, such as multiple subtopics and new topics extended from the original one. In contrast, non-content conversations usually had relatively simple and linear structures. These qualitative findings in return provided insights for the differences in structural properties. For instance, it is possible that learners developed bonds with the same peers through multiple rounds of exchanges in the same content conversations, which encouraged more subsequent interactions and resulted in higher edge weight.

The qualitative examination of threads contributing to the learner-only community and the two instructor communities in the content network also yielded useful findings. The learner-only community showed unique nascent community-like characteristics. For instance, some members in this community called on peers to have group discussions and expressed the desire for study partners; they used many social presence indicators when interacting with each other; they valued the collaborative discussions and felt they learned from them; some members who received help often revisited the conversation to help answer others' questions. Examination of the two instructors' contributions revealed contrasting facilitation patterns and styles. One instructors not only revisited the threads that he/she had participated in, but also commented on other learners' replies to learner-initiated threads. This instructor often tried to encourage and help learners to work out the answer or solution themselves, using hints and leading questions. He / she also used a variety of social presence indicators such as greetings and addressing learners by name in his/her messages. In contrast, the other instructor only replied to the thread starting posts. He / she tended to provide straightforward answers or instructions to address learners' questions and used social presence cues infrequently. These qualitative findings may help explain the social network properties (such as node degree and edge weight) for these communities.

Part 3: Untangling the relationship between interaction and learning in MOOCs

Research need: Unpack the relationship between learning and forum interaction in MOOCs

Understanding the connections between discussion forum engagement and learning outcomes can have multifold implications. Theoretically, it can provide a foundation to better investigate and articulate the mechanism(s) by which interaction in forum discussion contributes to and/or reflects learning. Practically, such understanding can inform the facilitation of forum activities to maximize the intended type of learning. It might additionally provide grounds for the inclusion of MOOC forum activity as an integral (rather than supplemental) element of pedagogical design.

Prior to computation: Conceptualizing and operationalizing learning and interaction

When investigating the relationship between learning and interaction in forum discussions, we need to first define the two. Learning is maybe most straightforwardly and frequently measured by course performance, although the specific performance measures used can vary course by course (e.g. pass / fail, normal / extinction, grades). There are two issues that credit special attention. First, in addition to reflecting difference in the kind of learning outcomes being measured, performance measures may associate with some latent factors (e.g. orientations, commitment) that impact the outcomes and interaction, and should be taken into consideration when interpreting the observed relationships between the two. For instance, a learner who participated actively in the discussions may fail to pass a MOOC due to the lack of interest in obtaining a certificate, rather than having learning difficulties. Second, before entering performance variables into computation models, researchers may want to know how the performance assessment was operationalized in the specific learning context, such as whether multiple submissions for quizzes were allowed, whether more weight was given to formative assignments or summative exams, or whether the assessment was conducted through "quantitative" automated grading or more "qualitative" approaches, such as peer reviewed projects or writing assignments. These variances can have important implications for interpreting the observed relationships between learning and interaction. In this regard, CSCL theories on learning assessment can provide valuable insights. Compared to learning outcomes, defining interaction in MOOC discussions can be even more complicated. Researchers need to make two primary decisions: what interaction to measure and how to measure it. First, what to measure is a non-trivial decision that reflects fundamental assumptions about what contributes to / reflects learning. For instance, variables can be constructed for activities such as posting, editing, reading, voting, and following threads. Second, how a certain form of interaction is measured is a critical decision. For instance, forum contributions can be measured for quantity (Gillani & Eynon, 2014), acceptance by peers (Coetzee, Fox, Hearst, & Hartmann, 2014), cognitive engagement characteristics (Wang, Yang, Wen, Koedinger, & Rosé, 2015), and relatedness to course content (as we did in this project). Thoughtful decisions on these fronts can help yield findings that both explain what contributes to learning and are actionable for supporting learning and teaching.

Computation: Does content/non-content discussion involvement relate differently to performance?

In the MOOCeology project, we approached this topic by examining the connections between forum interaction (measured by quantity of forum contributions and several social centrality properties, both differentiated based on content relatedness) and course performance (measured by final grade and pass /fail) [Wise & Cui, 2018]. The purpose was two-fold. One was to investigate whether or not the quantity of content and non-content interaction differs in explanatory power for course performance; the other was to investigate whether or not

social centrality properties add to the explanatory power on top of interaction quantity. The study was conducted on the same statistics MOOC examined in Part 2. It was found that for relatively committed learners (who gained more than 1% for final grade), those who contributed to the discussion forum had a significantly higher rate of successfully passing the course than non-contributors (64% vs 32% passing); learners who made posts to both types of threads had a higher passing rate than those who only contributed to content or non-content threads (77% vs 60% / 57% passing). Among learners who successfully passed the course, there were no differences in course grade when comparing discussion contributors and non-contributors overall; however those who contributed to content-related threads performed slightly better than those who did not (course grade of 87% vs 85%). A regression model based on the number of posts made to content-related threads explained 3% of variance in course grades. Addition of other interaction quantity measures (including number of threads contributed to, total number of posts and non-content posts) did not add to the model's explanatory power significantly; neither did addition of any social centrality measures (including degree, weighted degree, closeness, betweenness, and eigencentrality in the content and non-content networks).

<u>After computation: A need to reconsider the definition of "learning" in MOOC discussions</u>
It is notable that this research did not document a strong relationship between MOOC discussion interaction and course performance. This can be explained in several ways. It is possible that the discussion forums were not helpful for improving course performance (as they were not pedagogically integrated into the course but a supplementary venue for optional participation). It is also possible that the discussions were helpful for course performance, but the variables we used were not well tuned to capture the relationship. This is a plausible explanation because we only measured the quantity of learner's forum contributions differentiated based on content-relatedness (in contrast to more nuanced differences, such as quality and questions / answers); and we did not take reading into consideration. However, on top of these two explanations, a third possibility that looks beyond what was in the model should be noted: certain type of learning did happen, but course performance is not the right proxy for it. For instance, Nelimarkka and Vihavainen (2015) found that some alumni learners participate in the same MOOCs repeatedly; instead of pursuing a high grade, their interest may involve networking and assisting others. Their developing expertise and identity in the domain can be considered as a form of learning, but not one captured by course performance. This interpretation of the lack of strong relationship between forum interaction and course performance presents a need to reconsider the definition of learning in MOOC discussions as well as to differentiate short term performance and long term learning.

Conclusions

The description above illustrates the ways that our work on the MOOCeology project has taken seriously the three concerns outlined at the start of this paper. We addressed the relative balance of responsibility accorded to computational processes and human insight by leveraging both in complementary ways in the DIPTiC method and conducting manual follow-up analysis on computational results. We attended to the process of learning in the context in which it occurs by going back to the data to understand how the top linguistic model features were used by learners and following up on communities identified by SNA methods to probe their interactional processes. Finally, we mobilized theory to both frame and be informed by the empirical analyses performed as we considered the meaning of different tie definitions and recognized the need to reconceptualize learning in MOOCs. Our work is not unique in attending to learning sciences concerns in the context of an EDS/LA project, but we believe by making our conscious consideration of them explicit, we offer an important contribution to a conversation that needs to happen at the intersections of these fields. In conclusion, we offer an initial set of principles for conducting "learning sciences aware" EDS/LA work. We see these as a starting point for dialogue about directions of EDS/LA work in LS, and perhaps EDS/LA work more broadly.

Initial principles for a learning sciences aware learning analytics

1. **Ground Analysis in Theory**: A theory of learning in the area being studied (or an explanation of why no existing theory is applicable) should be used to ground the framing of the study.

2. **Characterize the Context Richly**: Details of the learning context(s) from which the data was collected should be characterized in detail (e.g. in terms of pedagogy, technology, populations etc.).

3. **Justify Choice of Data and/or Features**: Decisions about what data, variables or features to collect, construct or include in an analysis should be clearly justified, ideally with reference to learning theory.

4. **Make Sense of High-Level Patterns using Low-Level Data**: Claims made based on computational analyses should be additionally supported by analysis methods that go back to the data to examine if / how the detailed traces bear out the interpretation of the higher-level patterns.

5. **Present Analytics Results Connected to Learning Processes**: Representative examples from the underlying data should be presented to help draw connections between the learning events as they occurred and their computational representations.

6. **Appraise Scope / Boundaries of Applicability**: The extent to which the models built (or results obtained) are thought to be specific to the context(s) studied or in what kinds of similar learning environments they might apply should be acknowledged.

7. **Consider Theoretical Implications**: Implications of the results for confirming, challenging, or refining existing theories of learning or new avenues for theorization should be addressed.

References

Auerbach, C., & Silverstein, L. B. (2003). *Qualitative data: An introduction to coding and analysis*. NYU press.

Buckingham Shum, S. (2016, March 25). *Algorithmic accountability for learning analytics*. Retrieved from http://simon.buckinghamshum.net/2016/03/algorithmic-accountability-forlearning-analytics

Bull, S., & Kay, J. (2016). SMILI: A framework for interfaces to learning data in open learner models, learning analytics, related fields. *International Journal of Artificial Intelligence in Education, 26*(1), 293-331.

Coetzee, D., Fox, A., Hearst, M. A., & Hartmann, B. (2014). Should your MOOC forum use a reputation system?. *Proceedings of CSCW 2014* (pp. 1176-1187). ACM.

Cui, Y., Jin, W., & Wise, A. (2017). Humans and machines together: Improving characterization of large scale online discussions through Dynamic Interrelated Post and Thread Categorization (DIPTiC). *Proceedings of Learning@ Scale 2017* (pp. 217-219). ACM.

Dillahunt, T. R., Wang, B. Z., & Teasley, S. (2014). Democratizing higher education: Exploring MOOC use among those who cannot afford a formal education. *IRRODL, 15*(5). doi: 10.19173/irrodl.v15i5.1841

Gillani, N., & Eynon, R. (2014). Communication patterns in massively open online courses. *Internet and Higher Education, 23*, 18-26.

Kizilcec, R. F., Piech, C., & Schneider, E. (2013). Deconstructing disengagement: Analyzing learner subpopulations in massive open online courses. *Proceedings of LAK'13* (pp. 170-179). ACM.

Knight, S., Wise, A., & Chen, B. (2017). Time for change: Why learning analytics needs temporal analysis. *Journal of Learning Analytics, 4*(3), 7-17.

Kuh, G. (2002). From promise to progress: How colleges and universities are using student engagement results to improve collegiate quality. *NSSE Annual Report*. Bloomington, IN: Indiana University.

Nelimarkka, M., & Vihavainen, A. (2015). Alumni & tenured participants in MOOCs: Analysis of two years of MOOC discussion channel activity. *Proceedings of Learning@ Scale 2015* (pp. 85-93). ACM.

Rossi, L.A, & Gnawali, O. (2014). Language independent analysis and classification of discussion threads in Coursera MOOC forums. *Proceedings of IEEE IRI 2014* (pp. 654-661). IEEE.

Scott, J., & Carrington, P. J. (2011). *The SAGE handbook of social network analysis*. London: SAGE.

Stump, G. S., DeBoer, J., Whittinghill, J., & Breslow, L. (2013). Development of a framework to classify MOOC discussion forum posts: Methodology and challenges. *Proceedings of NIPS 2013 Workshop on Data Driven Education* (pp. 1-20). NIPS Foundation.

Wang, X., Yang, D., Wen, M., Koedinger, K., & Rosé, C. P. (2015). Investigating how student's cognitive behavior in MOOC discussion forums affect learning gains. *Proceedings of EDM 2015* (pp. 226-233).

Winne, P. H. (2017). Leveraging big data to help each learner upgrade learning and accelerate learning science. *Teachers College Record, 119*(3), 1-24.

Wise, A., & Cui, Y. (2018). Unpacking the relationship between discussion forum participation and learning in MOOCs: Content is key. *Proceedings of LAK'18* (pp. 330-339). ACM.

Wise, A., Cui, Y., & Jin, W. (2017). Honing in on social learning networks in MOOC forums: Examining critical network definition decisions. *Proceedings of LAK'17* (pp. 383-392). ACM.

Wise, A., Cui, Y., Jin, W., & Vytasek, J. (2017). Mining for gold: Identifying content-related MOOC discussion threads across domains through linguistic modeling. *Internet and Higher Education, 32*, 11-28.

Wise, A., & Schwarz, B. (2017). Visions of CSCL: Eight provocations for the future of the field. *International Journal of Computer-Supported Collaborative Learning 12*(4), 1-45.

Wise, A., & Shaffer, D. (2015). Why theory matters more than ever in the age of big data. *Journal of Learning Analytics*, *2*(2), 5-13.

Wise, A., Speer, J., Marbouti, F., & Hsiao, Y. (2013). Broadening the notion of participation in online discussions: Examining patterns in learners' online listening behaviors. *Instructional Science*, 1-21.

Zhao, R., Papangelis, A., & Cassell, J. (2014). Towards a dyadic computational model of rapport management for human-virtual agent interaction. *International Conference Intelligent Virtual Agents* (pp. 514-527).

Renovating Assessment for the Future:
Design-Based Implementation Research for a Learning-in-Class Monitoring System Based on the Learning Sciences

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Abstract: Renovating assessment requires a shift to continuous formative assessment including lesson improvement which entails a collaborative Plan-Do-Check-Act cycle of teachers. However, it takes too much time to turn the cycle in ordinary life. Thus, we propose two ideas to develop an assessment system: first, a collaboration between humans and AI by utilizing teachers' assessment efforts to advance the knowledge of both, and second, an embedment of the collaboration in the DBIR community. Study 1 introduces the case of a veteran teacher who turned the PDCA cycle twice by finding a problem in his lesson with his colleagues using a dialogue analysis tool and by hitting upon a new plan, which engendered more productive students' dialogues, which referred to the expected keywords. Study 2 demonstrates the effects of the pre-registration of keywords into a dialogue transcription system on the recognition rate. Both results led us to propose a Learning-in-Class Monitoring System.

Keywords: learning assessment, knowledge constructive jigsaw, DBIR

Introduction

Assessment reform requires a radical shift from a "summative assessment which ranks individuals" to a "formative assessment of the learning environment that helps all the students reach the next level of learning" (Scardamalia *et al.*, 2012). Educational policy makers are also aiming for a similar shift in the revision of national curriculum guidelines (OECD, 2017). For example, the newly revised Japanese curriculum guidelines, the Courses of Study, introduced "active learning", emphasizing its use of formative assessment. However, teachers lack appropriate tools to do this. Therefore, we developed a Learning-in-Class Monitoring System and tested it in educational settings in a series of research, in order to check whether it could serve as a foundation for assessment.

Research indicates that one-off seminars or short courses do not contribute much to teacher learning, and effective professional development involves opportunities for teacher to have actual classroom practice (Voogt, 2010), to reflect upon their practices (Ross & Bruce, 2007), and to participate in a community of practice with peers and experts over an extended period of time for continuous improvement (Penuel *et al.*, 2007). This means that a collaborative Plan-Do-Check-Act cycle holds the most important place for teachers' development. However, for most teachers, too much time and effort is required in completing this cycle. If teachers engage in designing student-centered lessons, it takes much time to collect, transcribe and analyze students' conversations. Thus, we put forward two ideas: first, a reciprocal collaboration between human beings and AI by utilizing teachers' usual efforts of assessment to advance the knowledge of both, and second, embedment of such a collaboration in the design-based implementation research (hereafter DBIR: Penuel *et al.*, 2007). If we can succeed in helping teachers engage in the time-consuming but central step of the PDCA cycle, namely, the "Check" step, teachers will be able to learn from classroom practices as well as raise the quality of their practices more effectively.

Then, how can we help teachers check students' learning and the quality of lessons? We hypothesize that the other steps of Plan, Do, and Act can also serve to raise the quality of the Check activity, since assessment benefits from teachers' explicit plans and re-plans of what kind of learning they want to take place in the classroom. Thus, the PDCA cycle should be turned iteratively in a way where the assessment itself improves its quality. We represent such a cycle in Figure 1a, which has a teachers' collaborative PDCA cycle of lesson improvement in its inner circle. Support systems on the outer circle (Figure 1a: pale green and blue shadow boxes) help teachers turn the cycle in a timely manner. In addition, as teachers use these systems to plan, discuss, conduct, reflect upon, and share the lessons iteratively, the system including AI evolves to become smarter. We call this whole set of systems a Learning-in-Class Monitoring System, specifically, "CoREFs: Co-Renovation of Evaluation for the Future system".
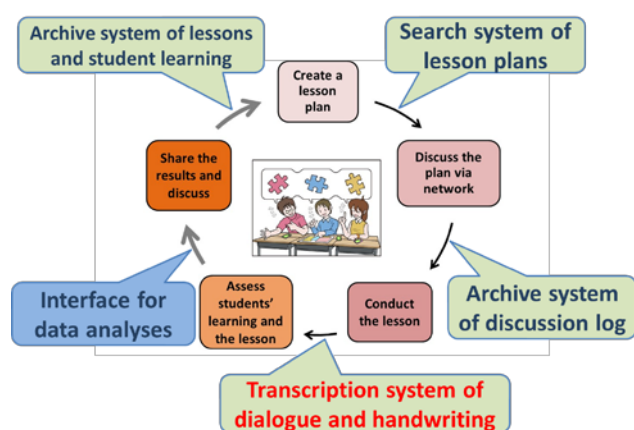
Figure 1a. PDCA cycle and
Learning-in-Class Monitoring System, "CoREFs".
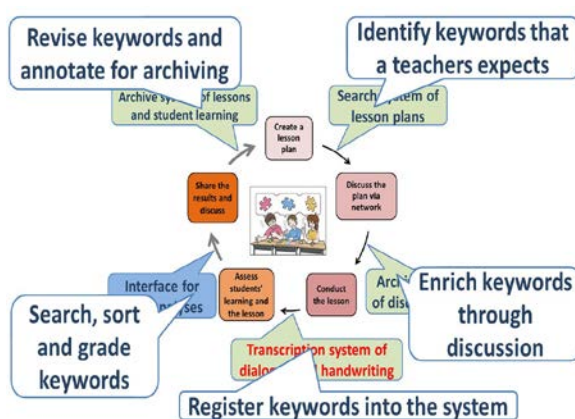
Figure 1b. How the cycle and system works in the
case of keyword detection.

For example, Figure 1b shows how such collaboration between humans and AI contributes to their co-evolution. When a teacher creates a lesson plan, s/he anticipates keywords that the students will refer to or write in the lesson according to her or his own goal of the day. Several teachers can simulate this lesson plan from multiple perspectives and build on a variety of keywords. On conducting the lesson, however, the teachers often find that students' expressions are more diverse than expected. In assessing student learning, the teachers put keywords into the analytic tool, learn how students use, share and improve their keywords, and sort and grade the keywords according to his or her newly-created criterion. The teachers feed the results back into the archive system with their reflections. When another teacher tries to conduct a similar lesson, s/he will be able to refer to an enriched database of students' actual written and dialogue data. If s/he is able to register appropriate keywords into the transcription system, the speech recognition rate will become higher, which is the most difficult part of dialogue analysis (red letter in the pale blue box of Figure 1a). Such kind of speech-to-text translation can promote in-depth analyses of collaborative learning by researchers, high-quality lesson improvements by teachers, and context-driven approaches to semantic analyses of learning by engineers, contributing to renovating the foundation of assessment.

But how? The scheme described above might sound plausible, but how can we create a community wherein teachers "not only share ideas but generate and refine new ideas through the dynamics of networked social interaction" (Scardamalia *et al.*, 2017)? It is difficult for diverse teachers to collaborate on one lesson without a shared vision of learning that they expect to take place in children. The shared task holds the key for *constructive interaction* (Miyake, 2008), in which every participant deepens her or his understanding through role exchanges of task-doing and monitoring. Here the DBIR can provide a promising support for diverse teachers to gather, learn from each other and form a community which shares a vision and/or instructional framework.

So, this research has introduced constraints of an instructional and assessment framework of the lesson as a simple but strong core of constructive interactions among all (Miyake, 2013). Specifically, this study builds on a Japanese learning sciences project by the Consortium for Renovating Education of the Future (hereafter CoREF), which utilizes a concrete lesson framework, "Knowledge Constructive Jigsaw" method (hereafter KCJ: depicted in the center of Figure 1a). The project has seen the teaching of approximately 2,000 lessons every year by teachers of all subjects across all grades from 1st to 12th, supported by 30 regional boards of education. The participating teachers, experienced as well as novice teachers, work together to design, practice and reflect lessons across subjects, schools and districts, either face-to-face or via the internet. Using this set of a common method and learning community around it, teachers can obtain "streamlined" data, reflect upon it collaboratively, and become "annotators" by using the system that we propose. Yet, we do not want to propose that the KCJ is the only way to do this, but wish to provide a set of constraints spanning across multiple levels in which this kind of cycle can be turned in any way.

In sum, we wish to propose the DBIR (CoREF project) for the Learning-in-Class Monitoring System (CoREFs) as a promising candidate for renovating assessment of the future in a series of research, among which this paper reports its initial trial. Hereafter, we first illustrate the KCJ method. Then, we introduce the case of a veteran teacher who turned the PDCA cycle twice using the KCJ and a dialogue analysis tool. This study examines the effect of double loops of the PDCA cycle on raising the quality of the "C" step, as well as giving hints on what functionalities are needed in the Learning-in-Class Monitoring System. In Study 2, we examine if the pre-

registration of keywords into an automatic transcription system of student's dialogues would raise the speech recognition rate. This study examines the effect of "P" step on raising the quality of data for "C" step in the cycle.

Framework of the Knowledge Constructive Jigsaw (KCJ)

The KCJ consists of five learning activities: (1) writing an answer to the day's given problem based on a rule of thumb, (2) an expert-group activity which allows each individual student to accumulate some pieces of knowledge relevant in solving the problem, (3) a jigsaw-type activity where students from different expert groups get together to exchange and integrate the accumulated pieces of relevant knowledge and form an answer, (4) a cross talk activity where the students exchange their ideas for solutions, involving the entire class, and (5) writing down an individual answer again to the same problem and newer questions. Compared with the original Jigsaw method (Aronson, 1978), this method emphasizes the role of a shared "problem" for knowledge construction. Although strongly scripted, this method is dynamically adaptable to any learning contents and situations in the sense that each teacher can decide the "problem (jigsaw task)" and "learning materials (for the expert activity)." The essential flow of activity allows constructive interaction among task-doers and monitors to take place naturally and repeatedly: the design requires each student to become a task-doer in the jigsaw group, and provides each student with the chance to become a monitor who infers what the other students say and why they say that, in order to integrate the ideas of others with their own.

From perspectives of data analysis and engineering, this method has two features. First, since it lets students write down their answers to the same question twice, that is, at the beginning of the lesson and its end, the change or improvement between two answers give hints to infer what kind of interaction including dialogue takes place during two time points. Second, since students externalize their ideas or prior knowledge at step (1) above, intake information from reading and discussion on the material as well as verbalize their ideas at step (2), exchange and integrate ideas at step (3), present their group's ideas and listen to the other groups' ideas at step (4), and finally externalize their ideas and next question at step (5), we can follow the information source and flow that crystalizes into each student's final understanding of the day.

Study 1

Study 1 demonstrates the effect of a keyword-detecting tool of students' dialogues for a teacher's "reflection on action" (Schön, 1987) when properly embedded in a collaborative PDCA cycle of lesson improvement. In the knowledge society, teachers should improve their lessons continuously for students' better knowledge construction. As "reflective practitioners" (Schön, 1987), teachers should not only be able to implement researchers' advice for improvement but also be able to find problems in their lessons, propose plausible solutions and implement them by themselves. Students' dialogues are precious resources for such reflection as analyzing students' learning processes, evaluating the lesson and planning the next one. In the field of Learning Analytics, it becomes important to best make information on students' learning processes accessible and useful to teachers, or to design an analytic tool from a "teacher-centered" perspective (Erkens *et al.*, 2016; Matuk, Cocco & Linn, 2016). Although there have been many conversation analysis tools in the field of CSCL, such as KBDeX (Oshima, Oshima & Matsuzawa, 2012), PolyCAFe (Trausan-Mau, 2013), and Tatiana (Dyke, Lund & Girardot, 2009), most of them are best used by researchers who have enough time to dig through the process data of different situations to yield generalizable analytic methods and findings. Instead of applying such methods to the automatization of analysis and recommending analytic results to teachers, our focus is on 1) raising the quality of the teacher's own "process of analyses" and 2) providing teachers with a PDCA cycle to "use" their analytic results for lesson improvements, since we assume that such experiences will have the effect of raising the quality of teachers' reflection and selection of keywords.

Method

Dialogue analysis tool

We developed two assessment tools utilizing observation chances in the KCJ format that enable "visualization" of the students' learning processes. The first tool is "a comparison of pre- and post-class comprehension," which simply asks the same question twice in the steps (1) and (5) above. Thanks to this, children are able to compare their own answers, and confirm whether they have seen progress. Teachers can also compare the answers with their expectations and ascertain to what extent children have deepened their understanding and how diverse their expressions are. The second tool is "multilateral dialogue analysis," which aims to auto-transcribe the students' conversations in all of the groups during the class and provide transcripts electronically searchable by keywords. Study 1 focuses on the latter tool, even though we here used a wizard of oz method (humans performing the speech transcription).

This tool supports an analysis of transcription after the lesson. It has two simple functions: one function is highlighting utterances that include keywords of the lesson, and the other is changing the scope of analysis. The tool has one window for analyzing one group dialogue carefully (Figure 2a), which represents each student in each column and each utterance in each cell. If a user enters a keyword in a colored area, then the cell including the keyword turns into a colored cell. The other window is for comparing dialogues of all groups (Figure 2b), which shows each student in each column and each utterance in just one line. Thus the user cannot see the contents of the utterances, but is able to grasp an overall image of the distribution of keywords. The user can change these two views by clicking on any part. By using these functions, teachers can both analyze whether and how each student discusses the topic in the expert or jigsaw group using keywords related to the lesson contents or social processes, and examine to what extent a found pattern is universal among the groups. According to Soller *et al.* (2005), our tool is classified as a *mirroring system*, which just displays states and changes of students' interaction.
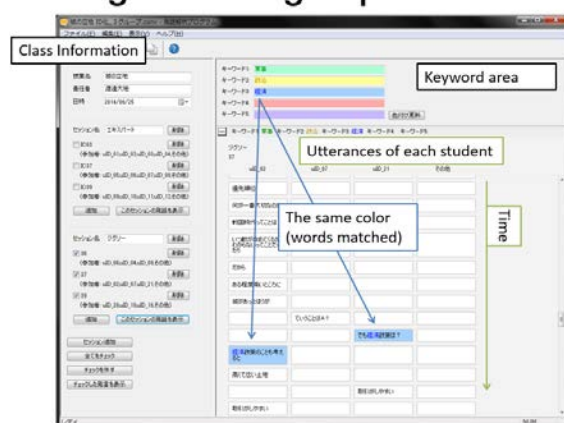
Figure 2a. The dialogue analysis tool: Close-up window.
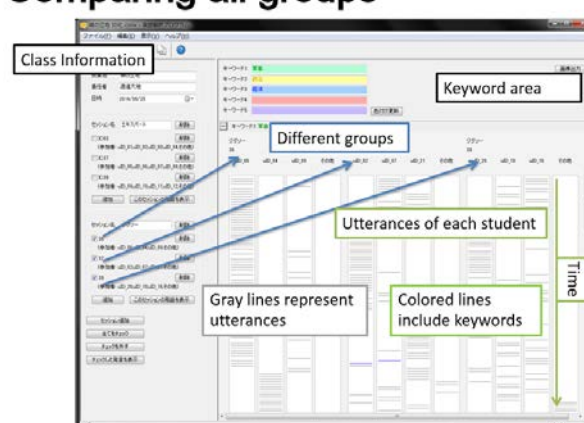
Figure 2b. Bird's-eye window.

Research setting and Teacher K

As shown in Table 1, this study focused on Teacher K's lesson improvement process spanning over the three-year period from the year 2014 to 2016, using the above dialogue analysis tool in a seminar described below in the year 2015. Since this research was conducted using a case study method, we will be giving its details together in the Results section. Underlined phrases and words in Table 1 are explained later.

The teacher (hereafter "Teacher K") who was the subject of this study is a junior-high school male teacher. He has been working as a science teacher for 28 years and has taught at seven junior-high schools in several cities and towns of a rural prefecture over his teaching career. He participated in the CoREF project from its initial stage, the year 2008, having developed more than thirty KCJ lesson materials. He has not only attended CoREF's teacher training workshops more than 30 times, but has also served on five occasions as a lecturer in these workshops and symposiums. He also participated in a seminar called "KCJ and Lesson Study Masters" in the year 2014, which saw 40 teachers taking part from all around Japan, providing them with more advanced contents of learning sciences, enabling the teachers to connect them with their own KCJ experiences, and also to discuss their learning sciences. As a master teacher, he not only opened his classes up to other teachers, but also traveled to other districts in order to conduct KCJ lessons in other teachers' classes.

Results

Teacher K taught a science lesson to 8th graders using the KCJ method on a unit of the mechanics of human body movements in the year 2014, and reflected on the lesson directly after teaching it, especially on the gap between what he had asked the students to do and what the students understood to be "today's task". By analyzing the students' dialogues in a seminar about a year later, however, he became aware of the difficulties students faced in extracting and integrating the information from the expert materials as well as the need to describe the task more clearly. After a further year, when given the chance to try teaching the unit again, he revised his lesson plan, which ultimately led to deeper understanding on the part of the students. Table 1 summarizes the whole process.

Table 1: Teacher K's lesson improvement

Phase	Event (Planning, implementing, reflecting and re-planning of the lesson)
1	**Planning of the first version of the lesson (30th June – 2nd July, 2014; on CoREF's mailing list)** Teacher K first intended to make students more <u>conscious of their body movements in their club activities or in their everyday lives</u>. Therefore, he planned to show a video of a person hitting a tennis ball, a baseball, or a volleyball, and to have the students explain the body movements of any player, handed out <u>three expert materials</u> of the "<u>nervous system</u>," "<u>skeletal structure</u>" and "<u>mechanism of muscles</u>" and formed jigsaw groups by student club (tennis, baseball, or volleyball) to allow the students to apply what they had learned in their activities. To this plan, one researcher expressed <u>the concern</u> that the task seemed too difficult for students in spite of the attractiveness of "solving personal problems". Teacher K, however, did <u>not follow this advice and took the risk of implementing his own initial idea</u>.
2	**Implementing the lesson and reviewing it in a meeting (4th July, 2014)** The lesson went over the allotted time since students had difficulty in integrating the information in the jigsaw groups and presenting it in the crosstalk. Directly after the lesson, Teacher K said in the meeting, "The children did not seem to be <u>conscious of their own movements</u>, so I should have used the video or whatever to enable them to think deeply about the inside workings of their bodies," which implied he had found some problems with his lesson but had just resorted to another *know-how* of teaching.
3	**Reviewing the lesson in a CoREF reflection sheet (July 2014)** In the CoREF reflection sheet, the teacher is requested to select any three students and compare their pre and post class answers. Teacher K reflected upon these answers and the impression of the class, writing "Although even <u>in bending one's arm</u>, "*the biceps brachii muscle contracts while the triceps brachii muscle relaxes*," the students' descriptions were too obscure to reach this level. This kind of goal demanded too much from the students because I myself did not have a clear image of what I had wanted from them. In redesigning the lesson, I would present the same movement to everybody regardless of the club the student belongs to," suggesting he reached the idea of making the task clearer.
4	**Reviewing students' dialogues of the lesson in the CoREF seminar (1st August, 2015)** About a year later from the lesson, a three-hour workshop in the "KCJ and Lesson Study Masters" seminar was held, utilizing *hand-transcribed* dialogues from Teacher K's lesson as described above. Fifty-three teachers including Teacher K used the dialogue analysis tool collaboratively to dig through one to three jigsaw groups of students. Before using the tool, Teacher K had planned to model students' learning from "understanding of the task" and "externalizing one's own initial thoughts" through "reacting to others' thoughts (keywords of "*I see*", "*Why?*", "*Uh?*", "*Aha*")" to "restructuring one's own thoughts". During actual use, a group including Teacher K entered a keyword "*In a word,*" but found that 8th graders did not use such a formal expression, and came to focus more on content words like "*ball*." After hearing other groups' findings, Teacher K wrote down not only communicative words like "*For example*" or "*Why?*" but also content words integrating three expert materials like "*command*", "*transmission*", "*reaction*" as promising keywords. Teacher K's change implies that even though he had assumed the content was not so difficult for his students, he found it was not the case. Actually, it was difficult for the students to discuss the materials by using and connecting the content keywords as he had expected.
5	**Planning of the second version of the lesson and its implementation (18th October, 2016)** When Teacher K was given the chance to teach the same unit and open up that class, he decided to try the KCJ lesson again. Although he changed <u>the expert materials</u> only slightly, he drastically changed the aim of lesson and the main task. He dropped the aim of "explaining everyday body movement" from the expected outcomes, and clarified the task by asking "<u>What are you doing to catch a falling ruler?</u>" and making it a common target for students to explain. He also clarified the expected outcomes such as "Students should explain "*I get stimulus that the ruler starts to move from the eyes. The stimulus is transmitted from the optic nerve through the sensory nerve and the spinal cord to the brain. Then the brain commands the muscles inside the thumb and forefinger to contract, the command of which is transmitted from the brain through the spinal cord and the motor nerve to the muscles inside the fingers, and the fingers successfully catch the ruler*"". By implementing this plan, almost all the jigsaw groups of students reached the expected outcomes and furthermore they tried to connect their learning outcomes to the following lessons.
6	**Reviewing the lesson in a CoREF reflection sheet (October 2016)** Teacher K wrote in the reflection sheet, "I felt that most of the students clearly understood <u>the mechanics of body movement</u>, due to a change in the task which dealt with a simple behavior. I realized that even though I changed the expert materials a little, the reaction of the students drastically changed with revision of the task and targeted material, at which I was surprised."

Discussion for the system requirement

Teacher K first stuck to his own hypothesis of the lesson. Thanks to the PDCA cycle supported by the KCJ method and its learning community embedded in the DBIR, Teacher K had been exposed to another person's hypothesis (researcher's concern) about the lesson and found "some" problems in his lesson. Yet, with the help of tool-assisted dialogue analysis in the community, he first realized the hidden problem of the lesson and came up with a newer plan. The dialogue analytics embedded in the collaborative PDCA cycle promoted teachers' own action research. It also implies that even a veteran teacher like K cannot imagine all of the dialogues of the students, and so can benefit from an activity of dialogue analysis.

Then, how are we able to reduce this whole process spanning more than two years in order to help teachers gain more timely feedback, especially when we aim to support a large number of teachers in our community simultaneously? Reviewing Table 1 from the perspective of keyword detection, enrichment and revision, we are able to consider the requirements of the Learning-in-Class Monitoring System. Single underlined phrases are the corpus from which keywords can be detected, and double underlined words or phrases are candidate keywords by themselves.

When a teacher tries to plan a KCJ lesson, she or he is supposed to make not only expert materials but also a "lesson design sheet" which includes a lesson objective, main task, and gist of expert materials. For example, Teacher K created the lesson plan and materials, which can provide the corpus for keywords (single underlined in phase 1 of Table 1). A "search system of lesson plans" (Figure 1a) should automatically conduct a morphological analysis to propose "hot words" in the texts when the plan and materials are uploaded. In addition, if the teacher sets the keywords by her- or himself (double underlined in phase 1 in Table 1 like "nervous system"), the system should be able to register those words. When the teacher consults with other teachers in the KCJ community, she or he posts the lesson design sheet and materials on the bulletin board or mailing list system. Others made comments on them such as suggestion, advice or mere concern (single underlined in phase 1 of Table 1). An "archive system of the discussion log" (Figure 1a) should automatically accumulate logs and learn to detect keywords from the discussions. A "transcription system of dialogue and handwriting" (Figure 1a) should have components of registering keywords, recognizing speech or handwritten letters, representing the recognized results and allowing correction of them. The system also should be seamlessly connected with an "interface for data analyses" (Figure 1b) like the dialogue analysis tool described above (Figure 2), that is, the transcribed dialogue is automatically imported from the transcription system into the analysis tool and represented there with its voice information. This integrated system should keep track of a teacher's search of keywords by registering words or phrases that the teacher looks for with their frequency (see keywords double underlined in phase 4 in Table 1). An "archive system of lessons and student learning" (Figure 1a) should include not only the lesson plan and materials but also all the transcribed data of each child of pre- and post-class answers to the same question and in-between dialogues (expert, jigsaw, cross talk activities), with teacher's reflection upon it (single underlined in phases 2, 3, and 6 in Table 1) and all the log data of search or dialogue analysis above. Then, when the teacher or another teacher tries a similar lesson, all those data can be used in the search system of lesson plans, upon which teachers can register newer keywords and corpora (single underlined in phase 5 in Table 1) and use them for the transcription system.

Study 2

We are now developing a whole set of systems and have reported here only a part of it: an automatic transcription system of student's dialogues.

Method

System

The system consisted of unidirectional microphones attached to each student, and automatic transcription tools with a cloud engine. This engine accepts pre-registration of keywords by the user up to 100 words. Using this system, we iterated the high-school Japanese lessons four times.

Participants and procedure

Fifteen students from high schools and/or prep school participated in the lesson, totaling up to sixty in the four iterations. The lesson let students deepen their understanding of a short story, a Japanese novel "*Kaban* (The Bag)" by Kōbō Abe, through the KCJ method. Students first read the story to ponder the main message of the story, and then were divided into three expert groups, one of which considered how the main character feels and changes his thinking as the story develops, another of which reflected how another character does so, and the third of which thought about the meanings of two expressions found in the novel. Three members from the expert groups formed

one jigsaw group to think again about the message of the story, reported their thoughts to the class and wrote down their answers individually at the end.

Through the first three iterations, we were able to get the accuracy rate of automatically transcribed data compared with the whole truth transcription, that is, 100% minus WER (the word error rate), of about 23% to 36% depending on the group at step (3) of the jigsaw activity. The reason why the rate differed greatly by group is that the acoustic and language models were not adjusted to the particular group, where group members simultaneously talk, take over each other's utterances, and sometimes suddenly burst into laughter.

Thus, we focused on transcribing the crosstalk at step (4), where a representative of each group presented their final answer in turn and the other groups quietly listened to that. Yet, they used many colloquial expressions instead of formal ones found in the material (the novel), and thus an extra "dictionary" was needed produced by their own conversations and writings. During the three iterations, we acquired the conversation data of a total of 100,000 Japanese characters (roughly corresponding to thirty to fifty thousand English words), which were classified into about 2,000 "different" (Japanese) words. We, the researchers, chose 49 hot words from them which also matched the objective of the lesson, registered the words into the system beforehand, and applied the system to the crosstalk at step (4) of the fourth (final) trial of the lesson.

Results

Table 2 represents the result. The "recognition rate" represents the accuracy of the words transcribed by the system, while the "recognition accuracy" means the accuracy of the transcription compared with the whole truth transcription. Pre-registration of keywords resulted in an accuracy gain of about 10%, since the recognition of the registered words (often hard-to-recognize words) contributed to that gain. Still, the rates are still too low to use them online by teachers. We need more words to register and need to know how to choose words to raise the rates.

Table 2: The accuracy rate of the transcription system with or without pre-registration of keywords

	Recognition rate	Recognition accuracy	Recognition rate of registered words
Third trial of the lesson (Without pre-registration)	66.7% (SD: 16.9%)	58.2% (SD: 20.2%)	---
Fourth trial of the lesson (With pre-registration)	74.0% (SD: 11.9%)	64.4% (SD: 5.8%)	63.5% (varied from 0 to 100%)

General discussion

We examined the effect of turning the cycle twice on raising the quality of the "C" step in the PDCA cycle in Study 1, and the effect of pre-registration of the keywords, that is, specification of "Plan" on raising the quality of data for "C" in Study 2. Combining the results of Study 1 and Study 2, we found promising results on the possibility of recruiting teachers as "annotators" of the PDCA cycle. First, although even a master teacher tends to reflect upon their lesson subjectively without records of learning processes, s/he can reflect upon it precisely and concretely with just a simple analytic tool. Second, the keywords that the teacher inputs can change as his or her understanding of the lesson topic and the students develops like the keywords Teacher K considered in Study 1 (italics in Table 1). Third, when the teacher deepens their understanding of the topic and how the students learn, s/he gets clearer in what kind of keywords s/he wants and gets better in re-designing the lesson, which results in gaining a higher rate of recognition of students' keywords, while the students feel freely to talk with their colloquial expressions in a more focused lesson. Such a reciprocal collaboration between systems and humans can contribute to enriching the iterative assessment cycle as a foundation for renovating assessment. In other words, an intertwined cycle of teaching and assessment can set an arena for mutual growth of humans and AI.
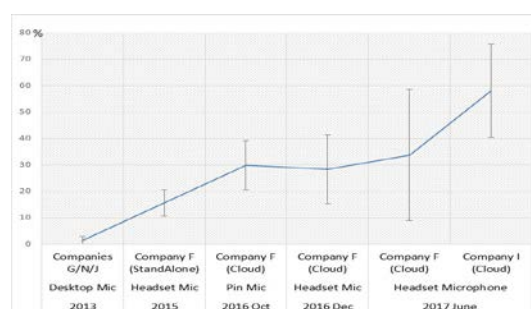
Figure 3. Recognition accuracy of transcription of jigsaw dialogues.

An immediate challenge for us is to raise the quality of the transcription system, as a core of the Learning-in-Class Monitoring System, or CoREFs, especially recognizing the jigsaw dialogues, where several groups simultaneously engage in discussions in the same room. Figure 3 shows an improvement of recognition accuracy of transcription of jigsaw dialogues over five years, with each year showing an average and SD of 3 to 19 groups of various lessons by various teachers. Although we cannot disclose the names of the recognition engines, in the year 2013 the recording environment was of low quality, which was improved in the year 2015 through the use of headset microphones. Cloud engines (used in Study 2) increased the accuracy of the year 2016 by 15% compared with the year 2015. In the year 2017 the engine increased accuracy by 25%, through accepting limitless pre-registration of corpora and dictionaries, which takes advantage of the features of the KCJ described in this paper and opens the arena for mutual growth of humans and AI.

References

Aronson, E. (1978). *The Jigsaw Classroom*. Beverly Hills, SAGE Publications.

Dyke, G., Lund, K. & Girardot, J-J. (2009). Tatiana: An environment to support the CSCL analysis process. In *Proceedings of CSCL'09, Volume 1,* 58-67.

Erkens, G., van Leeuwen. A., Janssen, J. & Brekelmans, M. (2016). Learning analytics to support teachers: Regulating teaching practices through analytics in CSCL. In C. K. Looi, J. L. Polman, U. Cress & P. Reimann (Eds.). *Transforming Learning, Empowering Learners: ICLS 2016, Volume 1,* 28-29.

Matuk, C., Cocco, F. & Linn, M. (2016). A teacher-centered approach to designing a real-time display of classroom activity. In C. K. Looi, J. L. Polman, U. Cress & P. Reimann (Eds.). *Transforming Learning, Empowering Learners: ICLS 2016, Volume 2,* 1122-1123.

Miyake, N. (2008). Conceptual change through collaboration. In S. Vosniadou, (Ed.). *International Handbook of Research on Conceptual Change*, 453-478. New York: Routledge.

Miyake, N. (2013a). Case report 5: Knowledge construction with technology in Japanese classrooms (CoREF). In P. Kampylis, N. Law,Y. Punie (Eds.), *ICT-enabled innovation for learning in Europe and Asia,* 78-90, European Commission, Joint Research Centre.

OECD (2017) *Educaiton 2030.* http://www.oecd.org/edu/school/education-2030.htm (retrieved 30th, Nov. 2017)

Oshima, J., Oshima, R. & Matsuzawa, Y. (2012). Knowledge Building Discourse Explorer: A social network analysis application for knowledge building discourse. *Educational Technology Research and Development*, 60 (5), 903-921.

Penuel, W. R., Fishman, B. J., Yamaguchi, R. & Gallagher, L. P. (2007). What makes professional development effective? Strategies that foster curriculum implementation. *American Educational Research Journal*, 44(4), 921-958.

Ross, J. & Bruce, C. (2007). Professional development effects on teacher efficacy: Results of randomized field trial. *The Journal of Educational Research*, 101(1), 50-60.

Scardamalia, M., *et al.* (2017). Toward a multi-Level knowledge building innovation network. In B. K. Smith, M. Borge, E. Mercier & K. Y. Lim (Eds.). In *Proceedings of CSCL2017, Volume 2*, 703-710.

Scardamalia, M., Bransford, J., Kozma, R. & Quellmalz, E. (2012). New assessments and environments for knowledge building. In P. Griffin, B. McGaw & E. Care (Eds.). *Assessment and Teaching of 21st Century Skills.* Dordrecht: Springer, 231-300.

Schön, D. A. (1987). *Educating the reflective practitioner: Toward a new design for teaching and learning in the professions.* San Francisco, CA: Jossey-Bass.

Soller, A., Martinez, A., Jermann, P. & Muehlenbrock, M. (2005). From mirroring to guiding: A review of state of the art technology for supporting collaborative learning. *International Journal of Artificial Intelligence in Education (IJAIED)*, 15, 261-290.

Trausan-Matu, S. (2013). Collaborative and differential utterances, pivotal moments, and polyphony. In D. D. Suthers, K. Lund, C. P. Rosé, C. Teplovs & N. Law (Eds.). *Productive Multivocality in the Analysis of Group Interactions*, Springer, 123-139.

Voogt, J. (2010). Teacher factors associated with innovative curriculum goals and pedagogical practices: Differences between extensive and non-extensive ICT-using science teachers. *Journal of Computer Assisted Learning*, 26(6), 453-464.

Acknowledgments

Applying Group Communication Analysis to Educational Discourse Interactions at Scale

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Abstract: The learning sciences field is in need of new automated methodological approaches that offer deeper insights into the dynamics of learner interaction and discourse across scaled learning platforms. In this paper, we explore MOOC learners' discourse by employing *Group Communication Analysis* (GCA), a methodology for quantifying and characterizing the discourse between learners in online interactions. Commonly used approaches in MOOCs derive insight into the learning processes from aggregated text or structural data. In contrast, GCA makes use of linguistic cohesion analysis across sequences of learners' interactions in multi-party communication. GCA calculates six inter- and intra-personal sociocognitive measures of such interactions and from these identify distinct interaction profiles through a cluster analysis. With this method, we were able to diagnostically reveal four robust profiles amongst MOOC learners. This study presents a unique analysis of the sociocognitive processes that comprise the interaction between learners. The scalability of the methodology opens the door for future research efforts directed towards understanding and improving scaled peer-interactions.

Introduction

The importance of peer interactions for the learning process has been emphasized in learning sciences and educational research (Bransford, Brown, & Cocking, 2000; Stahl, Koschmann, & Suthers, 2006). Studies in the distance courses, online and blended courses, and more recently in Massive Open Online Courses (MOOCs) environments have all stressed the need for developing peer to peer interactions to promote student learning and achievement of course goals (Bernard et al., 2009; Borokhovski, Tamim, Bernard, Abrami, & Sokolovskaya, 2012; Joksimović, Gašević, Loughin, Kovanović, & Hatala, 2015). Technology-based interactions, such as blogs and forums, play a key role in facilitating discussions among peers, instructors, and teaching assistants. While MOOC forums hold the potential for scalable peer-based learning, they are typically characterized by low overall participation and responsiveness (Yang, Sinha, Adamson, & Rose, 2013). Thus, a question facing the Learning at Scale community is how the potential of large scaled peer-learning environments can be achieved.

A burgeoning research body of literature focuses learning processes in groups across computer-supported collaborative work and broader learning sciences (Stahl et al., 2006; Stahl & Rosé, 2013; Suthers, Dwyer, Medina, & Vatrapu, 2010), often with the emphasis on sociocognitive group processes, such as coordination, common ground, elaboration and integration of ideas. Applying these well-developed theoretical lenses at scale, such as in MOOCs, is challenged by the vast amount of data. In order to move forward, the field is in need of new automated approaches that offer deeper insights into the dynamics of learner interaction and discourse across scaled learning platforms.

Scaled online educational platforms afford the collection of learning data at high granularity. However, thus far, efforts towards characterizing the dynamics of MOOC learners' interactions in forums have been limited to aggregate and surface level features. In cases where the analysis of MOOC forums reaches beyond quantifying the number of forum contributions, the efforts to derive meaning around peer interactions have been driven by SNA and automated content analysis of forum posts. Studies employing social network analysis (SNA) (Boroujeni, Hecking, Hoppe, & Dillenbourg, 2017; Dowell et al., 2015; Hecking, Chounta, & Ulrich Hoppe, 2017; Poquet, Dawson, & Dowell, 2017) characterize learners' social interactions in terms of reply-to behaviors and network attributes. Insights derived from SNA are limited because these strictly structural measures do not capture the deeper level interpersonal sociocognitive and semantic information found in the discourse interaction. Alternatively, automated natural language processing techniques could provide a productive path towards characterizing scaled peer-learning interactions. Indeed, language and communication has proven quite useful in explorations of group interaction phenomena, and has been applied to characterize the quality of learner-generated text at scale (e.g., Joksimović et al., 2018). Automated content analysis of forum posts at scale has been applied at both the student level (i.e. individual posts or totality of them per person) and group level (ie. text of the overall thread transcript). Aggregating the text of the individual or a thread offers a summative account of learner or group discourse characteristics, but it provides only coarse-level granularity, and disregards the sociocognitive processes

that reside in the interaction between learners' discourse contributions. Such approach is inadequate for obtaining insights around many core peer interaction issues because the analyses focus on individual cognition, rather than sequential meaning-making characteristics. In particular, these practices tend to obscure the sequential structure, semantic references within group discussion, and situated methods of interaction through which learning emerges (Çakır, Zemel, & Stahl, 2009; Reimann, 2009; Stahl, 2017; Suthers et al., 2010). As a result, current studies of peer discourse at scale cannot offer insight on many aspects of peer interaction such as coordination, and regulation, among others, and more nuanced techniques are needed.

To start unpacking sociocognitive processes at scale, learning and computational sciences require new automated methodological approaches that will provide deeper understanding of learners' communication patterns and interaction dynamics across MOOC platforms. Drawing on this, we explore MOOC learners' discourse by employing *Group Communication Analysis* (GCA), a methodology for quantifying and characterizing the discourse dynamics between learners in online multi-party interactions (Dowell, Nixon, & Graesser, 2018 under-review). GCA applies automated computational linguistic analysis to the *sequential* interactions of participants in online group communication. GCA both captures the structure of the group discussion, and quantifies the complex semantic cohesion relationships between learners' contributions overtime, revealing interpersonal processes in group communication. In doing so, this methodology goes beyond previous models for automated group communication, which often rely on counting the number of utterances exchanged between learners.

This study is focused on identifying learner interaction profiles based on the quality of each person's contributions to the forum discourse. Cluster analysis was used to identify prototypical MOOC learner interaction profiles. Each profile comprises six sociocognitive measures resulting from the GCA methodology of responsiveness, social impact, internal cohesion, newness, communication density, and participation. Measures used for cluster analysis are derived by tracking the sequential intra- and interpersonal patterns of cohesion between participants' discourse contributions. As such, the GCA provides a novel approach to describing learner behavior in MOOC settings. Its significance is in opening for further investigations of group level learning processes at scale, such as monitoring and social regulation, integration of ideas, creation of the common ground, sharing of information, and deepening of group ideas.

Theoretical foundations and group communication analysis

The GCA framework incorporates definitions and theoretical constructs that are based on research and best practices from several areas where sociocognitive processes, group interaction, and collaborative skills have been assessed. These include areas such as CSCL, CSCW, teams, organizational psychology, assessment in work contexts and PISA (Oecd, 2013). Despite differences in orientation between the disciplines where these frameworks have originated, the conversational behaviors that have been identified as valuable are quite similar, and the GCA provides six learning-relevant interaction measures (summarized in Table 1), which are briefly reviewed below (Dowell et al., 2018 under-review).

Posting a message on the forums is often operationalized by researchers and instructors as participation (Hrastinski, 2008) and considered a requirement for any online learning group interaction. It signifies a willingness and readiness of learners to externalize and share information and thoughts (Hesse, Care, Buder, Sassenberg, & Griffin, 2015). Participation, has been shown to have a beneficial influence on various learning outcomes, including retention rates, learner satisfaction, and social capital (Hrastinski, 2008). GCA approaches *participation* as a necessary, but not sufficient component for characterizing the interactions between MOOC learners.

Internal cohesion is a sociocognitive measure that can serve as a proxy for individual self-monitoring and reflection processes during peer interactions. That is, successful collaboration requires that each individual monitor and reflect on their own knowledge and contributions to the group (Barron, 2000; Oecd, 2013); a behavior explained within self-regulation theory (Chan, 2012; Malmberg, Järvelä, & Järvenoja, 2017; Zimmerman, 2001). Consequently, during peer-learning individuals need to appropriately build on and integrate their own views with those of the group (Kreijns, Kirschner, & Jochems, 2003). Given that a participant's current and previous contributions should be, to some extent, semantically related to each other, a measure of internal cohesion can indicate the extent to which they have monitored and reflected on their previous discourse (i.e. self-regulation). Overly high levels of internal cohesion might suggest that a participant is not evolving their thoughts, but rather reiterating the same static view. Conversely, low levels of internal cohesion might indicate that a participant has no consistent perspective to offer the conversation, and is echoing the views of others, or is only engaging at a surface level within discussion thread topics.

Learners must also monitor and build on the perspectives of their collaborative partners to achieve and maintain a shared understanding of the task and its solutions (Dillenbourg & Traum, 2006; Graesser, Dowell, & Clewley, 2017; Hmelo-Silver & Barrows, 2008; Stahl & Rosé, 2013). In the CSCL literature this shared

understanding has been referred to as knowledge convergence, or common ground (Clark & Brennan, 1991; Roschelle & Teasley, 1995). It is achieved through communication and interaction, such as building a shared representation of the meaning of the goal, coordinating efforts, and viewpoints of group members, and mutual monitoring of progress towards the solution. ***Responsivity*** is a sociocognitive GCA measure, which captures monitoring and regulatory processes externalized during communication with peers. This measure reflects the extent to which an individual monitors and incorporates the information provided by the peers in their new contributions. The measure is implemented by examining the semantic relatedness between the individual's current contribution and the previous contributions of their collaborative partners. For example, if an individual's contributions are, on average, only minimally related to those of their peers, it would the individual exhibits low responsivity.

The GCA's ***social impact*** measure captures the extent to which a learners' contributions are seen as meaningful, or worthy of further discussion (i.e. uptake), by their peers. Social impact is measured through the analysis of the semantic relatedness between the learner's current contribution and those that follow from their collaborative partners. Individual messages that are more semantically related to the subsequent contributions indicate a high social impact of their authors on the unfolding group discourse.

Peer interactions provide the opportunity to expand the pool of available information, thereby enabling groups to reach higher quality solutions than could be reached by any one individual. However, despite the intuitive importance of (new) information sharing, a consistent finding from research is that groups predominantly discuss information that has been already shared (known to all participants) at the expense of information that has not been shared (known to a single member) (see Mesmer-Magnus & Dechurch, 2009 for a review). The distinction between given (old) information versus new information in discourse is a foundational distinction in theories of discourse processing (Price, 1981). Given information includes words, concepts, and ideas that have already been disclosed in the discourse; new information involves words, concepts and ideas that have not yet been mentioned, and builds on the given information or launches a new thread of ideas. The GCA captures the extent to which learners provide new information, compared to referring to previously shared information, with a measure called ***newness***.

The team performance literature also advocates for concise communication between group members (Gorman, Cooke, & Kiekel, 2004). An example of this can be seen in formal teams, like military units, which typically adopt conventionalized terminology and standardized patterns of communication. It is suggested that this concise communication is possible when there is more common ground within the team and the presence of shared mental models of the task and team interaction (Klein, Feltovich, Bradshaw, & Woods, 2005). The GCA's ***communication density*** measure was first introduced by Gorman et al. (2003) in team communication analysis to measure the extent to which a team conveys information in a concise manner. Specifically, the rate of meaningful discourse is defined by the ratio of semantic content to number of words used to convey that content.

Semantic-based GCA measures

Five of the GCA measures are semantic-based metrics (i.e., all but participation). The GCA relies on Latent Semantic Analysis (LSA) to infer the semantic relationship among the individual contributions. LSA, an automated high-dimensional associative analysis of semantic structure in discourse, can be used to model and quantify the quality of coherence by measuring the semantic similarity of one section of text to the next. LSA represents the semantic and conceptual meanings of individual words, utterances, texts, and larger stretches of discourse based on the statistical regularities between words in a large corpus of natural language (Landauer, McNamara, Dennis, & Kintsch, 2007). When used to model discourse cohesion, LSA tracks the overlap and transitions of meaning of text segments throughout the discourse.

Conversations, including MOOC forum discussions, commonly follow a statement-response structure, in which new statements are made in response to previous statements, and subsequently trigger further statements in response. Learners may, in a single contribution, refer to concepts and content presented in multiple previous contributions, made throughout the conversation either by themselves or other learners. Thus, a single contribution may be in response, to varying degrees, to many previous contributions, and it may in turn trigger, to varying degrees, multiple subsequent responses.

The analytical approach of the GCA was inspired by analogy to the cross- and autocorrelation measures from time-series analysis. Cross-correlation similarly measures the relatedness between two variables, but with a given interval of time (or lag) between them. That is, for variables x and y, and a lag of τ, the cross-correlation would be the correlation of $x(t)$ with $y(t + \tau)$, across all applicable times, t, in the time-series. Such cross-correlation plots are a commonly used in the qualitative exploration of time series data. While we might apply standard auto- and cross-correlation to examine temporal patterns in *when* participants contribute, we are primarily interested in understanding the temporal dynamics of *what* they contribute, and what the evolution of the

conversation's semantics can teach us about the scaled peer-interaction. With this in mind, the GCA provides a fine-grained measure of the similarity of participants' contributions to capture the multi-responsive and social impact dynamics that may be present in online interactions. That is, the semantic cohesion of contributions at fixed lags in conversations can be computed much in the same way that cross-correlation evaluates correlation between lagged variables. Various measures of this auto- and cross-cohesion form the basis of the GCA's semantic-based measures.

Methods

MOOC and participants

We analyzed forum discussions from an eight-week long iteration of the course [removed for review] offered on the Coursera platform in 2013. The subject area of the analyzed MOOC fell under the domain of a combination of learning and life sciences. The course objective was to introduce the educational theory as it relates to health professionals, familiarize students with a variety of teaching techniques, as well as with the practical approaches for matching instructional methods with desired educational outcomes. The dataset for the analysis in this study included 644 participants, i.e. all those who posted messages on the course forum. Forum data was collected from the Coursera platform and included all the information specified within the Coursera discussion forums data documentation.

Modeling conversational structure and preprocessing

MOOC forums make use of a tree hierarchical data structure of enchained messages: threads, which initiate a new discussion; posts, which are messages on a thread; and comments, which are messages used to reply to a post. During the 8-week course period for the MOOC used in this research, there were 180 threads, 2,335 posts, and 1,437 comments. The number of contributions (i.e., comments or posts) varied across threads (M=137.80, SD=81.43, $Q1$=85, $Q3$=209, Min=1, Max=244). The GCA was applied to all threads individually.

Conversations within a MOOC thread can be organized in two ways, visual or temporal. Under the visual approach, all posts and associated comments on thread would be organized as one would view them if they browsed at a historical (i.e., completed course) thread. That is, the order of the conversation respects the labeled dependency between posts and comments on posts, but ignores the temporal order of the contributions. Consequently, the visual organization hides the true semantic relations between learner contributions. As the name suggests, the temporal approach orders learners' contributions in temporal order. That is, this organization reflects the way a learner would encounter posts and comments at a given moment in time, thereby retaining the temporal semantic relations between learner contributions. The temporal ordering more accurately represents the evolving development of learners' ideas over time and thus was used to analyze the data in this study. Prior to the GCA analysis, all comments and posts were preprocessed and information that was not a part of the actual discourse (e.g., HTML) was removed in a cleaning process. The openNLP R library (Hornik, 2016) was used for word tokenization, sentence segmentation, and parsing. Table 1 provides overview of GCA measures.

Table 1: GCA Measures

Measure	Description
Participation	Mean participation of any participant above or below what you would expect from equal participation in a group of the size of theirs
Overall Responsivity	Measure of how responsive a participant's contributions are to all other group members' recent contributions
Internal Cohesion	How semantically similar a participant's contributions are with their own recent contributions
Social Impact	Measure of how contributions initiated by the corresponding participant have triggered follow-up responses
Newness	The amount of new information a participant provides, on average
Communication Density	The amount of semantically meaningful information

Analysis

A k-means cluster analysis approach was adopted to discover communication patterns associated with specific learner profiles during MOOC forum interactions. Cluster analysis is a common data mining technique that involves identifying subgroups of data within the larger population who share similar patterns across a set of variables. Cluster analysis has been previously applied in the analysis of learner behavior in MOOCs (e.g.,

Kizilcec, Piech, & Schneider, 2013) and has proven useful in building an understanding of individuals' behaviors in many digital environments more broadly (e.g., Wise, Speer, Marbouti, & Hsiao, 2012).

In our analysis, we first compute the mean for each learner across the six GCA measures, which provides a global account of individuals interaction dynamics across the conversations in the MOOC forums. The data were then normalized and centered to prepare them for analysis. Prior to clustering, multicollinearity, collinearity and cluster tendency were assessed through variance inflation factor (VIF), Pearson correlations, and Hopkins statistic, respectively. The results support the view that multicollinearity and collinearity were not an issue with VIF > 7, and at $|r| \geq 0.7$. The assessment of cluster tendency is a particularly important in the context of unsupervised machine learning because clustering methods will return clusters even if the data does not contain any inherent clusters. The Hopkins statistic (factoextra R package) did show evidence of clustering, H = .08, which is well below the threshold of H > .5 (Han, Pei, & Kamber, 2011, p. 486). Given that cluster analysis can return any number of specified clusters, we used the NbClust R package which provides 26 indices for determining the relevant number of clusters (Charrad, Ghazzali, Boiteau, & Niknafs, 2014). Detailed specification of each index can be found in Charrad et al. (2014), and majority vote between indices indicated k=4 was appropriate.

Findings

Investigation of the cluster centroids helps identify if the clusters are conceptually distinguishable. Centroids represent the prototypical entity (learner) in each cluster. With K-means, the centroids are in the means of the points in the cluster. In the context of GCA profiles, we may interpret the centroids as measures of behavior typical of a distinct style of interaction. The centroids for the four-cluster k-means solution are presented in Figure 1. The clustering was performed on normalized data; zero in this figure represents the population average (all 644 learners) for each measure, while positive and negative values represent values above or below that average.

We see some interesting patterns across the four-cluster solution. Cluster 1 ($N = 135$) were above average participators; they also exhibit above average social impact, responsiveness, newness and communication density, coupled with high internal cohesion. Learners in these clusters are investing a high degree of effort in the discussions and display self-regulatory and social-regulatory skills. Not only are these individuals responsive to other learners, but they are engaging in effective information sharing and their contributions seem to warrant further discussion from the group members or provide new information (i.e., social impact and newness). This suggests these learners are invested in the prevailing social climate. Cluster 2 ($N = 363$), makes up more than half of the MOOC learners. Here, we see learners with only average participation, but when they do contribute, they attend to other learners' contributions and provide meaningful information that furthers the discussion (i.e., overall responsiveness, and social impact). It is interesting to note that these students are not among the highest participators, but their discourse signals a social positioning that is conducive to a productive exchange within the MOOC interactions. This pattern is suggestive of a student that is engaged in the interaction, but perhaps takes a more thoughtful and deliberative stance, than learners in cluster 1. Cluster 3 ($N = 27$), is the smallest cluster and was characterized by learners who have the highest participation, newness, communication density and second highest internal cohesion, however very low scores across all other measures. This suggests that, when they contribute, their discourse is more in response to themselves than other MOOC learners since they exhibit relatively higher internal cohesion than responsiveness or social impact. Furthermore, their contributions do not seem to warrant further discussion from learners. This pattern might be reflective of individuals driving the discourse agenda forward by offering a larger volume of contributions as compared the Cluster 1 or 2. In contrast to the cluster 1 and cluster 2 these learners have a higher degree of internal cohesion compared to social impact or responsiveness, which signals the they may be more concerned with a personal narrative than with productive peer interactions. It is plausible that these learners are highly motivated, exhibiting strong individual learning goals through their leadership and at times dominance in the discourse. Cluster 4 ($N = 119$), in contrast, is characterized by a combination of low responsivity, internal cohesion, social impact, and participation, coupled with high newness and average communication density. This pattern is similar to lurking and off-topic behaviors. Overall, the four-cluster model appears, at least upon an initial visual inspection, to produce meaningful MOOC learner profiles. We then proceeded to evaluate the quality and validity of this model.

In the current research, we evaluated the internal, cluster coherence, and stability validation criteria. A commonly reported internal validity measure, Silhouette, measures how well an observation is clustered by estimating the average distance between clusters and ranges from -1, indicating that observations are likely placed in the wrong cluster to 1, indicating that the clusters perfectly separate. The average silhouette (AS) for our model was positive (AS = .38), indicating the MOOC learners in a cluster had higher similarity to other learners in their own cluster than to students in any other cluster. A MANOVA, ANOVAs, followed by Tukey's *post hoc* were used to evaluate cluster coherence or the extent to which learners in the cluster groups significantly differed from each other on the six GCA variables. This coherence evaluation showed that the four-cluster model exhibited nice

separation across the GCA measures. The stability and validity of the cluster model was assessed using a non-parametric bootstrapping procedure (B=100 runs), which resampled from the original data with replacement to construct bootstrap matrices and clusters, and iteratively used the *Jaccard coefficient* to compute the structural similarity of the resampled clusters with the cluster derived from the original data. The Jaccard's similarity values showed very strong prediction for all four clusters with .96, .97, .93, and .88 for clusters 1-4, respectively. Given the extent of these evaluations, we feel that the identified learner profiles can be considered as robust and stable constructs in the space of scaled peer interactions, and that the GCA measures capture the critical socio-cognitive processes necessary for identifying such profiles.
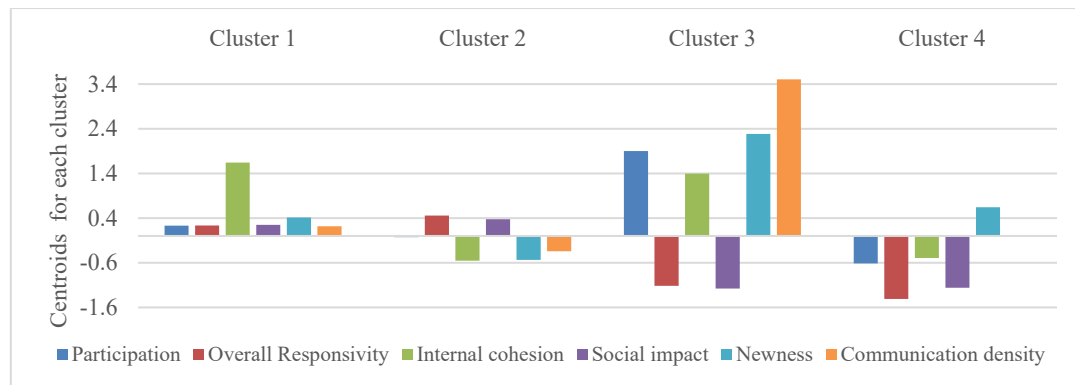
Figure 1. Centroids for the four-cluster solution across the GCA variables.

Discussion

A primary objective of this research was to evaluate the application of a new methodological approach, *Group Communication Analysis* (GCA), in the context of scaled peer-interactions. There are multiple lenses by which one might view discourse and learner profiles in scaled learning environments (Chua, Tagg, Sharples, & Rienties, 2017; e.g., Hecking, Chounta, & Hoppe, 2016; Kizilcec et al., 2013). The GCA lets us view discourse as a dynamic and evolving sociocognitive process that resides in the interaction between learner's communicative contributions. Our results suggest that these sociocognitive discourse patterns, as captured by the GCA, diagnostically reveal MOOC learner interaction profiles, and that the observed patterns are robust. The study presents initial interpretation of the clusters and the methodological validation of such profiling. However, further validation of these profiles is needed including triangulating qualitative analysis of individual learner discourses, as well as replicating the results in other contexts, and understanding the behaviors and learning outcomes associated with different profiles.

The findings present some methodological, and practical implications scaled peer-interaction research in the L@S, Artificial Intelligence in Education (AIED), and Learning Science communities. The application of the GCA to scaled peer-interactions represents a novel methodological contribution, capable of detecting distinct patterns of interaction representative of the learner profiles in MOOC interactions. The natural language metrics that make up the GCA provide a mechanism to operationalize such profiles, and insights into how they are constructed and maintained through the sociocognitive processes within scaled learning interactions. Moreover, as the methodology is readily automated, substantially larger corpora can be analyzed with the GCA than is practical when human judgements are required to annotate the data. Ideally, the GCA provides the greater learning sciences community with a toolkit to obtain objective, domain independent, and deeper explorations of the micro-level inter- and intra-personal patterns associated learners' interaction profiles.

The individual GCA measures and the detection of MOOC learners' interaction profiles could be of practical value for instructional designers of MOOCs. For instance, the internal cohesion of learners in cluster 1 was exceptionally high in comparison to the more socially oriented measures, like responsivity or social impact. Instructional designers could use this information to provide real-time scaffolding to encourage learners to reflect more on their peer's viewpoints. Such interventions could lead to the design of improved online learning environments and more collaborative, scaled peer-interactions.

The previous applications of GCA focused on detecting roles in small group interactions and validating the methodology in the context of practical learning outcomes (Dowell et al., 2018 under-review). A particularly notable discovery out of that research suggested the difference in outcome measures across the social roles was not a product of learners being more prolific during interactions. Instead it appeared that simply participating a lot was far less important than the nature of that participation (as captured by the internal cohesion, responsivity,

and social impact measures). That is, the quality of conversation, more than the quantity, appears to be the key element in the success for both groups and individuals in small group learning interactions. Our future research efforts will focus on further validating the clusters with human judgements and exploring the practical implications of the identified profiles with learning relevant processes, such as retention and performance in scaled learning environments.

References

Barron, B. (2000). Achieving coordination in collaborative problem-solving groups. *Journal of the Learning Sciences*, *9*(4), 403–436.

Bernard, R. M., Abrami, P. C., Borokhovski, E., Wade, C. A., Tamim, R. M., Surkes, M. A., & Bethel, E. C. (2009). A Meta-Analysis of Three Types of Interaction Treatments in Distance Education. *Review of Educational Research*, *79*(3), 1243–1289.

Borokhovski, E., Tamim, R., Bernard, R. M., Abrami, P. C., & Sokolovskaya, A. (2012). Are contextual and designed student–student interaction treatments equally effective in distance education? *Distance Education*, *33*(3), 311–329.

Boroujeni, M. S., Hecking, T., Hoppe, H. U., & Dillenbourg, P. (2017). Dynamics of MOOC Discussion Forums. In *Proceedings of the Seventh International Learning Analytics & Knowledge Conference* (pp. 128–137). New York, NY, USA: ACM.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (2000). *How people learn: brain, mind, experience, and school* (Exp Sub edition). Washington, D.C: National Academies Press.

Çakır, M. P., Zemel, A., & Stahl, G. (2009). The joint organization of interaction within a multimodal CSCL medium. *International Journal of Computer-Supported Collaborative Learning*, *4*(2), 115–149.

Chan, C. K. K. (2012). Co-regulation of learning in computer-supported collaborative learning environments: a discussion. *Metacognition and Learning*, *7*(1), 63–73.

Charrad, M., Ghazzali, N., Boiteau, V., & Niknafs, A. (2014). NbClust: An R package for determining the relevant number of clusters in a data set. *Journal of Statistical Software*, *61*(6).

Chua, S. M., Tagg, C., Sharples, M., & Rienties, B. (2017). Discussion analytics: Identifying conversations and social learners in FutureLearn MOOCs. In L. Vigentini, W. Y. P. L, & M. L. Urrutia (Eds.), *7th International Learning Analytics and Knowledge Conference* (pp. 36–62). ACM.

Clark, H., & Brennan, S. E. (1991). Grounding in communication. In L. B. Resnick, J. M. Levine, & S. D. Teasley (Eds.), *Perspectives on socially shared cognition* (pp. 127–149). Washington, DC: American Psychological Association.

Dillenbourg, P., & Traum, D. (2006). Sharing solutions: Persistence and grounding in multimodal collaborative problem solving. *Journal of the Learning Sciences*, *15*(1), 121–151.

Dowell, N. M., Nixon, T., & Graesser, A. C. (2018). Group communication analysis: A computational linguistics approach for detecting sociocognitive roles in multi-party interactions. *[revise and Resubmit] Behavior Research Methods*. Retrieved from https://arxiv.org/abs/1801.03563

Dowell, N. M., Skrypnyk, O., Joksimović, S., Graesser, A. C., Dawson, S., Gašević, S., … Kovanović, V. (2015). Modeling learners' social centrality and performance through language and discourse. In C. Romero & M. Pechenizkiy (Eds.), *Proceedings of the 8th International Conference on Educational Data Mining* (pp. 250–257). International Educational Data Mining Society.

Gorman, J. C., Cooke, N. J., & Kiekel, P. A. (2004). Dynamical perspectives on team cognition. *Proceedings of the Human Factors and Ergonomics Society … Annual Meeting Human Factors and Ergonomics Society. Meeting*, *48*(3), 673–677.

Gorman, J. C., Foltz, P. W., Kiekel, P. A., Martin, M. J., & Cooke, N. J. (2003). Evaluation of latent semantic analysis-based measures of team communications content. *Proceedings of the Human Factors and Ergonomics Society … Annual Meeting Human Factors and Ergonomics Society. Meeting*, *47*, 424–428.

Graesser, A. C., Dowell, N. M., & Clewley, D. (2017). Assessing Collaborative Problem Solving Through Conversational Agents. In A. A. Davier, M. Zhu, & P. C. Kyllonen (Eds.), *Innovative Assessment of Collaboration* (pp. 65–80). Springer International Publishing.

Han, J., Pei, J., & Kamber, M. (Eds.). (2011). *Data mining: Concepts and techniques*. Boston, MA: Elsevier.

Hecking, T., Chounta, I.-A., & Hoppe, H. U. (2016). Investigating Social and Semantic User Roles in MOOC Discussion Forums. In *Proceedings of the Sixth International Conference on Learning Analytics & Knowledge* (pp. 198–207). New York, NY, USA: ACM.

Hecking, T., Chounta, I. A., & Ulrich Hoppe, H. (2017). Role Modelling in MOOC Discussion Forums. *Journal of Learning Analytics*, *4*(1), 85–116.

Hesse, F., Care, E., Buder, J., Sassenberg, K., & Griffin, P. (2015). A framework for teachable collaborative

problem solving skills. In P. Griffin & E. Care (Eds.), *Assessment and teaching of 21st century skills* (pp. 37–56). Springer Netherlands.

Hmelo-Silver, C. E., & Barrows, H. S. (2008). Facilitating collaborative knowledge building. *Cognition and Instruction*, *26*(1), 48–94.

Hrastinski, S. (2008). What is online learner participation? A literature review. *Computers & Education*, *51*(4), 1755–1765.

Joksimović, S. a., Gašević, D. a., Loughin, T. M. c., Kovanović, V. b., & Hatala, M. d. (2015). Learning at distance: Effects of interaction traces on academic achievement. *Computers and Education*, *87*, 204–217.

Joksimović, S., Dowell, N., Poquet, O., Kovanović, V., Gašević, D., Dawson, S., & Graesser, A. C. (2018). Exploring development of social capital in a CMOOC through language and discourse. *The Internet and Higher Education*, *36*(Supplement C), 54–64.

Kizilcec, R. F., Piech, C., & Schneider, E. (2013). Deconstructing Disengagement: Analyzing Learner Subpopulations in Massive Open Online Courses. In *Proceedings of the Third International Conference on Learning Analytics and Knowledge* (pp. 170–179). New York, NY, USA: ACM.

Klein, G., Feltovich, P. J., Bradshaw, J. M., & Woods, D. D. (2005). Common ground coordination in joint activity. In *Organizational Simulation* (pp. 139–184). John Wiley & Sons, Inc.

Kreijns, K., Kirschner, P. A., & Jochems, W. (2003). Identifying the pitfalls for social interaction in computer-supported collaborative learning environments: A review of the research. *Computers in Human Behavior*, *19*(3), 335–353.

Malmberg, J., Järvelä, S., & Järvenoja, H. (2017). Capturing temporal and sequential patterns of self-, co-, and socially shared regulation in the context of collaborative learning. *Contemporary Educational Psychology*, *49*(Supplement C), 160–174.

Mesmer-Magnus, J. R., & Dechurch, L. A. (2009). Information sharing and team performance: a meta-analysis. *The Journal of Applied Psychology*, *94*(2), 535–546.

Oecd. (2013). *PISA 2015 collaborative problem solving framework*. Oxford, U.K: OECD Publishing.

Poquet, O., Dawson, S., & Dowell, N. (2017). How Effective is Your Facilitation?: Group-level Analytics of MOOC Forums. In *Proceedings of the Seventh International Learning Analytics & Knowledge Conference* (pp. 208–217). New York, NY, USA: ACM.

Price, E. F. (1981). Toward a taxonomy of given/new information. In P. Cole (Ed.), *Radical Pragmatics*. New York, NY: Academic Press.

Reimann, P. (2009). Time is precious: Variable- and event-centred approaches to process analysis in CSCL research. *International Journal of Computer-Supported Collaborative Learning*, *4*(3), 239–257.

Roschelle, J., & Teasley, S. D. (1995). The construction of shared knowledge in collaborative problem- solving. In C. E. O'Malley (Ed.), *Computer-supported collaborative learning* (67–97). Berlin: Springer-Verlag.

Stahl, G. (2017). Group practices: a new way of viewing CSCL. *International Journal of Computer-Supported Collaborative Learning*, *12*(1), 113–126.

Stahl, G., Koschmann, T., & Suthers, D. D. (2006). Computer-supported collaborative learning: An historical perspective. In R. K. Sawyer (Ed.), *Cambridge handbook of the learning sciences* (pp. 409–426). Cambridge: Cambridge University Press.

Stahl, G., & Rosé, C. P. (2013). Theories of Team Cognition: Cross-Disciplinary Perspectives. In E. Salas, S. M. Fiore, & M. P. Letsky (Eds.), *Theories of team cognition: Cross-disciplinary perspectives* (pp. 111–134). New York, NY: Routledge.

Suthers, D. D., Dwyer, N., Medina, R., & Vatrapu, R. (2010). A framework for conceptualizing, representing, and analyzing distributed interaction. *International Journal of Computer-Supported Collaborative Learning*, *5*(1), 5–42.

Wise, A. F., Speer, J., Marbouti, F., & Hsiao, Y.-T. (2012). Broadening the notion of participation in online discussions: examining patterns in learners' online listening behaviors. *Instructnl. Science*, *41*, 323–343.

Yang, D., Sinha, T., Adamson, D., & Rose, C. P. (2013). Turn on, Tune in, Drop out": Anticipating student dropouts in Massive Open Online Courses. In *Proceedings of the 2013 NIPS data-driven education workshop* (pp. 1–8). NIPS Foundation.

Zimmerman, B. J. (2001). Theories of self-regulated learning and academic achievement: An overview and analysis. In B. J. Zimmerman & D. H. Schunk (Eds.), *Self-regulated learning and academic achievement: theoretical perspectives*. Mahwah, N.J.: Lawrence Erlbaum Associates Publishers.

Acknowledgements

Transhumanism and Education:
Embodied Learning in an Era of Altered Bodies

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Abstract: In the past decade, both cognitive science and the learning sciences have been significantly altered by an increased attention to the theme of *embodiment*. Broadly speaking, this theme complements (or pushes back against) the notion of purely abstract, "disembodied" cognition and emphasizes the role of physical interaction with the environment in the course of learning and development. A common, if usually implicit, assumption in this work is that learners' bodies are more or less constant from one era to another: after all, human senses, limbs, physiology, and the basic parameters of cognition are part of an ongoing evolutionary human endowment. This assumption, while historically reasonable, is likely to need reconsideration in the near future, as a variety of "transhumanist" technologies (enhanced senses, bodies, and internalized interfaces with the outside physical environment) become more prevalent in children's lives. This paper discusses several foundational issues and questions that are poised to emerge, and to challenge our enduring ideas about children and education, in the foreseeable future.

Introduction: Embodied learning and human enhancement

As a field, the learning sciences by now has a sufficiently long history (over 25 years since the founding of the flagship journal) so that it is possible to identify "phases" of disciplinary interest. Whereas the earlier years of research focused primarily on applying computational cognitive models to educational scenarios (e.g., by studying cognitive misconceptions in students, or creating intelligent tutoring systems based on symbolic models of the learners' cognition), the past decade has witnessed an increased attention to the notion of *embodiment* in learning. Broadly speaking, this notion emphasizes a number of core ideas: (a) that cognition and learning cannot be thoroughly understood without attention to the physical and environmental context in which they are manifested, (b) that brains and their associated bodies (whether human, animal, or robot) must be studied as an interrelated system, and (c) as a consequence, purely abstract symbolic formalisms (of the sort associated with traditional cognitive science) are an insufficient basis for studying and improving learning and education. (For eloquent extended statements of this argument, see for instance Clark (1997), Pfeifer & Bongard (2007), and Gallagher (2005).)

The application of these rather general ideas to specific educational projects takes a variety of forms. Some research has focused on creating physical objects or experiences that promote understanding of abstract mathematical ideas (Abrahamson, 2017; Hall & Nemirovsky, 2011); in a sense, this work could be seen as a continuation of an earlier tradition of "mathematical manipulatives" (such as number rods, clock faces, or geoboards) to provide a real-world scaffolding to notions such as numbers or modular arithmetic. Other efforts have focused on "full-body" interfaces and activities in which children move within larger settings that illustrate mathematical or computational ideas (Ma, 2017; Malinverni & Pares, 2014). Yet another style of work has pursued the tradition of "hands-on" science and engineering education, often in conjunction with new technologies and computational media, creating novel scientific instruments or construction materials (Blikstein *et al*., 2016; Resnick *et al*., 2000; Eisenberg *et al.,* 2002). Computationally-enriched wearables have been employed as an entrée to computer science, engineering and the natural sciences (Buechley *et al*., 2013), integrating bodily movement with a variety of educational content. In short—and this is only a brief sketch of the territory—it is now fair to say that the perspective of embodiment has become increasingly central and productive within the learning sciences and the design of novel educational technologies.

While the "embodied learning sciences" arguably take a non-traditional stance toward cognition and educational design, at the same time they have implicitly, almost reflexively, taken a highly traditional–even conservative–stance toward the "bodies" in which embodied education takes place. There appears to be, in all this research, a steadfast (and admittedly historically plausible) assumption that the basic physical parameters of "the student" are constant, from one era to another. According to this view, students--like all human beings--have more or less the same sensory endowment; likewise, they share the same basic, evolutionarily determined human morphology and physiology. (1) As a result of this assumption of "bodily constancy", the focus of design in the embodied learning sciences is on *the external environment*–creating new scientific instruments, classroom apparatus, physical experiences, and enriched settings. The essential idea behind this sort of design is

that, by altering the external world and creating a richer or more instructive physical environment, we can accommodate the tangible or kinesthetic dimensions of student learning.

The purpose of this paper is to challenge this (usually unstated) notion of bodily constancy, and to argue that emerging movements in technology create the opportunity to rethink the "embodied learning sciences" from the perspective of changing the nature of the body itself. Before expanding on this idea, however, it should be noted–as an important prefatory note–that in the enduring practice of mathematics and the natural sciences, "embodiment" is often considered as something of a hindrance to understanding. This theme would not have been unfamiliar to Plato, whose veneration of classical geometry was combined with a distrust of physical bodies that had never actually experienced, in the course of real living, ethereal objects such as a "circle" or "straight line". More generally, much of scientific and mathematical content is difficult to learn (and to teach) precisely because it challenges the assumptions of day-to-day physical experience. Understanding Newtonian mechanics is made more arduous by the ubiquitous role of friction in our everyday world; quantum mechanics, with its notions of photons that somehow pass (with a given probability) between two separated slots at once, is even more puzzling. Scientific ideas that play out over long periods of time–continental drift, the evolution of species–are hard to envision; vast differences of scale (the distance between the earth and moon compared to the distance between the earth and sun) are problematic; events that take place at time-scales too short for human perception (e.g., the physical deformation of a batted ball when it is first hit) render ideas from basic physics more mysterious. For this reason, much of the attention to "embodied learning" centers–as it must–on translating abstract or physically unfamiliar content into the comfortable zone of basic, biological human understanding.

Transhumanist technologies: altering "embodiment" in education

It now appears that "basic, biological" human understanding can itself be a target of experimental redesign. The reason for this development is that a variety of new technologies are beginning to enable extension or alteration of human sensing, action, and cognition. (Cf. Barfield, 2015; Jebari, 2015; Lilley, 2013; Seedhouse, 2014.) Not all of these technologies are at equivalent stages of development or deployment; some may achieve the status of availability (by hobbyists, researchers, commercialization) before others; and many pose a variety of thorny, even disturbing, ethical or intellectual questions. Nonetheless, there is clearly a kind of collective momentum visible in the move toward these *transhumanist* technologies for human enhancement. Even if some of the more futuristic ideas never materialize, the most plausible of these technologies–those which are likely to become available in *some* form over the next decade or two–bid fair to profoundly alter our ideas about learners' bodies and minds, and thus in turn alter the opportunities and boundaries of embodied learning.

The main lines of technological development, for the purposes of this discussion, fall into three general categories:

Sensory extension. One body of work in transhumanist development involves the extension, elaboration, or customization of human senses. In one simple (and early) instance of the idea, Platoni (2015) describes a small community of hobbyist "body-modders" who implant small magnets in their fingers; as a result, they are able to "feel" nearby magnetic fields (including, as it happens, the fields generated by alternating current sources). The current state of the art for most of these devices is still rather primitive, but there are clear avenues for further experimentation (assuming that there is the will for both researchers and potential subjects to make the attempt). For instance, while devices such as cochlear implants are generally conceived as restorative devices, it is not hard to imagine variations of such implants that would enable the wearer to "hear" sounds at frequencies or amplitudes outside the normal human range of sensation. The most extreme versions of sensory extension involve this sort of internal bodily modification (e.g., via implants); but many less extreme technologies–for instance, wearables for long-term usage–might have analogous effects. People with eyeglasses or contact lenses already know something of the power of "external" sensory enhancements when these become near-constant presences at the surface of the body. One might imagine similar sorts of attachments for (among other possibilities) "hearing" ultrasound, "seeing" the polarization of light, or "smelling" traces of organic solvents. As the design techniques for such extensions become more nuanced, one might expect a move toward tunable or selectively deployable senses: a person might, for example, choose to see varying light frequencies under different circumstances. For the purposes of embodied learning, then, the upshot of these technologies could be a steady alteration both in the *range* of sensation (what we can see, hear, smell, or touch) and in the *conscious control* of sensation (when we choose to deploy various sensory extensions).

Bodily/actuator extension and brain-machine interfaces. While the previous examples focused on the extension of what we can *sense*, it is likewise possible to extend the range and nature of actions that can be taken with the body. Current work in robotic exoskeletons and customized or high-performance prosthetics (see Piore (2017), Ch. 1) augurs an expanding landscape of bodily actions. In many instances, such extensions to

bodily actuation are complemented by novel types of brain-machine interfaces; in the most straightforward examples, signals from an externally placed electroencephalogram (EEG) "cap" might be used to control limbs or actuators even at some distance from the physical body. One might imagine, then, new limb-like devices that allow people to grip objects of very small size, or of extremely high fragility (like certain types of bubbles in air); other types of extensions might permit people to extend the frequency range of their voices (e.g., for communication with certain animals, or with appropriately enhanced human sensory apparatus). As with sensory extensions, the distinction between an "external" augmentation (a handheld tool, for example) and an "inbuilt" augmentation (a prosthetic limb, for example) admits of many intermediate variants. Likewise, and again as with sensory extensions, the design issues include not only the nature or range of the bodily extension in question but the types of interfaces that we could use to control or tune these extensions: under some circumstances we might, say, elect for different types of hand-grips.

Cognitive and genetic enhancement. Probably the most controversial of plausible enhancements to human performance is through the direct alteration of an individual's genome via techniques of genetic manipulation. The advent of CRISPR technology (Doudna & Sternberg, 2017) has greatly altered the accuracy, ease, and affordability of such alteration (though it is almost certain that CRISPR is itself not the last word in genetic therapy). Some types of genetic alterations (e.g., to remedy the mutation that causes sickle cell anemia (Ledford, 2016)) have relatively straightforward and predictable effects, while many others (e.g., attempting to change genes to "improve intelligence") are far more complex and poorly understood. It is nonetheless likely that we will eventually-perhaps in the near-term future–begin to see efforts to link genetic alterations to "enhancements" of various types. These efforts may take the form of animal experiments, life-saving experiments in humans, or "hobbyist" attempts (whether illicit or ill-informed) much like those of the body-modders in Platoni's account. Over time, it is likely that the connection between such efforts and issues of learning or cognition will become too prominent and urgent to avoid notice. A less dramatic–and more immediate–issue has to do with the use of pharmacological methods of (particularly cognitive) enhancement. (Cf. Wenner Moyer, 2016.) The efficacy, safety, and specificity of many "cognitive-enhancement" substances are still much in debate (caffeine, nicotine, and Modafinil are among the substances investigated); it may not be too much of a stretch, however, to imagine the development of substances whose direct advertised purpose is to (e.g.) improve mathematical cognition, manual dexterity, or other functions of brain and body. For both genetic and pharmacological enhancement techniques, the target of improvement is biochemical–the intent is not to add some sort of novel material to the body (as in cochlear implants) but rather to alter the fundamental chemistry of the learner's body itself.

These emerging technologies leave us with a number of larger questions–perils as well as opportunities–for education and learning. Broadly speaking, there are many reasons to believe that the effects of these technologies on educational issues–on the lives of young people in general–will be profound. The consensus within the "embodied cognition" literature is that the functions of the human mind are intimately linked with those of the body. By implication, alterations to the body should in turn produce alterations to the mind. A person able to perceive fluid flow (via sight or touch) with high accuracy might in turn have an unexpected way of understanding fluid dynamics. A person able to feel the textures of solid objects with high precision might have a unique style of working with ceramics or stone. A person able to distinguish colors or tones in a novel manner might create unexpected graphical or musical compositions. A person who is able–genetically or pharmacologically–to concentrate on abstractions for extended periods of time might have advantages in certain types of mathematical reasoning.

As the range and specificity of enhancements evolves in time, so too will the issues posed for learning and education. Several of these issues will be discussed in the final section of this paper, but it is clear that issues of safety (what are the downsides of "enhancement"?), equity (will enhancement only be available to the very wealthy?), and choice (who gets to decide whether and when these technologies should be employed?) are paramount. Other questions–perhaps less central, but still fascinating–are likely to arise as well. Will it be possible (or desirable) to design new curricula for students with altered bodies? Might one create a physics curriculum for those able to sense a wider range of electromagnetic radiation; or a chemistry curriculum for students with enhanced 3D visualization skills? Might it be possible to design new types of interfaces for students with (say) enhanced manual apparatus or extreme levels of hand-eye coordination? Pursuing these scenarios, the advent of enhancement technologies poses deep questions for the disciplines themselves. Perhaps, as a society, we prefer *not* to encourage or allow certain types of human augmentation, even if that augmentation might be done in the service of creating new mathematical, scientific, or artistic ideas. That is, we might collectively decide that a goal like "the advancement of mathematics" is secondary to some essential notion of human constancy or limitation.

The remainder of this paper will discuss several general issues at the intersection of human enhancement and the learning sciences. We will explore in turn the themes of designing extended senses for science education; creating new types of physical apparatus or experiences for altered bodies; and treating the learner him- or herself as a target of "educational technology design". In the final section of the paper we explore several of the (very pronounced) ethical issues that are likely to emerge as techniques of "enhancements for learning" evolve over time.

Human enhancement and its impact on education: Several scenarios

The previous section outlined the general argument that technologies for human enhancement are likely to have a powerful impact on the practice of education, and on cognitive science more generally. In this section, we discuss several possible avenues by which this impact might be manifested.

Extended senses for science education

As noted earlier, the evolutionary limitations of human perception pose an enduring challenge for science education. It is hardly surprising that we intuitively believe that the earth is flat, that land masses (like continents) don't move over time, that stars are eternal, or that air is continuous rather than particulate in nature: these are the beliefs consistent with our everyday experience and sensory apparatus. One line of pursuing science education, then, would be to begin by designing devices and techniques for extending human perception in ways that mesh with scientific notions beyond those for which we are originally adapted.

A natural inspiration for sensory enhancement exists already in the animal world. Bees are capable of detecting the polarization of sunlight; eagles have far more acute distance vision than human beings; star-nosed moles "feel" the earth in front of them with their remarkable noses; dogs can respond to tones beyond the range of human hearing; fish use their lateral line sensory organ to detect nearby disturbances of water currents. In each of these cases–and many more–one need not postulate an "unnatural" sensory talent (like "seeing" at an atomic scale); we already have existing biological models of potentially expanded cognition. A transhumanist "style" of educational design would be to create sensory augmentations to which students could adapt over long periods of time (e.g., through wearables or implantation) rather than external laboratory apparatus: for instance, rather than designing a handheld microphone for detecting sounds available to dogs, the transhumanist approach would be to design earphones (or, in more extreme form, novel forms of implants) to extend the student's everyday perception of sound. Realistically, augmentations of this type would be designed to be reversible, either by removing a wearable or by "turning off" specific effects of a particular implanted device. The (admittedly early) experience of Platoni's body-modders suggests, however, that sensory extensions are perceived as benefits by their recipients, and it might well be that young scientists will, over time, strongly prefer to extend their sensory abilities in various ways.

Not all animal-themed sensory extensions need be "simple" extensions for extending the physical range of sight or hearing. One might design computationally enriched extensions that are more complex in nature, aligned with the social demands of particular species. For example, songbirds are particularly alert to the calls of members of their own species; one might therefore design sensory extensions for "picking out" the calls of particular species of birds. A student equipped with this type of augmentation might have a "tunable" sense of hearing, alert to distinct calls at different times. In the same vein, sensors for specific pheromones could give students a particular ability to detect the nearby presence of particular insect species; or sensors for particular types of pollen could be used to note the presence of certain plants. Even in human affairs, sensors of this complex type might have their uses: a computational sensor for (e.g.) levels of vocal stress, or particularities of facial expression, might be employed as an informal (and imprecise) "lie detection" organ, or a sensor for particular accents, patterns of speech, and word usage might be used as a "geographic origin" detector.

The notion of making such sensory extensions "tunable" is likely be a recurrent one. For instance, one might design highly sensitive tactile wearables that would allow students to touch surfaces and (if the touch sensation were modeled on that of a fly, or spider) "feel" the irregularities in even a smooth surface such as wood paneling. Conceivably this sort of wearable would allow for varying range of sensitivities so that the user could feel surfaces at progressively higher levels of resolutions: "feeling" objects in the manner of a human, a mouse, a housefly, or a dust mite in succession.

Designing physical apparatus or scientific experiences for extended bodies

Most educational design in science education concerns the creation of sample experiments, experiences, or types of apparatus. In line with the examples of the previous subsection, it should be possible to create new types of educational materials for extended sensory and bodily functioning. One might imagine creating circuit design kits for students equipped with sensory augmentations to "feel" the nearby presence or absence of direct current

(there are a variety of ways of imagining the engineering of such augmentations); or a chemical indicator for students with an augmented or extended perception of color.

Many possible examples along these lines could be constructed by creative redesign of "classical" school experiments and apparatus. For example, a venerable scientific toy is the "tornado in a bottle" in which water is swirled within a plastic bottle (draining into another) to create a pattern much like a whirlpool. One limitation of this toy is that the fluid phenomenon can only be seen from the outside: the student can see the "tornado" as from an external camera, but not from the perspective of a person caught within the tornado itself. It might be possible to give students experiences with a panoramic cylindrical "eye" designed for such apparatus; by placing the eye toward the center of the upper bottle, and by conveying the visual input from that eye to the student, it might be feasible to experience this (and other) fluid phenomena "from within". The utility of this sort of apparatus would depend on the student's ability to interpret visual input from novel geometries of "eye-like" devices (e.g., cylindrical or spherical "eyes" (cf. Krishnan & Nayar, 2009)); this in turn might be the subject of studies in human sensory augmentation.

Still other traditional science experiments could be the subject of experimentation with devices for augmented sensing or actuation. One might create extensions to fingertips so that they could feel the surface tension of liquids (a subject of the classical "floating needle" demonstration), or so that they could have an enhanced perception of static electricity (the focus of the "balloon adhering to a sweater" demonstration). The purpose of these types of scenarios would not be to redesign simple experiments into horribly complex or expensive variants, but rather to provide opportunities to investigate the potential for enhanced sensing of scientific phenomena.

Transhumanist technologies as part of "learner design"

Over an extended period of time, it is plausible that the language of educational design will begin to incorporate the affordances of transhumanist technology. Traditionally, educational designers think of themselves as creating *external* materials for a (more or less constant) human physiology. We create scientific visualizations and notations for standard human eyes and visual systems; we create instrumentation and physical materials to be operated and shaped by standard human hands; we devote more time to explaining those concepts that are least consonant with human experience.

This type of education implicitly assumes that we can only teach what human minds and bodies can learn. And the physical body is an important element in this equation: indeed, one of the recurring themes of embodied cognition is the interdependence of "abstract" cognition and the affordances and constraints of our biological inheritance. The roboticist Rodney Brooks expresses the idea succinctly:

> "[T]he physical manifestation of the body is primary. The stuff of intelligence has evolved in conjunction with that body, and is a modulator of its behavior, rather than a primary and central control system." [In (Pfeifer & Bongard, 2007), p. xv.]

By altering, even in relatively mild ways, the constraints and affordances of the learning body, we can begin to explore alternative dimensions of human thinking and learning. Human bodies and senses are in fact not fixed quantities. Again, this is hardly an original observation: the results of early research in embodied cognition imply that human perception is in fact surprisingly malleable, mediated by historically evolving material and cultural artefacts. As Clark (2014) observes,

> "[H]uman cognition is structured by culturally distributed processes that spawn a succession of designer environments whose impact on the development and unfolding of human thought and reason can hardly be overestimated…. [T]he human-built environment becomes a potent source of a new intergenerationally transmissible structure that surrounds, scaffolds, and perhaps even fundamentally transforms the activity of our biological brains." [p. 245]

The overall implications of this line of thinking are that human cognition–the ideas and concepts available to us–are strongly influenced by the materials we use and the environments in which we develop. By the same reasoning, humans with extended or altered experience of their environments–through augmented sensation, a greater range of human actuation and functioning, or genetically mediated alteration of sensation, cognition, and control–are likely to develop different types of cognitive strengths and limitations from those with which we have become familiar over evolutionary time.

For the learning sciences, education will thus increasingly be viewed as a potentially integrated system of both experience design and what might be called "learner design". A physics curriculum may be conceived as

a combination of material to be learned, media and environments through which to highlight and present that material, and human faculties through which to interact with those media and environments. A music curriculum may be conceived as a combination of instruments for performance and composition, and human bodies and senses tailored to those instruments. A foreign language curriculum may be conceived as materials and experiences to present the language and sensory extensions to hear and distinguish novel phonemes with greater ease.

The upshot of this sort of development might be that new *types* of material could eventually be learned. It might be possible to create mathematical "manipulatives" or experiences to communicate ideas of non-Euclidean geometry or four-dimensional spaces. It might be possible to design or teach specific forms of mathematical or physical analogs to synesthesia, linking distinct modes of perception: just as people with the condition sometimes report that numerals are linked to colors in their minds, one might imagine (say) links between colors and imaginary numbers, or between musical tones and specific types of matrices.

At this stage in our argument, it is likely that the reader is experiencing a salutary sense of caution (or perhaps alarm): what is happening, or is about to happen, to education and (more broadly) the human condition itself? These questions are indeed urgent, and they are the subject of the final section of this paper.

Human enhancement and education: Social and ethical issues

As with any long-term (and speculative) discussion of major technological change, the social and ethical issues raised are complex; this is particularly true when the plausible long-term changes are likely to impact basic notions of "human nature" itself, and when the eventual subjects of change are likely to include children and adolescents. Broadly, there are several recurring strains in this sort of discussion–strains that have in their way become clichés, but are no less important for being commonplace. One such strain is that technological change tends to be accompanied by unexpected (and often malign) side-effects. In urbanized society, problems such as environmental degradation, diseases linked to diet (such as diabetes), loss of privacy, and many others are intimately connected to technological developments that were originally envisioned with human betterment in mind. Another recurring strain is the notion of "technological inevitability": the notion here is that as technology becomes available, there is little we can do to control its use. If (say) technologies such as genetic alteration or cognitive-enhancing pharmaceuticals are invented, people are going to experiment with them regardless of the potential dangers to themselves or their communities.

In the case of transhumanist technologies, a number of social and ethical issues deserve particularly close examination:

Safety. We have very little experience–very little to go on–in assessing the long-term impact of transhumanist extensions on human health and safety. What would it mean for someone to actually experience an enhanced sense of hearing or touch over a period of years or decades? What would it mean for a child to grow up, from an early age, with the ability to see wavelengths outside the normal human range? What would it mean for a person to control, over extended periods, novel sorts of limbs with functionality beyond those of human limbs?

In our view, the short (and honest) answer is that no one can possibly know the answers to these questions in the absence of experimentation; and (to borrow from the "technological inevitability" theme) it is overwhelmingly likely that there will indeed be certain people, like Platoni's body-modders, all too willing to experiment on themselves. If history is any guide, these people will primarily be teenagers or young adults; and thus, the longitudinal nature of the experimentation will follow from the self-selection of the subjects. While it is certainly possible that dangers will be unearthed in this process, it must nevertheless be pointed out that a myriad of technological developments over the past century–motion pictures, television, accessible recorded music, home computers, mobile phones, and many more–have themselves been "social experiments" performed on child subjects. There has been, and continues to be, intense argument over the effects of television viewing on children; more recent books (Twenge, 2017; Freitas, 2017) have pointed out the downsides of social media for their young users. The point here is not to disparage the potential dangers of transhumanist technologies, but merely to note that there is nothing unique in the deployment of technology with unknown and well-intentioned, but potentially adverse, effects. It would be desirable if these new technologies could be held to a higher standard of safety than previous technologies; but there is little reason at present to predict that this will be the case.

Availability and Equity. Another prominent issue raised by transhumanist technologies is that of equity: if such technologies do indeed prove desirable, will they be accessible only to certain select (most likely, wealthy) people? In the worst case, one might imagine a broad sort of growing "divide" between those who have access to technologies for extension and those who do not; and the sense of this divide will be felt most keenly among younger populations. Again, this is not the first time that such issues have been raised: unequal

access to the Internet, or to advanced medical technologies, is a painful manifestation of economic inequality. In our own view, one design principle to uphold as these technologies become more prevalent is to facilitate and allow inexpensive or "hobbyist-based" versions of the technologies, even at the concomitant risk of reduced regulation; but this will undoubtedly be a source of fierce debate in the near-term future.

Choice and Control. An especially disturbing issue in this context is that of choice: will individuals be able to determine whether or not they wish to experiment with various forms of human augmentation? This issue is highlighted by the applications to education and childhood development: should a parent be permitted to deploy some particular technological extension on his or her child? Conversely, should a parent always be *prevented* from deploying any technological extension on a child, regardless of the circumstances? At what age (if any) would we allow individuals to self-experiment: should eighteen-year-olds have the right to explore changes to their bodies or genomes without parental consent? A particular concern here is the potential commercialization of certain types of augmentation technologies: should companies be able to offer, and advertise, enhancement technologies as pharmaceutical firms currently do (with problematic results) with medications?

None of these issues, in our own view, is dispositive for rejecting the idea of transhumanist technologies out of hand, even if such rejection had a hope of being effective in the long term. The terrain here is highly complex, and the coming years are bound to be stormy ones for education and the learning sciences, and for society more generally. The argument here is that there is good reason to be excited and even optimistic about the possibility for human betterment, and for expanded possibilities for human achievement in the sciences, arts, and engineering, as a result of these emerging technologies. As human beings alter themselves, and their environments, they will experience new varieties of childhood–and new interpretations of the material and cultural worlds in which they grow.

Endnotes

(1) For the purposes of this necessarily brief discussion we will ignore important lines of work focusing on education for students with sensory or physical impairment.

References

Abrahamson, D. (2017). Embodiment and mathematics learning. In Peppler, K., ed. *The SAGE Encyclopedia of Out-of-School Learning*. Thousand Oaks, CA: SAGE Publications, pp. 248-252.

Barfield, W. (2015). *Cyber-Humans: Our Future with Machines.* New York: Springer.

Blikstein, P. *et al.* (2016). Using the bifocal modeling framework to resolve "discrepant events" between physical experiments and virtual models in biology. *Journal of Science Education and Technology*, 25(4), pp. 513-526.

Buechley, L. *et al.*, eds. (2013). *Textile Messages: Dispatches from the World of E-Textiles and Education*. New York: Peter Lang Publishing.

Clark, A. (1997). *Being There.* Cambridge, MA: MIT Press.

Clark, A. (2014). *Mindware.* (Second edition.) Oxford: Oxford University Press.

Doudna, J. & Sternberg, S. (2017). *A Crack in Creation.* Boston: Houghton Mifflin Harcourt.

Eisenberg, M., *et al.* (2002). Computationally-enhanced construction kits for children: prototype and principles. In *Proceedings of the International Conference of the Learning Sciences,* pp. 79-85.

Freitas, D. (2017). *The Happiness Effect.* New York: Oxford University Press.

Gallagher, S. (2005). *How the Body Shapes the Mind.* Oxford: Oxford University Press.

Hall, R. and Nemirovsky, R. (2011). Introduction to the special issue: modalities of body engagement in mathematical activity and learning. *Journal of the Learning Sciences,* 21: pp. 1-9.

Jebari, K. (2015). Sensory enhancement. In Clausen, J. and Levy, N., eds. *Handbook of Neuroethics.* Dordrecht, Netherlands: Springer.

Krishnan, G. & Nayar, S. (2009). Towards a true spherical camera. *SPIE Human Vision and Electronic Imaging.* (13 pages)

Ledford, H. (2016). CRISPR deployed to combat sickle-cell anaemia. *Nature*, October 12, 2016.

Lilley, S. (2013). *Transhumanism and Society*. Dordrecht, Netherlands: Springer.

Ma, J. (2017). Multi-party, whole-body interactions in mathematical activity. *Cognition and Instruction,* 35:2, pp. 141-164.

Malinverni, L. & Pares, N. (2014). Learning of abstract concepts through full-body interaction: a systematic review. *Educational Technology & Society* 17(4): pp. 100-116.

Pfeifer, R. & Bongard, J. (2007). *How the Body Shapes the Way We Think*. Cambridge, MA: MIT Press.

Piore, A. (2017). *The Body Builders.* New York: Harper Collins.

Platoni, K. (2015). *We Have the Technology.* New York: Basic Books.

Resnick, M., *et al.* (2000). Beyond black boxes: bringing transparency and aesthetics back to scientific investigation. *Journal of the Learning Sciences* 9(1): pp. 7-30.

Seedhouse, E. (2014). *Beyond Human.* Berlin: Springer.

Twenge, J. (2017). *iGen.* New York: Atria Books.

Wenner Moyer, M. (2016). A safe drug to boost brainpower. *Scientific American Mind*, March 1, 2016.

Acknowledgments

Scaffolding Peer Facilitation in Computer-Supported Problem-Based Learning Environments

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Abstract: In this study, we explore the forms of expert-like facilitation that are adopted by students in the context of a collaborative game-based learning environment centered on an ecological problem. Utilizing a case study approach, we examined four focus group discussions with middle school students (N=10) to explore the nature of peer facilitation in CSCL group processes to better inform our design iterations. Peer mediated feedback (Walker, Rummel, & Koedinger, 2009) can be supported by including simple prompts and further supported by attending to an activity system (Kaptelinin & Nardi, 2012), which includes the software system and classroom context to support student facilitation. Put differently, the ontology of CSCL group processes must consider different group formations to scaffold student facilitation and learning.

Background

Problem-Based Learning (PBL) is an instructional method that engages groups of students in collaborative problem solving and reflection of this process (Barrows, 2000). A critical element of PBL is the role that scaffolds, or supports that students receive in their learning process, which is often delivered by expert facilitators. While research in artificial intelligence and computer supported collaborative learning have successfully designed adaptive or intelligence-based scaffolds that explore how to support CSCL interactions and learning (for a review, see Magnisalis, Demetriadis, & Karakostas, 2011), most modeling techniques and software technologies focus on delivering explicit scaffolds to students (e.g., suggesting the next course of action). The research presented here represents an integration between the learning sciences and artificial intelligence focusing on how to scaffold group inquiry learning by attending to peer mediated feedback (Walker et al., 2009). Specifically, we focus on a facilitating a design space where the adaptive collaborative learning support (ACLS) system provide hints to students so that they can better support their peer's self-regulated learning, in addition to the direct feedback that students receive. We consider how this unfolds in the context of the collaborative game-based learning environment centered on an ecological problem. A primary goal of this work is to answer the following questions; 1) what forms of expert-like facilitation are undertaken by students in group inquiry and 2) what are the implications for designing adaptive scaffolds that support this process?

Theoretical framework

We adopt activity theory (Engeström, 1987; Kaptelinin & Nardi, 2012) as our primary theoretical lens in considering the forms of facilitation that students engage in as part of the PBL process. Activity theory considers learning as a collective activity, which consist of persons in activity (e.g., students and teachers, etc.) interacting with social others and material objects as they work towards individual and collective goals (known as the object). Additionally, participants' actions are mediated by tools, rules, and division of labor In a PBL scenario, students may take on roles (i.e., division of labor) to organize their work toward finding a solution to the problem at hand (i.e., the goal). These roles are often structured and defined by rules for action and interaction. Attending to these expectations in a group task as students use technology-rich learning environments will inform how to design the ACLS system.

Methods

The data sources are drawn from a larger study, which aimed to get feedback from students about design of a collaborative game-based learning environment centered on an ecological problem. In 45-minute activities, groups of middle school students (N=10) worked together to create a scientific model explaining on a whiteboard tool. Students used a Phenomenon-Mechanisms-Component (PMC) conceptual framework (Hmelo-Silver, Jordan, Eberbach, & Sinha, 2017) and explained how components (C) interact, giving rise to mechanisms (M) and/or ecological phenomenon (P).

There were four focus group sessions in two after-school clubs (three in one club; fourth in another). Due to the nature of the after-school club, there were a few returning participants in the multiple focus group sessions in the first club. In each activity, students generated a model explaining the decrease in fish population in a pond. Students were provided information about the problem in their journal, categorized according to Phenomenon (yellow), Explanations/Mechanisms (green) or Evidence (blue, Figure 1). To build their model, students moved information from their journal to a whiteboard. To facilitate the construction of the model, only Components of the statements (e.g., underlined concepts), and arrows that demonstrated the relationships among the Components, Evidence and Explanations could be manipulated by the students.
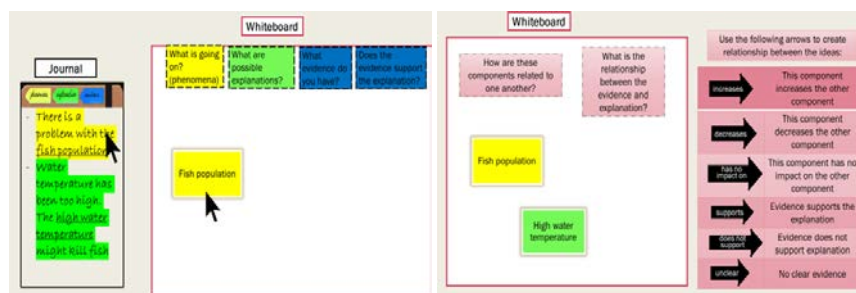
Figure 1. Information provided to students.

Two groups of students worked with physical pen and paper models that approximated ACLS interactions whereas another two worked used an online whiteboard tool to generate their models. These sessions were videotaped and transcribed. A case study approach was utilized to facilitate preliminary explorations of the nature of peer facilitation in group processes to better inform our design iterations. To answer our research questions, we adopted a fine-grained analysis of how students collaborated with one another to generate their models.

Results

Due to space constraints, we present key findings and present two excerpts that illustrate them. A key takeaway from the four sessions is the rich discussion that occur alongside students' physical and digital interactions when gathering information and using the whiteboarding tool. When using the whiteboard tool, students were oriented towards a shared goal of explaining the phenomenon, sharing their explanations and defending these explanations based on the information that they have. This pattern of discussion and negotiation was observed across all groups, even with limited expert facilitation. This suggests that students were able to manage the inquiry process by using the materials provided to them and adopted facilitation roles even when unassigned (see excerpt 1). In the following segment of discussion, students were provided with the physical model and provided with the prompts in the whiteboard (see figure 1). Students were tasked to generate a hypothesis as to why the fish is dying by explaining the relationship between temperature, algae, and dissolved oxygen.

Excerpt 1. Debating the mechanisms behind the fish kill phenomenon

1	Steve	Guys, my idea is this look it says that the fish um- ((*looks at background information*))
2	Neal	Are dying
3	Steve	((*reads information*)) Temperature, the temperature data shows that it has been an average of 90 degrees for this month
4	Neal	Which means the algae will grow
5	Steve	((*reads information*)) High water temperature does not kill this type of fish according to the vet
6	Neal	And also-
7	Steve	The fish are used to the high temperature-
8	Neal	Yeah
9	Steve	And so- the high temperature would make more algae and the more algae
10	Henry	Gets rid of
11	Steve	Some of them die and that makes more dissolved oxygen
12	Neal	No, the dissolved oxygen is good-
13*	Henry:	Is it?
14	Neal	Yeah, dissolved oxygen is good for fish

15	Steve	And then it doesn't give them very much sunlight [...] and they would die because they are used to the sunlight
16	Neal	I just want to say something
17	Steve	And they would die because of all the green muck on the pond
18	Jack	Let Neal say something
19	Neal	So so the sunlight is helping the algae live which means that the algae is um getting rid of um dissolved oxygen and dissolved oxygen is if there is not (.) it if there is low dissolved oxygen the fish die
20	Steve	Oh yeah
21*	Neal	And you're saying the opposite

The discussion highlights how students articulate, contest and/or build on each other's ideas (e.g., lines 2, 4, and 13). The students have a shared goal of developing a model that meets the rules of the PMC framework. We see a variety of moments where different mediators shape the groups collaborative inquiry (e.g., the information provided, student prompts). A mediating factor in this productive discussion is the facilitator role that these students take on as they work with one another (lines 13 and 18). Jack adopts a facilitator role, asking his peers to cede the floor for other voices (line 18). Steve, on the other hand, generates discussion by explicitly sharing the information to the group. The students in the discussion also make inferences based on the data provided (line 3 and 9). These actions mirror the processes that Quintana et al. (2004) suggest should be attended to when designing software scaffolds (e.g., sense making, process management, and articulation and reflection. A key takeaway is the context within which the discussion occurs. Given that students were creating the physical model, the discussion occurred as they were working with the model. We see similar productive group inquiry when students were using the digital tool to generate their model (excerpt 2).

Excerpt 2. Student and facilitator scaffolds in group inquiry when using a digital model

1*	Natalie	Algae doesn't increase the green muck. That doesn't make sense.
2	Evan	Yes it does because algae- dead algae is green muck.
3	Kate	Yeah. But then-
4	Natalie	So then the water temperature (5 second pause) the water temperature-
5	Kate	((*reading information from the screen*)) Yeah it says the green muck is actually dead algae.
6	Natalie	Yes, we know. Ok. So the water temperature also-
7	Evan	((*mutters*)) Ok it decrease-
8*	Natalie	So hold on. We have the sunlight that increases the algae, the algae which increases the green muck, even though they're the same thing, which makes zero sense. But, then it decreases the fish population so then -
9	Evan	((*working on the model as Natalie is speaking*)) The algae. Ok. The green muck also decreases algae. Er, has no impact on algae.
10	Natalie	Yeah
11	Evan	No- green muck decreases it because it is dead algae. Or something like that.
12	Natalie	The green muck is the same thing as the algae. So the algae cannot increase by green muck. And the green muck cannot decrease by algae.
13	Evan	But algae can decrease by green muck.
14*	Natalie	No, it cannot. Because they're the same thing!
15*	Kate	((*to Evan*)) What are you saying? I am so confused.
16	Evan	Ok ok, well then in that case. Green muck has no impact on algae.
17	Natalie	Yes.
18	Evan	Ok.
19	Natalie	So you need to take away the increases arrow
20	Evan	I already did that
21	Natalie	Flip around that has no impact arrow.

The group of students in excerpt 2 utilized the roles that were introduced; the timekeeper, facilitator and the modeler. Like their peers in excerpt 2, the students in this group also negotiated their ideas, specifically debating how to represent green muck or algae in the model. Students again drew on provided information (line

5) but also engaged in sense making processes (lines 8-14). Moreover, Natalie engaged in overt process management, directing Evan on how to manipulate the model.

Implications and future directions

In both excerpts, peer mediated feedback came in the form of questioning, often accompanying explanations that could be debated or were unclear (see asterisked lines in excerpts). While we did not provide explicit hints for students, the constraints provided to students in the form of the modeling tool helped students with this sensemaking practice. From a design perspective, embedding scaffolds that signal students to question the relationships in the model is a next logical step. Simple prompts such as "does this make sense" similar to how students voice their questions will likely support and facilitate group inquiry. However, this alone is not sufficient to ensure productive discussions. Students must also be aware of the kinds of roles that they need to adopt as part of the group inquiry process, especially since these roles are not always necessarily defined by students themselves.

Another implication of the rich group interaction that students have as they engage in the modeling process, whether digitally or physically is that such interaction might not be accounted for by the system. For example, behaviors and actions in a digital environment are often captured by user input (e.g., movement in the physical space). Often, non-actions are construed as inactive or disengagement from group inquiry and interactions. The results from the focus groups however suggest that students engage in productive actions outside of the digital space.

Based on these findings, we generate two design take-aways. We suggest two group formations that will support student facilitation and learning. First, students can be assigned to PBL groups and solve the problem presented to them. In the PBL groups, the ill-defined problem in the game-based learning environment will be introduced by various stakeholders who will present different facets of the information provided to student at each given stage. For instance, the stakeholders might all discuss algae as a contributing factor to the fishkill problem, but these ideas will be presented in various ways (e.g., graphs, simulations, pictures). Scaffolding the PBL group could take the form of process management, such as making sure that students engage in hypothesis generation and reflecting on their group in-game learning actions and processes.

Secondly, given that students naturally engage in discourse outside of the technology, this means that the classroom configuration must support this form of discourse. For instance, students could be physically arranged in the classroom to sit with peers who are assigned the same stakeholder, thereby generating groups of expert peers. Scaffolding provide to the expert peer group can take the form of facilitation prompts meant to trigger discussions and sense making processes. In this way, the spatial configuration will support students group inquiry process and ensure that these ideas are then communicated to their in-game members in chat. We believe that this is a productive approach since research has also suggested that timing student interactions around successfully completing tasks and reporting them in chat will support students group inquiry (Van Eaton, Clark, & Smith, 2015).

References

Barrows, H. S. (2000). *Problem-based learning applied to medical education*: Southern Illinois University School of Medicine.

Engeström, Y. (1987). *Learning by Expanding: An Activity-Theoretical Approach to Developmental Research*. Helsinki: Orienta-Konsulti Oy.

Hmelo-Silver, C. E., Jordan, R., Eberbach, C., & Sinha, S. (2017). Systems learning with a conceptual representation: a quasi-experimental study. *Instructional Science, 45*(1), 53-72.

Kaptelinin, V., & Nardi, B. (2012). Activity theory in HCI: Fundamentals and reflections. *Synthesis Lectures Human-Centered Informatics, 5*(1), 1-105.

Magnisalis, I., Demetriadis, S., & Karakostas, A. (2011). Adaptive and intelligent systems for collaborative learning support: A review of the field. *IEEE transactions on Learning Technologies, 4*(1), 5-20.

Quintana, C., Reiser, B. J., Davis, E. A., Krajcik, J., Fretz, E., Duncan, R. G., . . . Soloway, E. (2004). A scaffolding design framework for software to support science inquiry. *Journal of the Learning Sciences*, 337-386.

Van Eaton, G., Clark, D. B., & Smith, B. E. (2015). Patterns of Physics Reasoning in Face-to-Face and Online Forum Collaboration around a Digital Game. *International Journal of Education in Mathematics, Science and Technology, 3*(1), 1-13.

Walker, E., Rummel, N., & Koedinger, K. R. (2009). *Beyond explicit feedback: new directions in adaptive collaborative learning support.* Paper presented at the Proceedings of the 9th international conference on Computer supported collaborative learning-Volume 1.

How Gender Cues in Educational Video Impact Participation and Retention

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Abstract This work describes a large-scale randomized experiment in an introductory data science MOOC on the Coursera platform. The experiment subtly altered gendered situational cues in course videos, placing either male or female data scientists in video backgrounds and using matching male or female aides for tutorial videos. The experiment explores whether prior work on ambient cues would generalize beyond a physical classroom environment and into an online environment at scale. We find strong evidence that the female condition induces strong positive effects on overall course activity and discussion posting behavior by female students, but also strong evidence of a smaller negative effect on these outcomes for male students. We find no effect on students' persistence through the course. This experiment suggests that subtle personalized alterations of educational environments can influence students' engagement patterns in large-scale digital learning environments, but that gendered interventions may negatively impact some students.

Introduction

MOOCs offer the potential for millions of learners around the globe to access high-quality educational content at scale. Despite reaching incredible numbers of students (1), MOOCs have seen far less of the experimental learning science research that has evaluated traditional educational environments such as in-person primary and secondary education. As a result, little is known about how course environments and mechanisms of delivery within the learning environment can influence MOOC participants. This is a particularly noteworthy literature gap because of the heterogeneity of most MOOC environments relative to in-person educational settings: students can learn from, interact with, and passively observe other learners with vastly different cultures, backgrounds, and motivations (Kizilcec and Brooks 2017). This background can influence how learners participate in this educational phenomena (Kizilcec and Cohen 2017).

In this work, we examine the effect of situational cues relating to gender in an introductory data science MOOC. This course, which has had awarded nearly ten thousand certificates and engaged nearly one hundred thousand learners in its first year, has significant gender imbalance, with roughly 84% of the learners being male. In addition, persistence in the course is lower for women than men (see Figure 1).
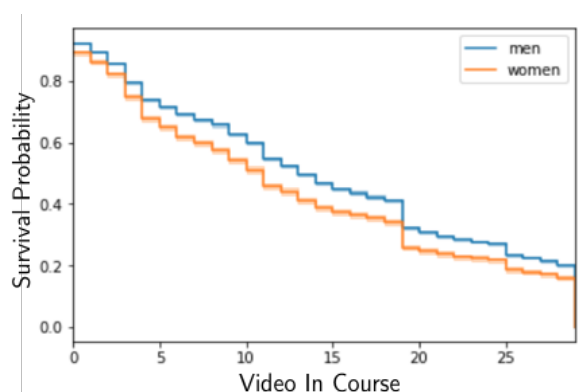
Figure 1. Kaplan-Meier survival curves for men (blue, top) and women (orange, bottom) enrollees over time (expressed as the order of the lecture in the course). Note the gap between curves (significant at p≈0.0000 using a log-rank test) demonstrates the lack of retention of women, even as early as the first lecture in the course.

The current work is guided by prior research by Cheryan et al. (2009) which evaluated how stereotypical cues within the learning environment, even those unrelated to content (i.e., posters and objects in the classroom, such as Star Wars posters or video games), can affect female students' sense of belonging when considering enrolling in the discipline of Computer Science. Cheryan et al. conducted a randomized in-person experiment ($n = 39$, women = 22), where stereotypically masculine or neutral cues were crowdsourced from

outside of the subject pool and placed in physical classrooms before subjects were introduced. The subjects were told they were participating in a survey on interest in technical jobs and internships. Cheryan et al. find that female students who participated in the stereotypically masculine classroom condition were significantly less interested in computer science than were men, but that there was no gender difference with respect to interest in computer science in the neutral classroom. Importantly, under the neutral condition there was (i) no statistically significant impact on male students, and (ii) no observable gender performance difference on a short STEM-based assessment item.

Other research has demonstrated effects related to stereotype threat -- the concern that others will judge one negatively due to a stereotype that exists about one's group -- for female students in engineering environments. In these environments, stereotypes can negatively affects female students' performance in engineering coursework, but Bell et al. (2003) showed that making contextual changes which reduce stereotype threat (i.e., changing the framing of a test from being a diagnostic of ability to being non-diagnostic and not producing gender differences) can eliminate performance gaps.

We are particularly interested in understanding scalable mechanisms to address these issues in large online courses. Ideally, such mechanisms could be automatically delivered based on user models of the learner, customizing the environment to best accommodate their success. With MOOCs being particularly reliant on video-based instruction, and with these videos being such a salient aspect of the learner experience, we focused our experimentation with potential customizations of the video itself, altering elements of the video with respect to gender representation (described more fully in Section 2: Experiment). These alterations resulted in the creation of two conditions, one situational cues aimed at supporting women (the *female condition*) and one with situational cues aimed to support men (the *male condition*). We then pre-registered (2) the following hypotheses:

> H1: That there will be higher retention rates among women in the female condition than of women in the male condition.
>
> H3: That there will be higher ... (c) forum participation ... of women in the female condition than of women in the male condition.
>
> H4: That there will be no difference in the rate of participation of males between the two conditions.

<div align="right">(Brooks & Gardner, 2017)</div>

Experiment

The experiment took place in a large data science MOOC hosted on the Coursera platform. Students using the platform must provide their name and email address to Coursera, and optionally fill out a demographics survey. Coursera records the gender for those who fill it out in the demographics survey, and runs an inferencing process (3) to determine gender of participants by name otherwise. Learners were randomly assigned to either the female (n = 23,365, male students = 18,482) or male conditions (n = 23,287, male students = 18,478). The course consists of a total of 29 lectures and several assignments. Learners can sign up for free (auditing; no graded assessments available), paid (full course including assessments, either at a flat or monthly rate), or for financial aid (experience the same as paid learners). Upon successful completion of either the paid or financial aid experience, learners are provided with a certificate of achievement. Data collection for the current analysis was conducted over a ten month period, with new cohorts beginning every two weeks.

Each condition differs only in two ways. First, all of the videos which include the instructor are shown with either men (Figure 2a) or women (Figure 2b) working in the background. Learners were introduced in the first video to this space as an educational technology incubator where data scientists were employed. We intentionally chose individuals to portray data scientists who exhibited physical masculine (e.g. the bearded individual in Figure 2a) or feminine (e.g. the woman wearing a skirt in figure 2b) traits. Actual video was composited in post-processing, with the instructor added via green screen chroma keying. Secondly, a tutorial assistant who delivered four lectures over the length of the course we either a man (Figure 2c) or a woman (Figure 2d) and were both introduced using a gendered name and wore stereotypical masculine or feminine dress. As many learners search for and connect with MOOC instructors on social media, and the instructional content is long and would be expensive to refilm, it was deemed intractable to change the video of the instructor directly.
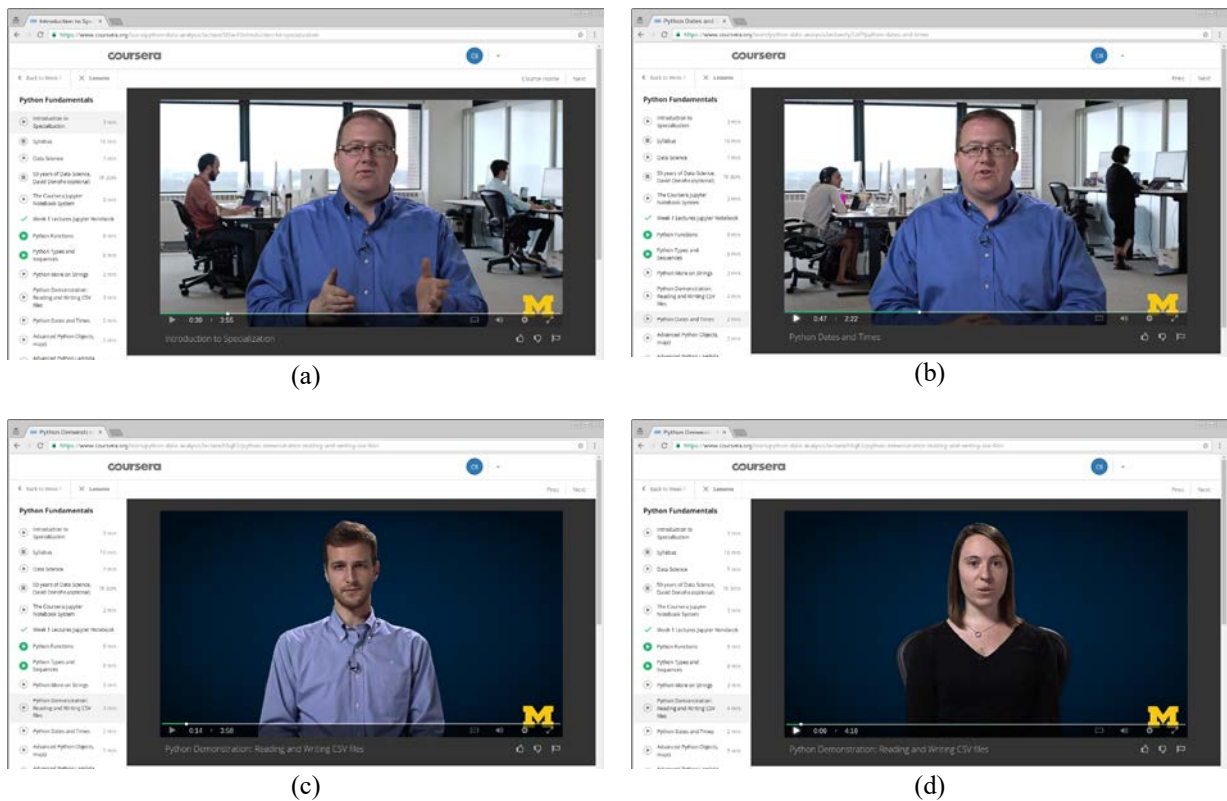
Figure 2. Male condition (left) and female condition (right). The top row shows the instructional video setting for each condition; the bottom row shows the assisted tutorial settings for each condition.

Results

Bayesian analysis

We evaluated the results primarily through the use of Bayesian data analysis techniques. Bayesian methods have much to offer learning science researchers, where evaluating experimental data under uncertainty about the underlying effects is common. In contrast to frequentist methods, which often make strong assumptions (as, for example, a *t*-test might assume normality across groups, or an ordinary least squares regression model might assume normally-distributed errors; both tests provide inferences conditional on the assumption that the null hypothesis is correct), Bayesian methods have the ability to incorporate uncertainty about these assumptions directly into the model through hierarchical modeling (J. K. Kruschke 2013). The Bayesian approach is particularly appropriate for the analysis of large-scale randomized experiments (J. K. Kruschke and Liddell 2015), such as those involving data from MOOCs. First, when the sample size is sufficiently large, significance tests of a null hypothesis of equivalence will always reject a null hypothesis of equivalence in the presence of any observed difference, no matter how small, because *p*-values are affected by both sample size and effect size (Wasserstein and Lazar 2016). Bayesian approaches differentiate between sample size and effect size (and estimate effects more precisely, but not necessarily with greater "significance" or magnitude, as *N* increases) (J. K. Kruschke and Liddell 2015). Second, Bayesian techniques support *probabilistic* statements about treatment effects, given the data. This is in contrast to the black-and-white conclusions usually drawn using null hypothesis significance testing methods, which provide little additional information about the uncertainty of the effect being observed, and which provide these conclusions conditional on the assumed correctness of the null hypothesis (typically, this is a null hypothesis that no effect exists, or that the difference between conditions is precisely zero). It has been widely noted that a null hypothesis of zero effect is often unrealistic, and a test which uses this hypothesis provides no evidence for whether the null hypothesis itself may be true (Cohen 1994). Finally, Bayesian estimates are not subject to frequentist concerns about multiple comparisons, because Bayesian analysis is only concerned with the posterior distribution based on the actual data -- not with

hypothetical unobserved data -- and because the hierarchical structure of Bayesian models imposes data-driven shrinkage on estimates under uncertainty (Gelman et al. 2012, Kruschke and Liddell 2015).

Retention (H1)

As a measure of retention throughout the course we calculated furthest video in the course a learner watch (regardless of order). We model this as an *ordinal* -- in contrast to metric -- outcome, for several reasons: different course weeks have different numbers of videos; some videos are required content and others are optional; and videos are different lengths (ranging from less than two minutes to 10 minutes or more). We adapt an ordinal logistic regression model (J. Kruschke 2014) to model the probability distribution of a learner in each condition dropping out at each of 29 videos in the course. The results of this model are shown in Figure 3. In particular, Figure 3c shows a comparison of the Bayesian Credible Intervals for the two groups with 95% credible intervals and there is little, if any, discernible effect on learners' penetration into the course as measured by their maximum video watched. Indeed, for the female students shown here, the probabilities of dropout at each video are nearly identical across each condition. As the 95% credible intervals overlap for each video we conclude there is no difference for retention of women between conditions, and H1 does not hold.
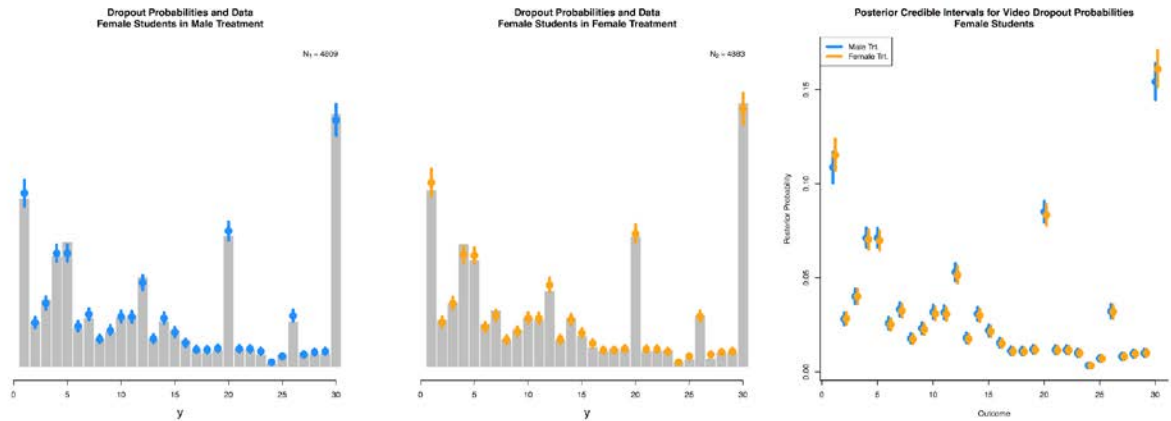
Figure 3. Actual (bars) vs. predicted (intervals) dropout probabilities for female students in the female (left) and male (center) conditions, and (right) a comparison of the Bayesian Credible Intervals for the two groups, which shows little evidence of an effect on the outcome evaluated.

Forum posting (H3c, H4c)

In addition to instructional videos, discussion forums are a primary component of courses, and are notable because participation in the discussion fora is entirely voluntary. We were therefore interested in whether condition assignments had an effect on the likelihood or frequency of users' engagement with course discussion forums. Because this analysis models a count-based outcome, we used a zero-inflated hierarchical Poisson model, which incorporated a latent variable to model learners with zero posts. This model allowed us to estimate (a) a latent variable indicator for whether a learners in each group would participate in the course (whether they would have a non-zero number of clickstream entries), and (b) for forum posters, an estimate of their expected number of posts (this is operationalized as the lambda parameter of a Poisson model, which is both the mean and variance of the distribution). The model specification is:

$$Y_i|\delta_i = 1, T_i = 1 \sim Poisson(\lambda_1)$$
$$Y_i|\delta_i = 1, T_i = 0 \sim Poisson(\lambda_0)$$
$$\delta_i|T_i = 1 \sim Bernoulli(\pi_1)$$
$$\delta_i|T_i = 0 \sim Bernoulli(\pi_0)$$

T_i is an indicator for being in the female condition, δ_i is a latent variable indicating whether the outcome of interest has a non-zero value, and Y_i is the outcome of interest (which is zero when $\delta_i = 0$). Standard noninformative priors were used for the hyperparameters, with $\pi \sim Uniform(0,1)$ and $\lambda \sim Gamma(0.001, 0.001)$.

This model estimated no difference in the probability of posting for students of either gender, in either treatment branch; the 95% Bayesian Credible Interval for $\pi_1 - \pi_0$ included zero for each gender, with the probability of posting for each group $\pi_1 \approx \pi_0 \approx 3.5\%$. However, for students who did post in the discussion forums, the female branch induced an increase of 1.78 posts per student, with the estimated mean for females in the female branch at 6.28 versus 4.62 for those in the male branch; the probability of the true difference being positive (for the female branch) for this outcome was asymptotic to one based on 10,000 Markov chain Monte Carlo (MCMC) samples from the posterior. We observed a smaller, negative effect of the female condition for male students. The estimated mean of male students in the female condition who posted in the discussion fora was 5.67 posts per student, versus 6.31 posts for those in the male condition, a *decrease* of 0.64 posts.
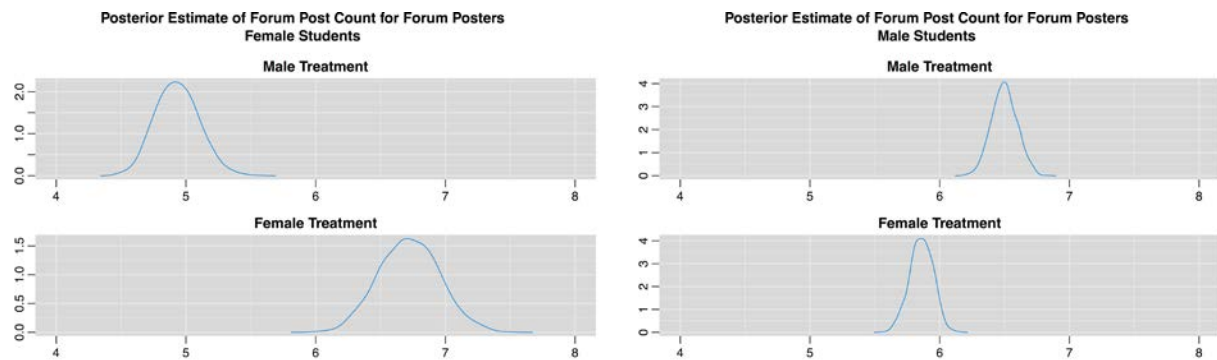
Figure 4. Posterior distributions of the number of discussion forum posts for female (left) and male (right) students in each condition who utilize the discussion fora. Note that there was no difference in the probability of posting for either group, according to the latent variable model used.

Engagement and activity (exploratory)

Another primary outcome of interest for this experiment was female students' engagement with course content. As such, we evaluated the treatment effect for both female and male students separately, comparing the effect of different treatments within each gender (each of our analyses follows this approach). To evaluate students' overall engagement with the course, we extracted the total number of clickstream entries for each student (each clickstream entry constitutes a request to the Coursera server, such as a page load, video view, or click). We employed a latent variable model with an identical structure as described in the previous section to assess the impact of each treatment branch on each gender and treatment group's propensity to engage with the course platform, and the number of clickstream events for students who did engage with the course.

Motivated by the forum analyses, we explored the clickstream data in an effort to build more theory around engagement. Specifically, we modeled the total number of entries in the clickstream logs for a user (excluding video heartbeat entries, which indicate when a video is loaded) as a coarse-grained measure of engagement. Results from this analysis are shown in the posterior density plots in Figure 4. For female learners, the female condition generated an average of 37.6 additional clickstream entries for students who participated in the course (those with nonzero clickstream counts), with a posterior estimated average of 480.0 clickstream events per active female student in the female condition, versus 442.3 for those in the male condition (an increase of 8.5%). Paralleling the effects observed in the forum analysis above, for male learners, the effect was in the opposite direction, but much smaller: the female condition produced an average *decrease* of 11.6 clickstream entries for students in this branch, relative to those in the male branch. Posterior estimated average clickstream events were 496.2 for male students in the female branch, versus 507.8 for those in the male branch (a decrease of 2.3%). There was no difference in the probability of students actively participating in the course in either treatment branch; we would expect this, as the treatment would not be visible to students who never accessed the course. Interactions of male students on average produced more clickstream events in the platform across all conditions.
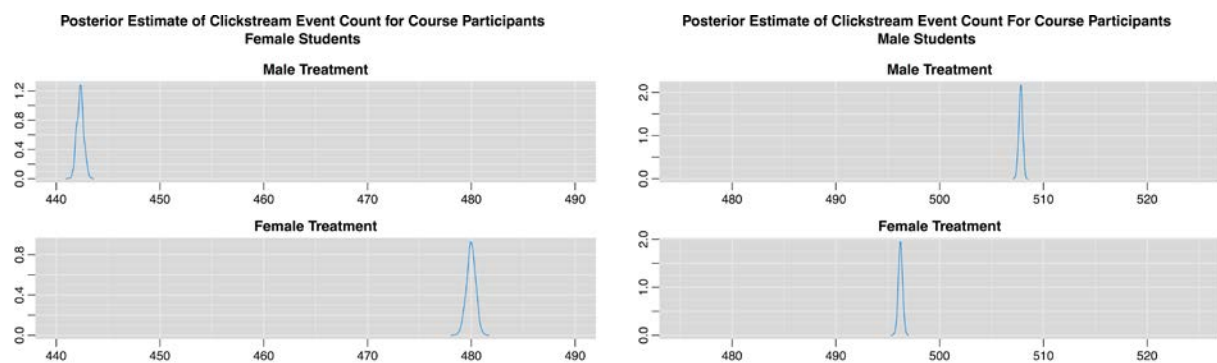
Figure 5. Posterior distributions of the number of clickstream events for female (left) and male (right) students in each condition.

Discussion

The issue of inclusivity in online learning environments is poorly understood, and most of the existing literature is conducted in traditional face-to-face educational environments. Yet a prototypical technology for the area of Artificial Intelligence in Education (AIED), for instance, is the adaptive and personalized learning system. MOOCs are one of the contexts in which personalized learning stands to have a significant impact, due to the sheer numbers of learners engaging in those systems. However, there has been limited experimentation with adaptive systems in MOOCs to date, even as studies show interventions and achievement vary by social group (Kizilcec and Cohen 2017; Kizelcec, Saltarelli, Reich and Cohen, 2017). In this work, we have aimed to impact the intersection of these fields with the learning sciences, and provide new evidence toward understanding the impact of situational cues in large scale online technical courses.

More specifically, we have demonstrated that stereotypically masculine or feminine cues in learning environments are not universally more or less welcoming to students of a gender matching the cues, and that the magnitude and direction of their effect varies by subjects' gender. This adds additional context to the results of the highly cited work of Cheryan et al. (2009), particularly in the case of Massive Open Online Courses. The distinctions between our experimental setup are important; whereas Cheryan et al. studied a small number of residential students at Stanford and their intent to enroll in Computer Science when introduced to the discipline in a crowdsourced, stereotypically masculine environment, we studied a large number of global learners and their activities (retention, forum posting, and overall engagement) while engaging in learning in an online environment with video-based situational gender cues. The differences in the experimental parameters, and our results, are significant, and clearly more work is needed to understand the impact of situational gender cues on student behavior. Our work here suggests that while retention is not affected by these cues, engagement in forums and overall course activity is, for both women and men.

The question of the underlying mechanisms related to environmental cues in video content, and why these mechanisms might or might not affect learners, is one which we have not examined here. Future work with our existing dataset, looking both at the qualitative analysis of learner perceptions as well as analysis of forum discussions, may reveal underlying mechanisms which mediate posting behavior. Regardless, the posteriors for both discussion forum posts (Figure 4) and clickstream entries (Figure 5) are strongly suggestive of an effect which varies in both magnitude and direction by gender, and the analysis provided for H1 suggests there is no strong effect on retention. Future studies varying the nature and frequency of gender-based environmental cues in diverse content and pedagogical environments are warranted in order to generalise this finding. Further, the question as to why the two populations showed different levels of sensitivity to the environmental cues is one which we have not explored, though work by Rudman and Goodwin (2004) has demonstrated that in-group biases are stronger for women in some situations. We note that despite having a greater impact on women (an increase of 1.78 posts per student, versus 0.64 posts for men), if the female treatment condition were deployed to all students at scale there would be a net loss of engagement due to the high gender imbalance in the course (84% male).

This implications of this work go beyond the immediate issue of inclusivity with gender, and begs for further experimentation on *personalization of video at scale*. Modern computing power, storage, and bandwidth makes real-time composition of video a tractable way to personalize a learning environment. Video makes up the backbone of MOOC experiences, and is a high value artifact which stems from the instructional and media

design activity which goes into offering these courses. Instead of focusing on producing "the best video", we argue that not only are there are many different videos which may be appropriate for different audiences using visual cues alone, but that we know very little about how such cues would impact learners at present. While our work has looked specifically at gender cues in video environments, it is not unreasonable to consider that there may be other environmental cues which have priming effects on learners. While it is not currently feasible to replace the main instructors (at least in scaled production environments) of MOOC educational video, we point to the vision of Stephenson (1995) in the fictional *The Diamond Age: Or, A Young Lady's Illustrated Primer* whereby the educational content itself was dynamically assembled based on the learner, the context, and the interpretations of the actions of live actors, facilitated in party by software systems similar to the current gig-economy. In this world, the ability to rapidly experiment with and learn the impacts of diverse sets of environmental cues would be possible, and through innovation in personalized video we believe that the areas of the learning sciences, learning at scale, and artificial intelligence in education are well positioned to provide both impact from and evidence on the effects of environmental cues.

Endnotes

(1) The Coursera platform, used in the current experiment, now boasts 29 million unique learners alone.

(2) Additional hypotheses which focused on regional sub-populations and other outcomes were registered but are not reported on here as analysis has yet to be finished. For consistency we have used here the hypothesis identifiers from the pre-registration.

(3) This process uses the python package *sexmachine*, which reports a 5-option likert value, from mostly female to mostly male, with androgynous as the balancing option. Only users with names which mapped to mostly male or mostly female were retained for analysis.

References

Bell, A. E., Spencer, S. J., Iserman, E., & Logel, C. E. (2003). Stereotype threat and women's performance in engineering. *Journal of Engineering Education*, 92(4), 307-312.

Brooks, C., & Gardner, J. (2017, November 30). Situational Gender Bias in Massive Open Online Courses. Retrieved from osf.io/7dxx2

Cheryan, S., Plaut, V. C., Davies, P. G., & Steele, C. M. (2009). Ambient belonging: How stereotypical cues impact gender participation in computer science. *Journal of personality and social psychology*, 97(6), 1045.

Cohen, J. (1994). The earth is round (p<. 05). *American psychologist,* 49(12), 997.

Gardner, J. & Brooks, C. (in press). Student Success Prediction in MOOCs. *User Modeling and User-Adapted Interaction.* doi: 10.1007/s11257-018-9203-z

Gelman, A., Hill, J., & Yajima, M. (2012). Why we (usually) don't have to worry about multiple comparisons. *Journal of Research on Educational Effectiveness*, 5(2), 189-211.

Kizilcec, R. and Brooks, C. (2017). Diverse Big Data and Randomized Field Experiments in Massive Open Online Courses. In Lang, C., Siemens, G., Wise, A. F., and Gaevic, D., editors, *The Handbook of Learning Analytics*, pages 211–222. Society for Learning Analytics Research (SoLAR), Alberta, Canada, 1 edition.

Kizilcec, R. F., & Cohen, G. L. (2017). Eight-minute self-regulation intervention raises educational attainment at scale in individualist but not collectivist cultures. *Proceedings of the National Academy of Sciences*, 201611898.

Kizilcec, R. F., Saltarelli, A. J., Reich, J., & Cohen, G. L. (2017). Closing global achievement gaps in MOOCs. *Science*, 355(6322), 251-252.

Kruschke, J. (2014). *Doing Bayesian data analysis: A tutorial with R, JAGS, and Stan*. Academic Press.

Kruschke, J. K. (2013). *Bayesian estimation supersedes the t test.* Journal of Experimental Psychology: General, 142(2), 573.

Kruschke, J. K., & Liddell, T. M. (2015). The Bayesian new statistics: two historical trends converge. *SSRN Electronic Journal.*

Lippa, R. A. (2010). Gender differences in personality and interests: When, where, and why? *Social and personality psychology compass*, 4(11), 1098-1110.

Rudman, L. A., & Goodwin, S. A. (2004). Gender differences in automatic in-group bias: Why do women like women more than men like men? *Journal of personality and social psychology*, 87(4), 494.

Stephenson, N. (1995). *The Diamond Ago: Or, A Young Lady's Illustrated Primer*. New York: Bantam Books.

Wasserstein, R. L., & Lazar, N.A. (2016). The ASA's Statement on P-Values: Context, Process, and Purpose. *The American Statistician* 70 (2). Taylor & Francis:129–33.

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Three Research Directions for Affective Learning Technologies

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Abstract: Looking to the future of advanced learning technology research, understanding, supporting and explicitly designing for the role of affect is of great importance. I highlight three emerging areas of research with current research exemplars. First, simulating affect is necessary to enhance human-like relationships with technology; for example, with artificially intelligent virtual agents, or teachable robots as learning companions. Second, sensing and responding to learner affect in immersive learning experiences as well as learning at scale is rapidly evolving; for example, through affective intelligent tutoring systems, or dashboards driven by multimodal analytics. Third, designing technology-based learning experiences that promote, elicit and support affective outcomes requires theory building within the learning sciences; for example, to realize outcomes such as empathy or curiosity and formulate linkages to learning. Finally, I suggest how research in these areas of affective technology afford new opportunities to prepare learners for future learning and work environments.

Introduction

Perhaps the most uniquely human attribute in learning is the learner's emotion or affective state (emotions, feelings, moods) during the learning process. A recent review of cyberlearning research reported that the role of affect and emotion in the learning sciences is of much interest (Roschelle, Martin, Ahn & Schank, 2017). In general, we might expect that states such as engagement, flow and curiosity enhance learning while other states such as frustration and boredom inhibit learning, although research indicates this is more complicated. In the design of learning technologies, accounting for these affective states is an important area of interdisciplinary research that spans the fields of the learning and computer sciences, psychology, engineering, neuroscience, and other convergent fields such as affective computing and cyberpsychology.

Three research directions

In this crossover paper, I highlight three areas of research for affective learning technology: 1) Simulating affect to enhance the human-like aspects of the technology; 2) Sensing and responding to learner affect in immersive environments and nonformal settings; and, 3) Supporting affective learning-related outcomes.

Simulating affect to enhance human-like aspects of technology

Based on the Computers as Social Actors (CASA) paradigm (Reeves & Nass, 1998), there is much evidence to support that learners respond to technology as human-like, even if it is not conscious. For example, the politeness effect with virtual agents indicates that polite, socially intelligent, pedagogical agents can positively impact learning (Wang et al., 2008), and there is strong evidence that virtual agents can serve as effective social influencers (Baylor, 2011). For technology to provide affective and motivational support during learning, it is more effective if it engages with the learner socially and emotionally.

Walker and Ogan (2016) suggest that the artificial-intelligence in education (AIED) community should actively design such technology-mediated social relationships. Particularly for affect, we must design affective characteristics that not only enhance the human-technology relationship but also align with the desired instructional role of the technology (e.g., as expert, mentor, learning companion, or peer; Kim & Baylor, 2016). Ultimately, making the technology more human-like can improve learning, through mechanisms such as the use of enthusiasm, (Lane et al., 2013) or the design of systems that "care" (Du Boulay et al., 2010).

The design of affective characteristics may be clear and simple to provide a strong message, such as through the teachable robot "Quinn" that provides feedback to learners with facial emotions together with causal attributions regarding the learning process (Muldner, Girotto, Lozano, Burleson, & Walker, 2014). Or the affective characteristics may be more complex to generate rapport with both emotional expression and nonverbal communication. For example, an embodied conversational agent serving as a virtual peer has rapport with the learner to facilitate science achievement in a culturally diverse classroom (Finkelstein, Yarzebinski, Vaughn, Ogan, & Cassell, 2013).

Overall, simulating affect to support and not detract from learning will likely lead to more human-like systems that enhance learner engagement through human-technology partnerships. Particularly for intelligent systems, more work is also needed to determine how technology should emote more realistic affect to show intention and/or articulate what is in the simulated "black box."

Sensing and responding to learner affect in both immersive environments and larger-scale nonformal settings

Moving from the technology to the learner, how can advanced learning technologies sense and respond to learners' affective states and the combination of affect and cognition that occurs in learning? We need to better understand this within immersive learning experiences as well as more distant learning contexts such as MOOCs. A recent 2017 inaugural summit on Emotion AI (see http://go.affectiva.com/emotion-ai-summit) suggests the importance of designing such systems not only from the perspective of academia, but also industry.

Arroyo and others (2009) described how "emotion sensors go to school" as integrated in an affective intelligent tutoring system. Continuing to the present day, the implementation of affect-aware systems is rapidly evolving. For example, the game-based learning environment Crystal Island serves as a platform to investigate how emotional responses, such as feelings of calm or tension, are involved in learning for middle grade science and literacy (Sabourin, Mott, & Lester, 2011). Incorporating advances from the affective neurosciences, the Affective Autotutor responds to student affective states including boredom, confusion and frustration (Immordino-Yang & Singh, 2011). For learning at scale, detecting learner engagement in MOOCs is important to support student success. While self-reported affect data can be collected as a first step (Dillon et al., 2016), such systems are now starting to incorporate more intelligent affect-aware feedback (Grawemeyer et al., 2016).

An interesting angle is the development of dashboards to provide "super-senses" for instructors to assess students' cognition, metacognition, emotion, and motivation using multimodal data. These dashboards can incorporate information from eye gaze behaviors, facial expressions of emotions, heart rate, and electrodermal activity (Azevedo et al., 2017). A major challenge here is how to integrate multimodal information that may include multichannel physiological signals. More systematic research on interface design for these dashboards is also needed to make them usable for teachers or other leaders. Importantly, as we continue to build such systems and integrate technologies such as detecting emotion through facial recognition, careful consideration must also be made to ethical issues including privacy.

In this research area, more research is needed to better integrate multimodal data with other techniques such as natural language processing. Developing these affect-aware learning technologies requires advances in computer science and engineering in particular, an area referred to as *affective computing*, per Picard's classic book (1995).

Supporting affective learning-related outcomes

Finally, we need research on the design of learning experiences to promote and support desirable affective outcomes and related motivational constructs such as engagement, interest and curiosity. We also need theory-building in the learning sciences to understand these technology-mediated cognitive-affective states and make the connections back to learning. For example, Leutner (2014) presents the Cognitive-Affective Theory of Learning with Media (CATLM) as an extension of Mayer's Cognitive Theory of Multimedia Learning, which suggests how affective features of instruction can increase learner engagement, generative processing, and deeper learning. D'Mello and Graesser (2012) propose a model that describes the role of cognitive disequilibrium and its dynamic relationship to learners' affective states; specifically, that if such cognitive challenges are resolved, the learners will return to a state of engagement/flow, but if not, can trigger frustration and ultimately boredom. To support and understand affective learning outcomes in nonformal settings like MOOCs, much more research is needed, and in particular, there is a need for more experimental approaches as noted in a recent review article (Joksimović et al., 2017).

What affective states should we promote and support and what are the unique affordances of technology? Immersive virtual reality (VR) environments are particularly powerful in the capacity to induce distinct affective states such as joy, sadness, boredom, anger or anxiety (Felnhofer et al., 2015), and there are ethical concerns given that simply acting as an avatar in VR, for example, can serve as an emotionally-intensive experience and have unintended impact. On the positive side, perspective-taking as implemented through technology can serve as an effective way to promote empathy. Ben Shapiro's initial work (https://www.colorado.edu/atlas/pet-project) involves students designing wearable technology that allow them to sense the world through the eyes of a pet; for example, they create earmuffs that allow for the frequencies that dogs hear, and augmented reality lenses that simulates dog vision. Through this perspective-taking, students develop empathy for the pet and this in turn facilitates their curiosity to ask scientific questions and enhance their overall interest in the scientific process. Accordingly, curiosity is a valuable outcome in relation to STEM learning, and there is much recent interest (e.g., a recent ACM SIG CHI 2016 workshop) in designing systems to support it and the closely related concepts of serendipity, interest, intrinsic motivation and goal-setting, and creativity.

Research in this area should advance our understanding of which affective learning outcomes to target and the implications for the design of learning technologies. If we were to explicitly design systems to elicit feelings of delight and surprise (which Baker and colleagues found to be rare (2010)) and even those of awe and wonder, the possibilities for enhancing interest in content such as STEM could be profound.

Conclusions and implications

Table 1 below provides a summary of these three research areas (e.g., simulating, sensing, and supporting learning affect), exemplars reflecting the current state, and future directions.

Table 1: Affective learning technology research: State-of-the-art and future directions

Research area	Current state-of-the-art	Future directions
Human-like technology (*Simulating* affect)	artificially intelligent virtual agents; social robots	Increasing realism, rapport, and social responsiveness; systems emoting to inform learner of intention and generating interest and buy-in
Affect-aware systems (*Sensing* learner affect)	affective intelligent tutoring systems; dashboards with multimodal data; MOOCs that assess learner engagement	Generating more meaningful learning-related information from multi-channel multimodal data; role of emotion AI and learning; more sensitive detection and modeling of learner affect for learning at scale
Affective learning outcomes (*Supporting* learner affect)	Support flow/engagement; cognitive disequilibrium as integral to the learning process	Discovering new strategies to elicit emotions such as empathy, delight, curiosity; modeling the complex relationship with learning and cognition; deeper investigation of the affordances VR

As we prepare learners for the future of work, the role of affect is fundamental for both designing and working within immersive and intelligent environments where technology can understand and use emotion in its partnership with the learner or worker. Such cyber-human systems of the future must both understand, respond to and communicate with gesture, emotional expressions and nonverbal behaviors.

Each of these three directions requires a highly interdisciplinary, or convergent, approach to understand the theoretical and empirical underpinnings of affective learning technologies. This can be problematic in evaluating impact- i.e., which field gets to determine the parameters for evaluation? Here it is important to broaden the scope of relevant research, and bring flexible, multi-dimensional evaluation lenses to bear in support of these exciting new directions.

References

Arroyo, I., Cooper, D. G., Burleson, W., Woolf, B. P., Muldner, K., & Christopherson, R. (2009). Emotion sensors go to school. In *Frontiers in Artificial Intelligence and Applications* (Vol. 200, pp. 17–24). https://doi.org/10.3233/978-1-60750-028-5-17

Azevedo, R., Millar, G. C., Taub, M., Mudrick, N. V., Bradbury, A. E., & Price, M. J. (2017). Using data visualizations to foster emotion regulation during self-regulated learning with advanced learning technologies. In *Proceedings of the Seventh International Learning Analytics & Knowledge Conference on - LAK '17* (pp. 444–448). https://doi.org/10.1145/3027385.3027440

Baker, R. S. J. d., D'Mello, S. K., Rodrigo, M. M. T., & Graesser, A. C. (2010). Better to be frustrated than bored: The incidence, persistence, and impact of learners' cognitive-affective states during interactions with three different computer-based learning environments. *International Journal of Human Computer Studies*, *68*(4), 223–241. https://doi.org/10.1016/j.ijhcs.2009.12.003

Baylor, A. L. (2011). The design of motivational agents and avatars. *Educational Technology Research and Development*, *59*(2). https://doi.org/10.1007/s11423-011-9196-3

D'Mello, S., & Graesser, A. (2012). Dynamics of affective states during complex learning. *Learning and Instruction*, *22*(2), 145–157. https://doi.org/10.1016/j.learninstruc.2011.10.001

Dillon, J., Ambrose, G. A., Wanigasekara, N., Chetlur, M., Dey, P., Sengupta, B., & D'Mello, S. K. (2016). Student affect during learning with a MOOC. In *Proceedings of the Sixth International Conference on Learning Analytics & Knowledge - LAK '16* (pp. 528–529). https://doi.org/10.1145/2883851.2883960

Du Boulay, B., Avramides, K., Luckin, R., Martínez-Mirón, E., Méndez, G. R., & Carr, A. (2010). Towards systems that care: A Conceptual Framework based on motivation, metacognition and affect.

International Journal of Artificial Intelligence in Education, *20*(3), 197–229. https://doi.org/10.3233/JAI-2010-0007

Felnhofer, A., Kothgassner, O. D., Schmidt, M., Heinzle, A. K., Beutl, L., Hlavacs, H., & Kryspin-Exner, I. (2015). Is virtual reality emotionally arousing? Investigating five emotion inducing virtual park scenarios. *International Journal of Human Computer Studies*, *82*, 48–56. https://doi.org/10.1016/j.ijhcs.2015.05.004

Finkelstein, S., Yarzebinski, E., Vaughn, C., Ogan, A., & Cassell, J. (2013). The effects of culturally congruent educational technologies on student achievement. In *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)* (Vol. 7926 LNAI, pp. 493–502). https://doi.org/10.1007/978-3-642-39112-5-50

Grawemeyer, B., Mavrikis, M., Holmes, W., Gutierrez-santos, S., Wiedmann, M., & Rummel, N. (2016). Affecting Off-Task Behaviour : How Affect-aware Feedback Can Improve Student Learning Categories and Subject Descriptors. In *Proceedings of LAK16 6th International Conference on Analytics and Knowledge 2016* (pp. 104–113). https://doi.org/http://dx.doi.org/10.1145/2883851.2883936

Immordino-Yang, M. H., & Singh, V. (2011). Perspectives from Social and Affective Neuroscience on the Design of Digital Learning Technologies. In *New Perspectives on Affect and Learning Technologies* (pp. 233–241). https://doi.org/10.1007/978-1-4419-9625-1_17

Joksimović, S., Poquet, O., Kovanović, V., Dowell, N., Mills, C., Gašević, D., … Brooks, C. (2017). How Do We Model Learning at Scale? A Systematic Review of Research on MOOCs. *Review of Educational Research*. Retrieved from First Published online at November 14, 2017

Kim, Y., & Baylor, A. L. (2016). Research-Based Design of Pedagogical Agent Roles: A Review, Progress, and Recommendations. *International Journal of Artificial Intelligence in Education*, *26*(1), 160–169. https://doi.org/10.1007/s40593-015-0055-y

Lane, H. C., Cahill, C., Foutz, S., Auerbach, D., Noren, D., Lussenhop, C., & Swartout, W. (2013). The effects of a pedagogical agent for informal science education on learner behaviors and self-efficacy. In *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)* (Vol. 7926 LNAI, pp. 309–318).

Leutner, D. (2014). Motivation and emotion as mediators in multimedia learning. *Learning and Instruction*, *29*, 174–175. https://doi.org/10.1016/j.learninstruc.2013.05.004

Muldner, K., Girotto, V., Lozano, C., Burleson, W., & Walker, E. (2014). The Impact of a Social Robot's Attributions for Success and Failure in a Teachable Agent Framework. In *Proceedings of the International Conference of the Learning Sciences* (pp. 278–285).

Picard, R. W. (1995). Affective Computing. *MIT Press*, (321), 1–16. https://doi.org/10.1007/BF01238028

Reeves, B., & Nass, C. (1998). The media equation. *The Media Equation: How People Treat Computers, Television, and New Media Like Real People and Places*, *34*, 19–36. https://doi.org/10.1109/MSPEC.1997.576013

Roschelle, J., Martin, W., Ahn, J. & Schank, P. (Eds). (2017). *Cyberlearning Community Report: The State of Cyberlearning and the Future of Learning With Technology*. Menlo Park CA: SRI International.

Sabourin, J., Mott, B., & Lester, J. C. (2011). Modeling learner affect with theoretically grounded dynamic Bayesian networks. In *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)* (Vol. 6974 LNCS, pp. 286–295). https://doi.org/10.1007/978-3-642-24600-5_32

Walker, E., & Ogan, A. (2016). We're in this Together: Intentional Design of Social Relationships with AIED Systems. *International Journal of Artificial Intelligence in Education*, *26*(2), 713–729. https://doi.org/10.1007/s40593-016-0100-5

Wang, N., Johnson, W. L., Mayer, R. E., Rizzo, P., Shaw, E., & Collins, H. (2008). The politeness effect: Pedagogical agents and learning outcomes. *International Journal of Human Computer Studies*, *66*(2), 98–112. https://doi.org/10.1016/j.ijhcs.2007.09.003

Acknowledgments

Early Career Workshop

Politicization as Learning:
Centring Racialization, Colonialism, and Gender in Learning Sciences Analysis

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Current research

I am a scholar of learning, identity development, and student-led social change. In order to theorize politicization within sociocultural learning frameworks, I focus on how student activists learn new practices and develop new worldviews in movement contexts. My research shows that learning is fundamental to social change, so I trace how student leaders in movements learn systemic critiques and prefigurative practices, and I show how people learn to become justice-oriented leaders. Within the Learning Sciences, my work has been part of a significant recent shift to address politics and power within studies of learning. My work is important for shaping what we know about learning and equity in social movements. Theorizing how student activists learn to understand, critique, and re-make social relations in their movements is fundamental to building a more equitable society and a generation of justice-oriented leaders.

My current research project examines the development of political consciousness within the climate change movement. A new generation of young people have seized on longstanding critiques of mainstream environmentalism as a white, colonial, and masculine movement, and they are working to shift its politics. My project explores how student fossil fuel divestment activists develop political critiques, alternative practices, non-dominant ways of knowing, and radicalized identities through their activism. Through a multi-year, participatory action research project that collected video of meetings, rallies, direct actions, caucus spaces, reflections, interviews, and stimulated recalls, this study examines the struggles over the legitimacy of different ways of knowing and being within multi-racial, multi- gendered, and settler colonial movements. We collected over 10,000 minutes of multi-camera video data, which we content-logged and coded collaboratively. Several different analyses have emerged, which draw on sociocultural views of learning, as well as different constellations of feminist, anti-racist, and Indigenous thought.

Several articles have emerged from this project. The first, accepted at the *American Educational Research Journal,* traces the politicization of students in the group. This paper uses the case of radicalized student activists within the fossil fuel divestment campaign to theorize politicization as a process of conceptual development, shifting practices and modes of participation, becoming cognizant of and challenging dominant epistemologies, and developing a shared identity as radical activists (Curnow, Davis & Asher, forthcoming). This work extends traditional work on learning in social movements, centring sociohistoric critiques and bringing robust theories of learning as a central analytic for theorizing changes in movement frames. Another article, building from the 2016 paper presented at ICLS (Curnow & Chan, 2016), analyzes gendered and racialized participation dynamics within the fossil fuel divestment campaign. It argues that expertise and leadership were conflated with white, masculine modes of practice, undermining women and people of colour's participation and leadership. This paper contributes to theorizations of "doing gender" by analyzing performances of racialized masculinity, arguing that disproportionate recognition of white men as leaders and experts was an ongoing interactional accomplishment by people of all genders. I also have an article building from ICLS 2016 (Curnow, 2016), which argues that situated learning theory must account for power dynamics and social relations in communities of practice. This contributes to the Learning Sciences by bringing an equity critique to situated learning and communities of practice theories, arguing that racialization, gender, and colonialism must be included in analyses of learning, identity development, and participation.

The publications from my dissertation build on my earlier articles on learning and leadership in the fair trade movement. In *Gender & Education,* I traced women's conscientization processes, demonstrating how consciousness-raising among a sub-community of practice forced shifts within the broader community. This challenged situated learning theory to account for power relations and theorize resistance to masculine leadership within a community of practice framework (Curnow, 2013). Another article argues that consensus-based decision-making and equity-oriented facilitation enabled participants to transform their self-identification to become activists through legitimate peripheral participation (Curnow, 2014b). In *Interface,* I used legitimate peripheral participation to theorize leadership development across the student fair trade network (Curnow, 2014a). I argue that leaders should construct opportunities for joint work with and between grassroots groups to develop shared political vision and build the ladder of engagement for rising leaders.

Contributions to the field

Often, scholars in the Learning Sciences conduct research, design interventions, and present findings without addressing the power dimensions of their work. My research begins from a different set of assumptions, acknowledging the positional ways we produce knowledge and organize systems of learning. The decolonizing, participatory, feminist, and sociocultural learning theories that my work brings to bear are central to my analysis of learning in social movements. A growing number of Learning Scientists are calling for exactly the kind of analysis that my work provides—deep analysis of the interrelations between power, politics, and learning.

Theorizing racialization, gender, and colonialism and learning

Last year, *Cognition & Instruction* published a call for a greater focus on power and equity in our discipline, arguing that learning is shaped by racialized, colonial, and gendered dynamics (The Politics of Learning Writing Collective, 2017). My work addressing these issues has been at the forefront of anticipating and responding to this call. My research turns the field away from the ubiquity of Eurowestern ways of knowing, bringing attention to the racialized, gendered, and colonial aspects of learning theory.

Analyzing and making space for reconciliation and anti-colonial pedagogies

I have invited papers in two forthcoming special issues, one on racialization and settler colonialism in the environmental movement for *Environment & Society* (Curnow & Helferty, forthcoming), and another on the pedagogical significance of territorial acknowledgments for *Curriculum Inquiry* (Asher, Curnow & Davis, forthcoming). These papers contribute to emergent discussions around Indigenous-settler reconciliation and decolonization by examining how settlers learn about settler colonialism and racism, and how that learning informs their participation in multiracial environmental campaigns. This research centres Indigenous methodologies in fields where these are not widely acknowledged, and plays an important role in making space for other ways of knowing and being that emphasize decolonial practice as a step toward reconciliation. In response to the Canadian Truth and Reconciliation Commission's calls to action, my research provides data on how social movements and educational institutions can create opportunities to learn that serve anticolonial and antiracist goals, enabling settlers to meet our obligations and better educate students around settler colonialism.

Social action as a learning process

My academic publications have been part of the shift in the Learning Sciences toward theorizing learning in the context of social movements. My publications in *Gender & Education* and *Interface* both brought sociocultural theories of learning into the analysis of student activism and gendered leadership development (Curnow, 2013; 2014a). Additionally, I have published papers theorizing learning in the context of social movements (Curnow & Gross, 2016; Curnow & Wilson, 2013), offering the strength of Learning Sciences tools to social movement scholars and activists in order to shift how scholars conceptualize learning and participation. These publications also add to the growing understanding of the nature of learning in social movements for scholars of learning, who tend to work within school settings rather than in social action contexts.

For the Learning Sciences, my work offers groundwork to theorize learning and citizenship practices and to integrate learning about racialization and settler colonialism as central learning accomplishments which can be measured, evaluated, and theorized.

References

Asher, L., Curnow, J., & Davis, A. (Forthcoming). The Limits of Settlers' Territorial Acknowledgments. *Curriculum Inquiry.*

Curnow, J. (2013). Fight the Power: Situated Learning and Conscientisation in a Gendered Community of Practice. *Gender & Education. 25(*7), 834-850. http://dx.doi.org/10.1080/09540253.2013.845649

Curnow, J. (2014a). Climbing the Leadership Ladder: Legitimate Peripheral Participation in Social Movements. *Interface. 6*(1), 130-155.

Curnow, J. (2014b). Becoming an Activist: Learning the Politics and Performances of Youth Activism through Legitimate Peripheral Participation. In Polman, J. L., Kyza, E. A., O'Neill, D. K., Tabak, I., Penuel, W. R., Jurow, A. S., O'Connor, K., Lee, T., & D'Amico, L. (Eds.). *Learning and Becoming in Practice: The International Conference of the Learning Sciences 2014, Volume 1* (pp. 206-213). Boulder, CO: International Society of the Learning Sciences.

Curnow, J. (2016). Situated Learning, Situated Knowledge: Situating Race, Colonialism, and Patriarchy Within Communities of Practice. In Looi, C. K., Polman, J. L., Cress, U., & Reimann, P. (Eds.). (2016). *Transforming Learning, Empowering Learners: The International Conference of the Learning Sciences 2016, Volume 1* (pp. 218-225). Singapore: International Society of the Learning Sciences.

Curnow, J. & Chan, J.R. (2016). Becoming an "Expert": Gendered Positioning, Praise, and Participation in an Activist Community. In Looi, C. K., Polman, J. L., Cress, U., & Reimann, P. (Eds.). (2016). *Transforming Learning, Empowering Learners: The International Conference of the Learning Sciences 2016, Volume 1* (pp. 146-153). Singapore: International Society of the Learning Sciences.

Curnow, J., Davis, A., & Asher, L. (Forthcoming). Politicization in Process. *American Educational Research Journal.*

Curnow, J. & Gross, A. (2016). Injustice is Not an Investment: Student Activism, Climate Justice, and the Fossil Fuel Divestment Campaign. In Rosen, S. & Connor, J. (Eds). *Contemporary Youth Activism: Advancing Social Justice in the United States* (pp. 367-386). Santa Barbara, California: Praeger.

Curnow, J. & Helferty, A. (Forthcoming). Contradictions of Solidarity: Whiteness, Settler Coloniality, and the Mainstream Environmental Movement. *Environment & Society.*

The Politics of Learning Writing Collective (Philip, T. M., Jurow, A. S., Vossoughi, S., Bang, M., & Zavala, M). (2017). The Learning Sciences in a new era of US nationalism. *Cognition & Instruction*, *35*(2), 91-102.

Wilson, B.R. & Curnow, J. (2013). Solidarity TM: Student Activism, Affective Labor, and the Fair Trade Campaign in the United States. *Antipode. 45*(3), 565-583. http://dx.doi.org/10.1111/j.1467-8330.2012.01051.x

Reasoning About Uncertainty and Efficient Decision-making in Engineering Design

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Introduction

Engineering design has been defined as a systematic, iterative and reflective process by which engineers understand a problem, generate potential solutions, evaluate them, and refine the ideas for solving users' needs while satisfying a given set of constraints (Dym et al., 2005). It uses design thinking, a complex process that learners often struggle with (Dym et al., 2005). Core characteristics of design thinking include tolerating ambiguity, maintaining a systems perspective, handling uncertainty, effective decision making, working in a team, and communicating design ideas effectively (Dym et al., 2005). My prior work suggests that when middle school students are primed with a suboptimal design and are then asked to solve an ill-structured engineering design challenge, they engage in various disciplinary practices and design thinking to take effective design decisions (Dasgupta, 2015). This research also suggested that uncertainty may have promoted learning about the disciplinary practices and scaffolds like the suboptimal design may have helped students manage uncertainty while they were taking effective design decisions.

Uncertainty likely plays an important role in facilitating content learning by creating opportunities for knowledge construction and transition of tacit understanding to normative understanding (Jordan et al., 2012). Further research is needed to develop a good understanding about the mechanism of efficient decision-making under uncertainty and the nature of appropriate scaffolds needed in the learning environment to support robust design thinking during the process. My current research focuses on this gap and draws on prior research in the fields of Learning Sciences, Engineering Education, Human-Computer Interaction and Neuroscience research.

Literature review

Prior research has demonstrated that there are various interpretations of uncertainty. Uncertainty can occur due to lack of a well-defined problem, lack of knowledge about the problem, incomplete information, abundance of conflicting information, inadequate understanding, presence of undifferentiated alternatives which often lead to conflict, and doubt between team-members (Lipshitz, & Strauss, 1997; Radinsky, 2008). At a very broad level, two categories emerge from this prior work – content uncertainty and relational uncertainty. Content uncertainty arises while solving an engineering design problem where all the criteria are seldom specified completely and one rarely has enough knowledge to solve the problem right away (Ullman, 2001; Jonassen, Strobel & Lee, 2006). Relational uncertainty arises out of a cognitive feeling of doubt between team members, discomfort about the unknown, and lack of a well-defined social position in the team (Jordan & McDaniel Jr, 2014; Radinsky, 2008). Learners employ various strategies to manage such uncertainties – reduce uncertainty, acknowledge uncertainty, suppress uncertainty, maintain uncertainty, and even increase uncertainty (Jordan & McDaniel Jr, 2014; Lipshitz, & Strauss, 1997; Ullman, 2001). Further research is needed to understand the mechanism by which learners reason about each type of uncertainty and the scaffolds and feedback processes that might be helpful in supporting the strategies thereby promoting efficient decision-making and robust design thinking (Dym et al. 2005).

Emerging research agenda

My research focuses on the following three strands- (a) designing *learning environments* for effectively priming and anchoring learners' design thinking and decision-making process under uncertainty, (b) understanding the *mechanism* by which learners reason about uncertainty and take informed design decisions, and (c) developing *feedback processes* (with and without technology) by which teachers can effectively promote productive decision-making under uncertainty and ensure that learners are engaging in robust design thinking.

Learning environments for supporting decision-making under uncertainty

I am working on developing a framework for characterizing various types of uncertainties, investigating how they are introduced in an engineering design problem-solving environment and how we can sustain them during the design activity by embedding various types of scaffolds in the learning environment to maximize the learning opportunity. I also investigate the role of the teacher when learners are engaged in managing

uncertainty and how teachers can support the decision-making process effectively. This strand draws from seminal research on scaffolding complex learning (Reiser, 2004; Quintana et al., 2004).

Mechanism of reasoning about uncertainty and taking informed design decisions

This strand focuses on characterizing various strategies used by learners for managing each type of uncertainty in an engineering design problem-solving environment. I focus on unpacking the mechanism of how learners reason about the uncertainty, the learning that happens from such engagement and the role of the activity, context and culture in which the learning occurs; thus, taking a situated learning perspective (Lave & Wenger, 1991).

Here, I take a multimodal analysis approach using electroencephalography (EEG), electrodermal activation sensors and eye-tracking in addition to audio-video data for drawing inferences about what and how learners are learning (Worsley, 2017). This approach enables me to explore the translation of neuroscience research (e.g., Kounios & Beeman, 2009) and investigate the neurological mechanisms underlying design thinking and apply findings about how the brain works to design learning environments and also refine theories of learning (Johri, 2011).

Feedback processes for promoting effective decision-making under uncertainty

Formative feedback is essential for making sustained progress towards the learning goals in a classroom environment. This line of research draws from Shute's framework for providing formative feedback (Shute, 2008) and focuses on identifying appropriate technology and understanding the process for providing effective formative feedback to the learners while they are engaged in managing uncertainty.

References

Dym, C. L., Agogino, A. M., Eris, O., Frey, D. D., & Leifer, L. J. (2005). Engineering design thinking, teaching, and learning. *Journal of Engineering Education*, *94*(1), 103-120.

Dasgupta, C. (2015). *Call the Plumber: Improvable Models as Priming Artifacts in Student Engineering Design Activities.* (Doctoral dissertation). Retrieved from https://indigo.uic.edu/handle/10027/19646.

Ullman, D. G. (2001). Robust decision-making for engineering design. *J. of Engineering Design*, *12*(1), 3-13.

Johri, A., & Olds, B. M. (2011). Situated engineering learning: Bridging engineering education research and the learning sciences. *Journal of Engineering Education*, *100*(1), 151-185.

Jonassen, D., Strobel, J., & Lee, C. B. (2006). Everyday problem solving in engineering: Lessons for engineering educators. *Journal of Engineering Education*, *95*(2), 139-151.

Jordan, M. E., Schallert, D. L., Park, Y., Lee, S. A., Chiang, Y. V., Cheng, A. C., . . . Kim, T. (2012). Expressing uncertainty in computer-mediated discourse: Language as a marker of intellectual work. *Discourse Processes*, *49*, 660–692.

Jordan, M. E., & McDaniel Jr, R. R. (2014). Managing uncertainty during collaborative problem solving in elementary school teams: The role of peer influence in robotics engineering activity. *Journal of the Learning Sciences*, *23*(4), 490-536.

Kounios, J., & Beeman, M. (2009). The Aha! moment: The cognitive neuroscience of insight. *Current directions in psychological science*, *18*(4), 210-216.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge Univ. Press.

Lipshitz, R., & Strauss, O. (1997). Coping with Uncertainty: A Naturalistic Decision-Making Analysis. *Organizational Behavior and Human Decision Processes, 69*(2), 149-163. doi:10.1006/obhd.1997.2679

Quintana, C., Reiser, B. J., Davis, E. A., Krajcik, J., Fretz, E., Duncan, R. G., ... & Soloway, E. (2004). A scaffolding design framework for software to support science inquiry. *The Journal of the Learning Sciences*, *13*(3), 337-386.

Radinsky, J. (2008). Students' roles in group-work with visual data: A site of science learning. *Cognition and Instruction*, *26*, 145–194.

Reiser, B. J. (2004). Scaffolding complex learning: The mechanisms of structuring and problematizing student work. *The Journal of the Learning Sciences*, *13*(3), 273-304.

Shute, V. J. (2008). Focus on formative feedback. *Review of Educational Research*, *78*(1), 153-189.

Worsley, M. (2017). Multimodal analysis. In J. Roschelle, W. Martin, J. Ahn, & P. Schank (Eds.), *Cyberlearning Community Report: The State of Cyberlearning and the Future of Learning With Technology* (pp. 46-50). Menlo Park CA: SRI International.

Studying the Process of Instructional Improvement Through the Lenses of Sense-Making Repertoires and Improvement Practices

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Although large numbers of educational reforms and innovations have been developed in the previous four decades, there has been relatively little change in instruction that happens in classrooms (Rowan, 2002). As a result, researchers have suggested that in order to bring about educational change, focus should be placed on the process of implementation and improvement, not just the development and testing of reforms (Bryk, Gomez, Grunow, & LeMahieu, 2015; Penuel, Fishman, Cheng, & Sabelli, 2011). These perspectives underscore the importance of examining the processes of teacher learning, instructional improvement, capacity-building, and organizational change across educational systems. Additionally, they highlight the potentially transformative power this focus can bring by studying designs for these systems-level goals.

My research broadly focuses on the process of instructional improvement in mathematics and science. I take both an observational and design-based approach to better understand and support teachers to productively engage in improvement, as well as support this improvement across educational systems. Additionally, my work encompasses processes at different time scales (e.g. micro- and macro-level instructional improvement), as well as processes that cross different contexts and actors (e.g. individual teacher learning, instructional coaching, administrator support). I bring two complementary perspectives to this work, (a) sense-making repertoires and (b) improvement practices, and consider both in interaction with tools and structures in educational systems. These two perspectives foreground the process of instructional improvements rather than the inputs and outputs of the process, and therefore, lead to new and different implications for designs that support teacher learning and instructional improvement.

Although I aim to understand processes of instructional improvement generally, I am particularly interested in improvements that promote equity and are deeply responsive to students as thinkers. Ideally, I hope my work can better enable teachers to empower students to be agents of change in their world through STEM. Therefore, my research has focused on teaching that is responsive to the disciplinary substance of student ideas (Hammer, Goldberg, & Fargason, 2012; Robertson, Scherr, & Hammer, 2015) and I plan to explore culturally-responsive dimensions of teaching (Ladson-Billings, 2014) and teaching that is responsive to classroom power dynamics (Hand, 2012).

Learning through teaching: The process of using everyday classroom experiences to improve teaching

My dissertation examined the way that secondary math teachers, primarily working with students from non-dominant communities, use their everyday classroom experiences to improve how they build on the substance of student mathematical ideas in their teaching. Therefore, this study focused on the process of individual teacher instructional improvement toward responsive teaching using the lens of teacher noticing (M. G. Sherin, Jacobs, & Philipp, 2011) for improvement. To examine this process, I conducted longitudinal point-of-view (POV) observations (B. L. Sherin & Sherin, 2010; M. G. Sherin, Russ, & Colestock, 2011; M. G. Sherin, Russ, Sherin, & Colestock, 2008) to access teachers' in-the-moment noticing for instructional improvement. During the observations, teachers collected video during a lesson from their own perspective using a wearable camera in the midst of teaching and used a remote to mark moments they thought would influence their efforts to improve their teaching. Shortly after the lesson, I interviewed teachers about the captured moments to uncover their in-the-moment cognition and how they planned to change their teaching based on their sense-making of the experiences. In addition to the longitudinal POV observations, I conducted design-based research around video-based professional development aimed at supporting teachers to develop responsive teaching practices based on the analyses of the longitudinal data. This research has begun to identify the sense-making repertoires and improvement practices used by teachers during the everyday processes of instructional improvement.

Sense-making repertoires

The focus on sense-making repertoires takes a more cognitive perspective on instructional improvement to analyze the common reasoning teachers use to improve their teaching, and in this case focused on reasoning used with everyday classroom experiences. This work found that one type of reasoning was particularly common and important during the improvement process: *causal reasoning about students*. When teachers use causal reasoning about students, they explain why events relating to students unfold the way they do (or will/did in the future/past), which I claim reflects the complex causal models teachers create (Dyer & Kaliski, 2016). I

also found that teachers used particular kinds of causal reasoning when they proposed changes to their teaching aligned with responsive teaching, suggesting that the type of causal reasoning can align with the type of improvement they propose to their teaching (Dyer, 2018). These findings question whether evaluation, another sense-making repertoire that is commonly underlies many models for instructional improvement, is in fact supportive of instructional improvement. While evaluation would highlight he importance of determining what worked or didn't work, the causal reasoning repertoire suggests that it may be most importance to consider why or how this work or don't work. As such, supports for teacher learning should enable teachers to be more analytical, possibly by eliciting and developing particular kinds of causal reasoning, rather than simply evaluating or describing teaching and learning. Specifically, in the case of practice-based teacher education (Ball & Cohen, 1999), these findings suggest that teachers need access to artifacts that provide evidence of the factors that influence student thinking or other outcomes, not just rich records of student thinking.

Improvement practices

Using a complementary perspective, my work has identified several improvement practices teachers engage in when using their everyday classroom experiences to improve their teaching, which often focused on positive classroom experiences. For example, one such method was *making infrequent successes more typical* (Dyer, 2017). In this method, a teacher notices a surprising, but positive event, such as a student making connections between ideas the teacher did not anticipate. The teacher then works to unpack what led to this positive, but isolated, event, and come up with a may to make it more typical. This improvement practice, as well as other that focus on positive classroom experiences, highlight how teacher improvement is not only a process to fix negative outcomes, as it is commonly framed in much of the models of instructional improvement. Instead, positive experiences can be important contexts for teacher improvement, leading to strengths-based approaches to instructional improvement instead of deficit perspectives that "fix" students or teaching practice (Dyer, 2017).

An ecological approach to instructional improvement

Previous work completed in the Learning Through Teaching project has highlighted the usefulness of the perspectives of sense-making repertoires and improvement practices for understanding the phenomenon of instructional improvement. Additionally, it has begun to identify specific types of sense-making repertoires and improvement practices, such as causal reasoning about students and making infrequent successes more typical. In future work, I plan to continue to identify additional types, leading to analytic frameworks to characterize the sense-making repertoires and improvement practices used by teachers and others. An important aspect of this future work would be to expand the contexts in which each of these perspectives are considered beyond the individual process of using everyday classroom experiences to improve teaching. Therefore I plan to examine data of formal professional development, instructional coaching, teacher collaborative work time, teacher evaluation, and informal conversations with other teachers. Most likely, different sense-making repertoires and improvement practices will be identified in these contexts, and the previously-identified methods may be used in different ways. As such, this work builds the foundation for an ecological, cross-context, theory for the process of instructional improvement.

An educational systems approach to instructional improvement

In addition to focusing on teachers when studying instructional improvement, the educational systems teachers are a part of are an important complementary perspective (Cobb & Smith, 2008; Coburn, 2016). In particular, I aim to study support for instructional improvement the meso-level actors and structures at the school, district, and regional levels in conjunction with teachers, who can be represented as micro-level instructional improvement actors. In my post-doctoral and current work, I study instructional improvement at a systems-level through partnership work with school districts that aim to support science and math teacher instructional improvement. These projects have worked in partnership with districts to develop supports and programs, such as teacher leader roles and teacher professional development programs, using methodologies such as design-based implementation research. Through this work and future work, I am to develop theories for sustainably supporting instructional improvement through capacity building and organizational change. In addition to studying how these meso-level actors make sense of and design structures to support teachers' sense-making repertoires and improvement practices, this work will explore the sense-making repertoires and improvement practices used in capacity-building in educational systems.

References

Ball, D. L., & Cohen, D. K. (1999). Developing practice, developing practitioners: Toward a practice-based theory of professional education. In L. Darling-Hammond & G. Sykes (Eds.), *Teaching as the learning profession: Handbook of policy and practice* (pp. 3–32). San Francisco: Jossey-Bass.

Bryk, A. S., Gomez, L. M., Grunow, A., & LeMahieu, P. G. (2015). *Learning to Improve: How America's Schools Can Get Better at Getting Better*. Cambridge, MA: Harvard Education Press.

Cobb, P., & Smith, T. (2008). District development as a means of improving mathematics teaching and learning at scale. *International Handbook of Mathematics Teacher Education*, *3*(Participants in mathematics teacher education: Individuals, teams, communities and networks), 231–254.

Coburn, C. E. (2016). What's Policy Got to Do with It? How the Structure-Agency Debate Can Illuminate Policy Implementation. *American Journal of Education*, *122*(3), 465–475. https://doi.org/10.1086/685847

Dyer, E. B. (2017). *Supporting Generative Change toward Responsive Teaching: How Teachers Use Classroom Experiences as Instructional Feedback*. Paper presented at the Annual Meeting of the American Educational Research Association, San Antonio, TX.

Dyer, E. B. (2018, April). *Developing Responsive Teaching Practices From Causal Reasoning About Classroom Experiences in Secondary Mathematics*. Paper presented at the Annual Meeting of the American Educational Research Association, New York City, NY.

Dyer, E. B., & Kaliski, P. (2016). *Secondary Mathematics Teachers' Use of Causal Reasoning About Classroom Experiences to Change Teaching Practice*. Paper presented at the Annual Meeting of the American Educational Research Association, Washington, D.C.

Hammer, D., Goldberg, F., & Fargason, S. (2012). Responsive teaching and the beginnings of energy in a third grade classroom. *Review of Science, Mathematics and ICT Education*, *6*(1), 51–72.

Hand, V. (2012). Seeing culture and power in mathematical learning: Toward a model of equitable instruction. *Educational Studies in Mathematics*, *80*(1–2), 233–247. https://doi.org/10.1007/s10649-012-9387-9

Ladson-Billings, G. (2014). Culturally Relevant Pedagogy 2.0: a.k.a. the Remix. *Harvard Educational Review*, *84*(1), 74–84. https://doi.org/10.17763/haer.84.1.p2rj131485484751

Penuel, W. R., Fishman, B. J., Cheng, B. H., & Sabelli, N. (2011). Organizing Research and Development at the Intersection of Learning, Implementation, and Design. *Educational Researcher*, *40*(7), 331–337. https://doi.org/10.3102/0013189X11421826

Robertson, A. D., Scherr, R., & Hammer, D. (Eds.). (2015). *Responsive Teaching in Science and Mathematics*. New York, NY: Routledge.

Rowan, B. (2002). The Ecology of School Improvement: Notes on the School Improvement Industry in the United States. *Journal of Educational Change*, *3*(3–4), 283–314. https://doi.org/10.1023/A:1021277712833

Sherin, B. L., & Sherin, M. G. (2010). Freezing time: what mathematics and science teachers "see" while teaching. In *Proceedings of the 9th International Conference of the Learning Sciences* (Vol. 2, pp. 180–181). International Society of the Learning Sciences.

Sherin, M. G., Jacobs, V. R., & Philipp, R. A. (2011). *Mathematics Teacher Noticing: Seeing Through Teachers' Eyes*. New York, NY: Routledge.

Sherin, M. G., Russ, R. S., & Colestock, A. A. (2011). Accessing mathematics teachers' in-the-moment noticing. In M. G. Sherin, V. R. Jacobs, & R. A. Philipp (Eds.), *Mathematics teacher noticing: Seeing through teachers' eyes* (pp. 79–94). New York, NY: Routledge.

Sherin, M. G., Russ, R., Sherin, B. L., & Colestock, A. (2008). Professional vision in action: an exploratory study. *Issues in Teacher Education*, *17*(2), 27–46.

Understanding the Role of Embodied Interaction in Preschool Children's Learning About Science in Informal Settings

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Abstract: Science researchers and practitioners are often challenged by how best to assess the effectiveness of science activities in preschool children whose language skills are still emerging. Yet, research has demonstrated the critical importance of early learning on individual potential. Building on evidence that movement is tightly intertwined with thinking, this project will investigate how thought and movement link as embodied leaning to enhance science understanding. During a 3-year period, researcher-practitioner teams across six museum sites will collaboratively investigate links between movement and learning outcomes at selected science exhibits for young learners. The study aims to gather evidence for embodied interactions during science learning and articulate design principles about how museum exhibits can most effectively encourage cognitive and physical engagement with science. Such guidelines are largely absent in the field of informal science learning; hence this project seeks transformational change in how learning is understood.

Embodied science learning

Recent research is suggesting that the way we think is inseparably linked to our body-based experiences in the world. In other words, our thinking is *embodied*. Embodied cognition is an umbrella term that refers to the theory that thought is intertwined with how the body interacts with the world; or more simply put, the idea that the mind not only drives the body, but that the body very much influences our thinking. There is currently a large appetite for understanding how preschool children engage in Science, Technology, Engineering, and Mathematics (STEM), particularly around areas of science learning in informal settings (museums etc.). Assessments into preschool children's conceptual knowledge of science, even assessments in more domain-general abilities, are scant (Tolmie, Ghazali-Mohammed, Morris, 2016) meaning science education researchers and practitioners often face the challenges of designing and evaluating learning experiences for very young children whose language skills are still emerging.

In this regard, gesture studies have drawn attention to the importance of visual and motor imagery underpinning thought in domains including science and mathematics that have previously neglected these more embodied representations (Novack, Goldin-Meadow & Woodward, 2015). Such research has particular value for young children whose knowledge is often assessed on linguistic abilities (Brenneman, 2011), despite the likelihood of developing visual and motor imagery underpinning certain concepts before being able to express their thinking verbally (Kontra, Goldin-Meadow & Beilock, 2012). Given the importance of spatial-dynamic relationships in science concepts, it is possible that children are able to demonstrate their emergent understanding through gesture (Alibali & Nathan, 2011; Sauter, Uttal, Alman, Goldin-Meadow & Levine, 2012). Gesture could therefore provide a unique opportunity to capture children's thinking and offer greater recognition of children's capacity in areas such as science.

Hence, building on the evidence that movement is tightly intertwined with thinking, a research project named Move2Learn (M2L) was launched. This is a 3-year internationally collaborative project with the University of Edinburgh, University College London, and the University of Illinois Urbana Champaign. M2L is also working with six practitioner sites across the UK and USA including the Glasgow Science Centre, Science Museum London, Grounds for Learning, Children's Museum Indianapolis, Sciencecenter, Ithica New York, and the Phillip and Patricia Frost Museum of Science in Miami. M2L is funded by the National Science Foundation (USA), The Wellcome Trust (UK) and the Economic and Social Research Council (UK).

The focus of M2L is on how embodied cognition theory can inform the design of museum exhibits and educational programmes. The project seeks to identify key elements or characteristics of informal body-based science experiences that do not simply engage children through physical movement, but also support the internalization and activation of key science concepts as an integral part of early science learning. The research is also dedicated to advancing the understanding of how preschool children (aged 3-5 years), especially those from under-represented communities, think, learn, and communicate about science. It also focuses on conducting translational research that will change and inform practice in the informal science learning sector worldwide. Part of this work will involve using immersive technologies, such as Kinect sensors and fitness tracking watches, given the increasing role these are having in science centres and museums.

By challenging traditional accounts of the mind-body relationship, this research is theoretically significant and there are also exciting implications for how we help children learn in areas such as science. It is possible that we can facilitate learning by designing exhibits that encourage particular 'meaningful' actions; we can also encourage specific gestures that simulate meaningful actions. For these reasons, a design-based methodology will be applied in order to address three key research questions:

1. What elements of sensory and action experiences are key to informing the design of exhibits that aim to exploit embodied interactions for learning?
2. What is the role of bodily enactment /gestures in assessing children's understanding of science concepts?
3. What cultural differences in the kinds of embodied engagement emerge across diverse museum settings?

One of the broader aims of the project is to be able to provide feedback to museum exhibit designers about the core features of an exhibit children respond to, why and how these work, and to use our results as a way to inform the future design of new exhibits using technology. The project is working very closely with museum practitioners in order to achieve this goal and to better understand how research could inform the design and development of exhibits to produce favourable outcomes e.g. attract more visitors from disadvantaged backgrounds.

The contribution of the research to the Learning Sciences field is threefold. Firstly, over the course of the project, the empirical findings will enhance understanding of the role of the body-based movements in science concept development within several diverse settings and for numerous science topics. From these findings common themes and general principles will be extracted that will provide insights into the nature of embodied learning and how interactive and communicative experiences (e.g. gesturing) can support this learning. Second, the project aims to develop a supplementary observation tool that will enable practitioners and researchers to identify and analyse children's actions, gestures and movements that align with science concepts under study and provide a useful and standardised way of assessing engagement. Finally, by the end of this project, principles for intentionally designing exhibits that elicit productive sensorimotor activities will be documented. These research-based design guidelines could include how an exhibit elicits movement, promotes social interaction and collaboration, aligns with a science concept or idea, uses gestures as part of the signage/interpretation process, prolongs dwell time, or assesses the degree to which adults physically engage with children.

This project will raise awareness of embodied approaches to learning as well as build stronger collaborations between informal science educators and Learning Sciences researchers. It is also likely that we can develop better ways to find out what children know and understand by looking at how they interact and gesture in formal settings too. This may be particularly valuable for children who are less able to express themselves verbally or through writing. Embodied Learning therefore offers exiting new avenues for both the design of science exhibits and how we facilitate children's interaction. It is also increasingly possible to take advantage of emerging technologies that can capture and respond to how children move their bodies in informal and formal science environments.

References

Alibali, M.W., & Nathan, M.J. (2012): Embodiment in Mathematics Teaching and Learning: Evidence From Learners' and Teachers' Gestures, *Journal of the Learning Sciences, 21*(2), 247-286

Brenneman, K. (2011). Assessment for preschool science learning and learning environments. *Early Childhood Research & Practice, 13,* 1

Kontra, C., Goldin-Meadow, S., & Beilock, S. L. (2012). Embodied learning across the life span. *Topics in Cognitive Science, 4*, 731–73

Novack, M.A., Goldin-Meadow, S., & Woodward, A.L. (2015). Learning from gesture: How early does it happen? *Cognition, 142*, 138-147

Sauter, M., Uttal, D.H., Alman, A.S., Goldin-Meadow, S., & Levine, S.C. (2012). Learning what children know about space from looking at their hands: the added value of gesture in spatial communication. *Journal of Experimental Child Psychology, 111*(4)587-606.

Tolmie, A., Ghazali-Mohammed, Z., & Morris, S. (2016). Children's science learning: a core skills approach. *British Journal of Educational Psychology, 86*(3), 481-497

Acknowledgments

Identifying Expansive Learning in Democratic Activity: A CHAT/DBR Approach to Community-Based Design Partnerships

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Introduction

My research uses interdisciplinary approaches to investigate the nexus of theory and practice regarding issues of social justice, equity, access, and learning in democratic activity. My research is a response to the ways in which the public is increasingly asked to engage in participatory processes. This is a paradigm shift for the planning field (Forester, 1993; Habermas, 1996; Healy, 1996) that has resulted in increased public participation, where participants from various social demographics are learning in real time the processes, as well as the civic capacities, that is the skills, identities and dispositions (Martinez-Cosio, 2006; Price et al., 2011) necessary for civic engagement. This new responsibility of decision-making power comes with both risks and rewards, as power differentials in decision-making practices have real-world consequences for communities (Taylor, 2007), and especially for under-represented communities such as Latino immigrants (May, 2017; Rocco, 2004). To better understand this phenomenon, my scholarship focuses on how under-represented communities engage civically in these processes and how collective civic participation influences the systemic evolution of said processes.

Literature review and methods

In studying participatory processes, I use Cultural Historical Activity Theory (CHAT), and design-based research to investigate the emergence of new forms of participation and the activity structures required for underrepresented communities to engage. Thus, I look at the internal capacities of a community over multiple years to understand its ways of knowledge building and expansive learning. I use CHAT inspired DBR, henceforth referred to as CHAT/DBR, since it "embrac[es] open-ended partnerships driven more by long term social aims" (O'Neill, 2016, p. 1) and because of the critical role that context plays to further understand development and learning (Gutiérrez & Jurow, 2016; Penuel, Cole, & O'Neill, 2016). Specifically, in my research, participatory democratic processes provides rich contexts of the "forces that construct and challenge social barriers to learning" (Tabak & Radinsky, 2014, p. 269) in a community setting. As such, my research joins the growing number of learning scientists placing equity and social justice as central to their research endeavors (e.g. see Tabak & Radinsky, 2014 for a literature review; Gutiérrez & Jurow, 2016).

Carrying out this kind of research is interdisciplinary and longitudinal and therefore entails collaborating with communities and stakeholders to design and re-design participatory processes for robust, inclusive, and equitable decision-making practices (Melendez, et al, 2018). Specifically, my research explores the ways power and inequity are produced, challenged, and reproduced when underprivileged communities, such as Latino immigrants, claim a space in participatory democratic processes. For example, my dissertation was a three-year ethnographic case study of the Participatory Budgeting process in Chicago's 49th Ward (PB49) (Meléndez, 2016). PB began in Brazil in 1989 as an initiative of the *Partido dos Trabalhadores, (PT)*. This innovation expands democratic participation through a process that gives the public direct say in how to spend public funds in their community (Cabannes, 2004). In the spring of 2009, the 49th Ward alderman initiated the first ever PB process in the U.S. in the highly diverse area that he represents. Thus, providing a unique study of how a process initially designed for equity and social justice goals evolved as it migrated north.

To investigate how PB49 materialized, public meetings where videotaped and segments related to Latino immigrant participation were transcribed. Following Wortham and Reyes (2015), analysis of participants' discourse (in English and Spanish) was done to present a way to "see" learning in democratic activity. The focus here was on collective and system-level learning across multiple scales of time (Lemke, 2000). Providing methods to "see" learning in democratic activity is key, as the scarcity of methods and detailed analysis of participants' engagement in participatory processes has prevented planning (Holden, 2008) and other related researchers from developing theories about how the learning of civic processes happens in practice (Mansbridge, 2003). Given the diversity of participants in this context, I took into account multiple mediating factors (e.g., language, education, race/ethnicity, immigration status) that influenced participation. I approached the PB49 process as a complex and evolving activity system (Engeström, 1990), in this case, an example of the emerging literature on fourth generation activity theory (Engeström, 2018).

As an active research participant, the ability to cross multiple identities (e.g. resident, Latino immigrant, etc.) enabled me to be sensitive to the competing identities and positions at play in the activity of PB49. It was through direct observation and participation in the activity system itself that I come close enough

to characterize the *lived-in* social worlds and lives of participants in the PB49 process (e.g. Lave, 1988). In this way, I was able to engage in the development of a flexible collaboration between the various stakeholders and constituents for refining the implementation of the PB49 process to better meet its ideals and goals (Gutiérrez & Jurow, 2016; Penuel, Cole & O'Neill, 2016; O'Neill, 2016). As part of my analytical approach, I identified tensions/contradictions (Engeström & Sannino, 2011) that emerged between participation and the structures of the environment to determine how and why these tensions/contradictions were resolved or not.

Findings

Findings revealed insights about how the dialectic of the environment and participation can be reconstituted to support under-represented communities in sustaining their civic engagement over time. Additionally, I identified key civic capacities that appear to play a role in enacting collective and system-level changes in democratic activity. Furthermore, my findings also add to theories of adult learning in community settings, design principles of participatory processes, and theories of civic engagement and leadership that contribute to the literature on cultural citizenship. My findings support a developing argument that approaching the design of participatory processes as learning environments can lead to greater clarity and transparency about how such contexts both afford and constrain civic participation, especially for under-represented communities. My findings and theorizing what they mean are further described and explained in my publications, which represent my emergent research agenda.

Emerging research agenda

My research agenda has taken off with publications that focus on four themes. First, the analytical approach used in my dissertation is an example of the potential that qualitative methods hold to capture the nuance and complexity that survey-based research often misses when looking at participation in community-based initiatives (Meléndez, 2017; 2018). Secondly, my research initiates a dialogue between the learning sciences and urban planning that benefits both fields. In doing so I aim to introduce the concepts of learning environments, interventions, and the methods of design-based research in order to argue for more iterative design of participatory process for equity using the toolbox of CHAT/DBR (Meléndez & Parker, 2018). In the learning sciences, by focusing on participatory processes, democratic activity itself is conceptualized as up for re-design (Meléndez & Radinsky, 2018). In so doing, I add my voice to the increase in calls in the learning sciences to focus on learning in community settings. The community settings are contexts where collaborative design can happen and is happening, with a focus on theorizing issues of power and equity in relation to the *praxis* or expansive learning that we should aim for when working with underrepresented communities.

Thirdly, I argue that even though most participatory processes are designed with equal participation as the aim, designing for equality sometimes inadvertently ignores the fact that participants from different communities come to participatory processes with power differentials. As such, these processes, I claim, should be more explicitly designed to foster equitable participation (Meléndez & Martinez-Cosio, 2018). Lastly, while critically assessing participatory budgeting in the United States, I look to describe and explain how as PB migrated from the global south to the global north, it has lost its emancipatory potential, as it is now used and marketed as part of the deliberate democratic movement. As such, I seek to engage and push on much of the research that is reported on PB in the U.S. that describes its successes without differentiating participation. (For an example of positive descriptors of participation writ large, see Ganuza *et al.*, 2016, while an example addressing differentiated participation can be found in Bherer *et al.*, 2016).

References

Cabannes, Y. (2004). Participatory Budgeting: A Significant Contribution to Participatory Democracy. *Environment and Urbanization.* 16 (1), 27-46.

Bherer, L., Fernández-Martínez, J. L., García Espín, P., & Jiménez Sánchez, M. (2016). The promise for democratic deepening: the effects of participatory processes in the interaction between civil society and local governments. *Journal of Civil Society*, *12*(3), 344-363.

Engeström, Y. (1990). Developmental Work Research as Activity Theory in Practice: Analyzing the Work of General Practitioners. In *Learning, Working and Imagining: Twelve Studies in Activity Theory* (Ed.), Y. Engeström. Pgs. 69-106. Helsinki: Orienta-Konsultit Oy.

Engeström, Y. & Sannino, A. (2011). Discursive Manifestations of Contradictions in Organizational Change Efforts: A Methodological Framework. *Journal of Organizational Change Management.* 24 (3), 368-387.

Engeström, Y. (2018). Expansive learning: Towards an activity-theoretical reconceptualization. In *Contemporary theories of learning* (pp. 46-65). Routledge.

Forester, J. (1993). *Critical theory, public policy, and planning practice*. SUNY Press.

Ganuza, E., Baiocchi, G., & Summers, N. (2016). Conflicts and paradoxes in the rhetoric of participation. *Journal of Civil Society*, *12*(3), 328-343.

Gutiérrez, K. D., & Jurow, A. S. (2016). Social design experiments: Toward equity by design. *Journal of the Learning Sciences*, *25*(4), 565-598.

Habermas, J. (1996). *Contributions to a discourse theory of law and democracy*. Cambridge: Polity Press.

Healey, P. (1996). The communicative turn in planning theory and its implications for spatial strategy formation. *Environment and Planning B: Planning and design*, *23*(2), 217-234.

Holden, M. (2008). Social Learning in Planning: Seattle's Sustainable Development Codebooks. *Progress in Planning.* 69, 1-40.

Lave, J. (1988). *Cognition in Practice.* Cambridge, UK: Cambridge University Press.

Lemke, J. L. (2000). Across the scales of time: Artifacts, activities, and meanings in ecosocial systems. *Mind, culture, and activity*, *7*(4), 273-290.

Mansbridge, J. (2003). Practice-Through-Practice. In *Deepening Democracy,* (Ed.), Fung, A. and Wright, E. O. Pgs. 175-199. New York: Verso.

Martinez-Cosio, M. (2006). It is not Just Who You Know: Dominant Knowledge and Civic Participation. *Journal of Civil Society*. 2 (2), 123-141.

May, S. (2017). Language Education, Pluralism and Citizenship. In *Language, Policy and Political Issues in Education* (Eds.): McCarty T, May S. 3rd: 31-45. Springer, New York

Meléndez, J. W. (2016). Identifying Expansive Learning in Participatory Budgeting: A Case Study of a Democratic Activity System (Doctoral Dissertation). Retrieved from http://indigo.uic.edu/handle/10027/21600

Meléndez, J. W. (2017). Learning in Chicago's 49th ward participatory budgeting process: How to study democratic activity across time and space by analyzing discourse. *BY THE PEOPLE*, 280.

Meléndez, J. W. (2018). Studying Learning in Neighborhood Level Democratic Activity. *Neighborhood Change and Neighborhood Action: The Struggle to Create Neighborhoods that Serve Human Needs*, 91.

Meléndez, J. W., & Martinez-Cosio, M. (2018)**.** Designing participatory environments: A case study for designing to support equitable civic engagement. Manuscript submitted for publication.

Meléndez, J.W., & Parker (2018). Learning in Participatory Planning Processes: Taking Advantage of Concepts and Theories Across Disciplines. Manuscript submitted for publication.

Meléndez, J.W., & Radinsky, J. (2018, June). From Stunted Limitations to Awakened Imaginaries: Expansive learning among Latino immigrant participants in participatory budgeting. In Meléndez & Radinsky (Co-Chairs), Community-Based Design Partnerships: Examples from a New Generation of CHAT/DBR. Symposium conducted at the International Society for the Learning Sciences, London.

Meléndez, J. W., Radinsky, J., Vossoughi, S., Marin, A., Bang, M., Nolan, C.,…Schmidt, A. (2018, June). Community-Based Design Partnerships: Examples from a New Generation of CHAT/DBR. Symposium conducted at the International Society for the Learning Sciences, London.

May, S. (2017). Language Education, Pluralism and Citizenship. In *Language, Policy and Political Issues in Education* (Eds.): McCarty T, May S. 3rd: 31-45. Springer, New York

O'Neill, D. K. (2016). Understanding design research–practice partnerships in context and time. *Journal of the Learning Sciences*, *25*(4), 497-507.

Penuel, W. R., Cole, M., & O'Neill, K (2016). Introduction to the Special Issue. *Journal of the Learning Sciences*, *25*(4), 487-496.

Price, P. L., Lukinbeal, C., Gioioso, R. N., Arreola, D. D., Fernández, D. J., Ready, T., & Torres, M. (2011). Placing Latino Civic Engagement. *Urban Geography. 32*(2), 179-207.

Rocco, R. (2004). Transforming citizenship: Membership, strategies of containment, and the public sphere in Latino communities. *Latino Studies*, *2*(1), 4-25.

Tabak, I., & Radinsky, J. (2014). Social justice research in the learning sciences. *Journal of the Learning Sciences*, *23*(3), 269-271.

Taylor, M. (2007). Community Participation in the real World: Opportunities and Pitfalls in New Governance Spaces. *Urban Studies. 44*(2), 297-317.

Wortham, S., & Reyes, A. (2015). *Discourse analysis beyond the speech event*. Routledge.

Young Children's Inquiry Within and Across Settings

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Introduction

My research expands representations of young children's (2-8yrs) science sensemaking. Three commitments inform my conceptualization of children's activity: (1) Everyday life makes sense, (2) children draw upon sensemaking resources in their everyday lives that help them understand the world, and (3) a primary challenge for educators is taking advantage of children's existing sensemaking resources while introducing new disciplinary sensemaking practices and ideas. My approach contrasts with approaches that emphasize children's inability, their misconceptions, or "deficits". Instead, I assume that it is the researcher's responsibility to understand the ways that the participants' activity makes sense and is well adapted to their experiences. In this way, my research aligns with asset-based approaches, expanding representations of children's sensemaking repertoires to better understand a broader array of young children's resources for learning science. Additionally, I do not see classrooms as isolated containers, sealed off from the family or the community. I recognize a central challenge for educators is to draw upon children's prior experience, including their cultural repertoires and family sensemaking practices. The result of these commitments is an approach that values all children's sensemaking as a resource for learning science regardless of age, class, race, religion, ethnicity, or language fluency.

Focusing on inquiry to expand resources for science learning

I study young children as they engage in inquiry—*moments during which participants orient to a phenomenon as a shared puzzle and explore that phenomenon by drawing upon sensemaking resources (they deem relevant) to the point of their own satisfaction* (Keifert & Stevens, accepted, Journal of the Learning Sciences). This conceptualization of inquiry was developed using data from the Early Learning Across Contexts project (PI Reed Stevens) consisting of hundreds of hours of video observational data of the same children in families and preschool, and again four years later in families and in elementary school. Here is an illustrative vignette:

> As Catherine (2y 11m) and Dad played in their backyard, Catherine was startled by a bee. Dad asked if she was asking the bee to "give you some honey, please". Catherine and Dad then engaged in a thought experiment. Dad asked, "Catherine if you grabbed a bee and ate it, do you think it would be as sweet as honey?" to which Catherine replied, "yes". Dad asked if she would eat it dead, and Catherine suggested that if it was dead they could chop it up. Catherine oriented to ended inquiry by turning away.

Through imagining eating a bee they explored relationships between themselves, honey which they like to eat, and bees that produce honey in a playful way. Moreover, they explored a situation that in reality would be undesirable (eating a bee) to explore these relations. This moment, and others like it from my prior work, may not seem like the inquiry typically seen in school. However, it is inquiry as a members' phenomenon—defined by participants' activity, rather than a definition managed exclusively by researchers. By examining what participants' count as inquiry, we can better recognize sensemaking resources children find relevant to exploring the world. For instance, in the moment above, Catherine and Dad engaged in a thought experiment about eating a bee to explore their relationship to bees and honey. By understanding what children think inquiry is and how they engage in inquiry, researchers and teachers make space for children's competence, and are better positioned to recognize and draw upon that competence for learning.

Recognizing children's competence prepares researchers and teachers to take advantage of children's sensemaking repertoires. The Science Through Technology Enhanced Play project (STEP; PIs Noel Enyedy, Joshua Danish) does that by privileging resources that are familiar to children, but which are often overlooked as productive for science disciplinary learning: collaborative play and imaginative embodiment. STEP supports students to imaginatively embody water particles in our physical sciences unit (states of matter), and bees in our biological sciences unit (bees, flowers, and pollination). Once they take on this imaginative identity, they explore a mixed-reality environment, allowing them to learn science concepts through iterative cycles of student-driven inquiry. My analyses of STEP extend my previous work, showing how even very young children can learn about complex science phenomenon when supported to draw upon familiar sensemaking resources (Keifert, Lee, Dahn, Illum, DeLiema, Enyedy, & Danish, 2017; Keifert, Enyedy, Dahn, Lee, Lindberg, 2018).

Family culture

Through further analysis of ELAC data I conceptualize *family culture* to explore how families engage in particular inquiry practices (Keifert, under review). I draw on M.H. Goodwin's *family ethos* (Goodwin, 2007) and Nasir, Rosebery, Warren, & Lee's *culture* (2006) to define *family culture* as constellations of practices in families, nested within larger cultural communities. For instance, while Catherine engaged in a particular kind of thought experiment in her family inquiry practice, thought experiments more generally are common in scientists' professional practice, a community to which her father belongs. In this way, Catherine's family practice is embedded within a broader constellation of practices of her father's professional community. Like larger communities of practice, families are locally organized cultures. In my analyses, I show how young children transform their world into culturally-relevant activity (C Goodwin, 1994; C Goodwin, 2017), and are seen by others in their family community as competent inquirers (Keifert 2012, under review). However, members of other communities may not share their understanding of practices and competence.

Connecting learning across settings

This nested nature of culture has implications for supporting children to learn as they move across settings. My prior work documented the family sensemaking practices of Catherine and her classmate Charlie and examined how these practices were differentially afforded in interactions with their teachers in their preschool classroom (Keifert, 2015). Charlie often attempted to engage teachers in inquiry of story narratives by asking questions like "Remember what this was like when this happened?" Several of Charlie's teachers engaged with him in response. However, Catherine attempted to engage others in her family practice of thought experiments by asking questions like "Imagine what this would be like if this happened?" just as she did with Dad and the bees. A series of these attempts about crickets were rejected ("What if the crickets got out?"), one after the other, by her preschool teacher. Even though both children shared a similar socioeconomic and cultural background (white, middle class), one encountered more difficulty in drawing on her family practice. In a conference paper that won best student paper award at the International Conference of the Learning Sciences (Keifert, 2012), I argued Catherine's family inquiry practice was constrained because there were few adults in the classroom who engaged in this form of imaginative exploration. Teachers' roles here are critical for supporting learning across settings.

This work illustrates that mismatches between cultural communities' practices across home and school settings have profound implications for children's experience—children may give up on trying to engage in familiar practices, may be told their practices are inappropriate or bad, or they may even be constructed as bad or problem children. After four more years of schooling, Catherine (age 7) articulated to me having abandoned attempts to engage in her family inquiry practice at school altogether, yet she was not constructed as a problem child by her teacher. Furthermore, she felt comfortable claiming that her own family activity more closely resembled science than what happened in school (she engaged in "experimenting" at home while at school it was just "testing" where "the teacher knows what's gonna happen"). A nested understanding of culture helps to articulate both the constraints on her family inquiry practice, and the protective layers of culture at the level of her father's professional science practice and her membership in white middle-class culture. Thus, an understanding of culture as nested positions researchers to recognize the constraints and affordances of culture at multiple levels for children as they move within and across settings for learning. This understanding also prepares researchers and teachers to better design to support children to develop horizontal expertise (Cole & Gajdamashko, 2009) as they move across learning settings.

Designing learning environments that privilege family practices

In future work, I hope to develop partnerships with teachers and families in a diversity of communities. I am interested in exploring how to create contexts for very young children from nondominant communities to share their family practices, and professional learning for teachers to support their noticing of these practices. Historically, classrooms have been created with expectations that children learn the canonical versions of disciplinary practices. Furthermore, extensive research in the learning sciences has illustrated that the sensemaking resources of children from nondominant communities is often excluded as non-scientific and non-academic (see Warren, Ogonowski, & Pothier, 2005 for thorough discussion). However, by supporting teachers to notice and value children's family inquiry practices as resources for science learning, I hope to shift classrooms into spaces for collaborative learning that privileges these resources.

In collaboration with families, I will document and explore a wide variety of children's competencies in engaging in family sensemaking practices. I will also develop video clubs and other professional learning opportunities to support teachers to notice and draw upon children's family sensemaking practices within

classrooms. In collaboration with teachers, I hope to develop learning opportunities that are (a) aligned with Next Generation Science Standards and/or state standards for science, (b) create opportunities for children to engage directly with scientific phenomena, (c) create interactional spaces that support children to draw upon family sensemaking practices and their cultural repertoires of practice, and (d) support children to learn with and from classmates. Through reflection and analysis with teachers, I hope to collaboratively design learning environments for young children that support bridges between home and school rather than barriers. This future research agenda is where the power of my commitments and my prior research and experience will combine to allow me to reconceptualize classrooms to empower all children, particularly those from nondominant communities, to learn through connected experiences across home and school.

Acknowledgments

References

Cole, M., & Gajdamashko, N. (2009): The concept of development in Cultural-Historical Activity Theory: Vertical and horizontal. In A. Sannino, H. Daniels, & K. D. Gutiérrez (Eds.), *Learning and expanding with Activity Theory,* (pp. 129-143). New York, NY: Cambridge University Press.

Goodwin, C. (1994). Professional vision. *American anthropologist*, *96*(3), 606-633.

Goodwin, C. (2017). *Co-operative action*. Cambridge University Press.

Goodwin, M.H. (2007). Occasioned knowledge exploration in family interaction. *Discourse Society, 18*(1), 93-110.

Keifert, D. (2012). Young children's everyday inquiry: A field study of a young girl's play across contexts. *Proceedings of the 10th International Conference of the Learning Sciences, Sydney AU, 1, 315-322.*

Keifert, D. (2015). *Young children participating in inquiry: Moments of joint inquiry and questioning practices at home and in school* (Doctoral dissertation, Northwestern University). Retrieved from Proquest. (3724286)

Keifert, D. Enyedy, N., Dahn, M., Lee, C., Lindberg, L. (2018). Tracing bodies through liminal blends during play-based inquiry in a mixed reality environment. *Proceedings of the 13th International Conference of the Learning Sciences, London, UK* (this volume).

Keifert, D., Lee, C., Dahn, M., Illum, R., DeLiema, D., Enyedy, N., & Danish, J. (2017). Agency, embodiment, & affect during play in a mixed-reality learning environment. *Proceedings of the 16th Interaction Child & Design Conference*, Palo Alto CA.

Nasir, N., Rosebery, A., Warren, B., & Lee, C. (2006). Learning as cultural process: Achieving equity through diversity. In K. Sawyer (Ed.), *The Cambridge Handbook of the Learning Sciences.* New York: Cambridge University Press.

Warren, B., Ogonowski, M., & Pothier, S. (2005). Everyday" and "scientific": Rethinking dichotomies in modes of thinking in science learning. *Everyday matters in science and mathematics: Studies of complex classroom events*, 119-148.

Understanding, Redefining, and Designing for Broadening Participation

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Introduction

I study broadening participation. As a learning sciences researcher with a critical sociocultural stance to learning and development, I believe that our work is inextricably linked to questions of social justice, power, and cultural repertoires of practice. My research is oriented around two core beliefs—persons develop in structures of social practice and we can come to understand these structures by examining participants' cultural learning pathways (Bell, Tzou, Bricker & Baines, 2012). Given this stance to learning and development, I choose design-based research and ethnographic methods as my dominant approaches because they both privilege the experiences of participants. By leveraging ethnographic methods within the larger context of design-based research, two types of findings emerge from my work that pertain to design and theory: 1) design principles—findings about program design, curricula, pedagogies, mentorship, and implementation within communities and 2) broadening participation theory—findings about learning, Deep Hanging, deepening participation, and identity development for participants from non-dominant communities.

Design principles

Design-based research in STEM OST environments has been central to my research on broadening participation. From September 2010 - June 2015, I ran an out-of-school time (OST) chemical oceanography program called Project COOL (Chemical Oceanography Outside the Laboratory) that served middle school youth from mostly non-dominant communities. COOL was a design-based research and broadening participation initiative funded by the National Science Foundation and the LIFE Center. During years 3-6 of the program, we brought undergraduate and graduate students into COOL to serve as mentors and facilitators. Learning sciences researchers have paid much attention to OST environments as transformative spaces for youth participants. My interest in layered learning environments expands this to include the learning trajectories of adult participants within OST broadening participation programming.

Broadening participation

My research on broadening participation resists catastrophizing narratives of underrepresentation within STEM careers and learning environments while exploring experiences of participants from non-dominant communities. I explore the notion of broadening participation as a tension between the need to add more people from non-dominant groups to existing STEM disciplinary paradigms and transforming definitions of participation to include the experiences of STEM participants from non-dominant communities. What follows is an illustrative narrative in action from my data:

> Angelica self-identified as Peruvian American and was a graduate student in Botany who came to graduate school with the goal of becoming like her undergraduate mentor, "the kind of person who could inspire students" (3/15/11). Angelica wanted to use her PhD to become an undergraduate professor. She wanted to create a program of Botany research that could also serve as a context for broadening STEM participation opportunities for students like herself. However, her dissertation committee's expectations of who and what she should become dominated any conversations she tried to have with them, "In my situation the expectation was just for me to primarily be a research student, and my training to be one for the person who would want to go into an R1 institution, though I'd never seen that to be what I wanted from the beginning. I got no help in how to develop myself as an educator" (3/15/11).

Settled expectations (Bang, Warren, Rosebery & Medin, 2012) constrained Angelica's available STEM participation pathways. When Angelica found COOL she viewed it as a pathway to creating her own educational theory and practice curriculum. She and other mentors from non-dominant groups explained in interviews that they saw the COOL program as a context within which they could resist settled expectations and redefine what counted to them as STEM participation.

As a sociocultural researcher with an equity-oriented frame, I take a critical stance towards understanding how individuals learn within structures of social practice (Bell et al., 2012; Dreier, 2009). I view

learning as deeply relational and situated. In my work, I define learning as the ways that participants deepen participation in complex activity systems (Bang & Vossoughi, 2016; Gutiérrez & Jurow, 2016), develop critical epistemic agency (Basu, Barton, Clairmont, Locke, 2009), develop identification within STEM disciplines (Carlone & Johnson, 2007), resist settled expectations (Bang et al., 2012), and develop science-linked identities (Nasir & Hand, 2008). I take a critical stance to understanding the affordances of out-of-school time (OST) learning environments and designing for broadening participation by considering powered relationships in STEM learning spaces. I am aiming towards a theoretical and practice-based understanding of the role OST learning environments can play in broadening STEM participation for people from non-dominant communities—Deep Hanging. This approach allows me to attend to both increasing participation in existing STEM paradigms and also redefining participation in learning spaces that honor participants and epistemologies from non-dominant communities which have historically been underrepresented in STEM.

Current work

I currently work on a project jointly funded by the National Science Foundation and Wellcome Trust—Learning and Environmental science Agency Research Network for Citizen Science (LEARN CitSci). Citizen Science is another space for broadening participation which positions the public to participate in contemporary science, learn scientific practices, and contribute to ongoing research. Citizen scientists ask their own questions, conduct their own analyses, and leverage the resources of science institutions to conduct research in their own communities. Ballard, Dixon, & Harris (2016) expanded upon Basu & Barton's (2009) notion of critical physics agency to define Environmental Science Agency (ESA)—youth enacting agency in environmental and citizen science contexts. Our goals in the LEARN CitSci project are to understand the ways that youth participate in environmental and citizen science programming facilitated by natural history museums and to characterize individual programs as designed environments which present affordances and constraints for youth engaging in ESA.

An emerging research agenda

I am interested in studying the affordances and constraints of designed learning environments in order to understand ways to maximize opportunities to redefine and broaden STEM participation. I introduce Deep Hanging as a theory of learning in practice. Deep Hanging entails authentic tasks in rich contexts, providing access, capitalizing on opportunity, and building interpersonal relationships which in turn strengthen identification with the discipline, facilitate learning, and redefine participation. I leverage my findings about non-dominant youth and adult participants' experiences to consider the affordances and constraints of designed-learning environments for broadening participation. These findings have coalesced into a set of design principles for layered learning environments- spaces that support mentor learning in broadening participation programming while supporting science learning and identity outcomes for youth. As my critical orientation continues to develop, I explore the narratives of participants from non-dominant communities in STEM, participatory design-based research (Bang & Vossoughi, 2017), and desettled expectations (Bang et al., 2012) to reevaluate my theory building about youth and adult experiences within broadening participation programming. I resist narrow definitions of STEM participation by examining the limits of epistemic agency (Scipio, 2017b), pushing back against the metaphor of the Leaky Pipeline, and exploring pedagogies of joy in broadening participation learning environments (Scipio et al., 2017a).

References

Ballard, H. L., Dixon, C. G. H., & Harris, E. M. (2017). Youth-focused citizen science: Examining the role of environmental science learning and agency for conservation. *Biological Conservation*, *208*, 65–75.

Bang, M., & Vossoughi, S. (2016). Participatory Design Research and Educational Justice: Studying Learning and Relations Within Social Change Making. *Cognition and Instruction*, *34*(3), 173–193.

Basu, S. J., & Calabrese Barton, A. (2009). Critical physics agency: Further unraveling the intersections of subject matter knowledge, learning, and taking action. *Cultural Studies of Science Education*, *4*(2), 387–392.

Basu, S. J., Calabrese Barton, A., Clairmont, N., & Locke, D. (2009). Developing a framework for critical science agency through case study in a conceptual physics context. *Cultural Studies of Science Education*, *4*(2), 345–371.

Bell, P., Tzou, C., Bricker, L., & Baines, A. D. (2012). Learning in diversities of structures of social practice: Accounting for how, why and where people learn science. *Human Development*, *55*, 269–284.

Carlone, H. B., & Johnson, A. (2007). Understanding the Science Experiences of Successful Women of Color : Science Identity as an Analytic Lens. *Journal of Research in Science Teaching*, *44*(8), 1187–1218.

Dreier, O. (2009). Persons in Structures of Social Practice. *Theory & Psychology*, *19*(2), 193–212.

Gutiérrez, K. D., & Jurow, A. S. (2016). Social Design Experiments: Toward Equity by Design. *Journal of the Learning Sciences*, *25*(4), 565–598.

Scipio, D. (2017a). *Authoring Joy: Multimodal artifacts as tools for broadening definitions of STEM participation.* In D. Scipio (chair). Pedagogies of Joy. Paper presented in symposia at the annual meeting of the American Educational Research Association. April 28, 2017. San Antonio, TX.

Scipio, D. (2017b). *Broadening Participation: Inclusive and transformative epistemic agency within a chemical oceanography laboratory.* In C. Krist & D. Keifert (chairs). Epistemic Agency as a Members' Experience. Paper presented in symposium at the annual meeting of the National Association for Research in Science Teaching. April 22, 2017. San Antonio, TX.

Acknowledgments

Creativity as a Lens to Frame Teachers' Use of Games for Learning

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Teacher education in game-based learning

Leading scholars in the field have theorized digital games as contexts with potential to promote "situated understandings, effective social practices, powerful identities, shared values, and ways of thinking of important communities of practice" (Shaffer, Squire, Halverson & Gee, 2005, p.7). Researchers have illustrated the use of games to support learners' personal identity and goals towards engagement in academic domains and professional careers (Foster, 2008; Squire, 2010). However, despite educational researchers' demonstrated attempts to capitalize on the potential of games for enhancing students' curricular experiences, research on educating teachers in incorporating games in their practice is severely lacking at both pre-service and in-service levels (Molin, 2017; Shah, 2015). This is problematic given that immersive and interactive digital technologies such as games are fundamentally shifting teachers' pedagogical roles in orchestrating student learning. Shaffer and colleagues (2015) argue that these shifts necessitate a complete re-envisioning of how teachers are prepared to design experiences and facilitate learning in digitally-evolving classroom ecologies.

Few, but powerful exemplars exist in the extant literature to illuminate how a skilled teacher works in synergy with a well-designed game to facilitate students' personally relevant engagement with academic material in game-based classrooms (Eastwood & Sadler, 2013; Silseth, 2012). Even fewer studies have (a) defined the knowledge and skills that are germane for teachers to identify and leverage the educational potential of games (Foster, Shah & Duvall, 2015; Shah & Foster, 2015), (b) illustrated the process of supporting teachers' motivation to incorporate games in their practice (Chee, Mehrotra & Ong, 2015; Foster & Shah, 2017), and (c) documented how teachers' roles and practice in teaching with games evolve over time (Bell & Gresalfi, 2017; Shah & Foster, 2014b). The emergent status of research on teacher education in game-based learning (GBL) is disadvantageous to teachers' growing interest in employing games for teaching, learning and assessment and the field of games and learning at large (Takeuchi & Vaala, 2014). In the absence of comprehensive approaches for supporting teachers to innovate in their practice using games, teachers are likely (a) to not consider all aspects of games that can impact student learning (e.g. teachers seek obvious content alignment to curriculum but do not have a consideration for inherent pedagogical approach), (b) to resort to using games as standalone tools for review and practice but not as ecosystems of designed experiences for students to explore their interests in (Shah, 2015; Shah & Foster, 2018). I argue that recent research on creativity and educational technology offers a useful lens to frame how we support teachers to cultivate analytical and pedagogical skills that may be beneficial for them to constantly innovate their practice by identifying, examining, designing, and repurposing technologically-mediated experiences and environments for learning.

Teachers, games, and creativity

Larry Cuban (1986) documented teachers' adoption of radio, television, computers- technologies that were claimed to catalyze transformational changes in formal education since the 1920s. His work underscored the significance of teachers' roles as gatekeepers of technological and pedagogical innovations in schools. Technologies of today are rapidly changing; they are more complex than before in the kinds of experiences they can afford, and they transcend traditional barriers of physical and social spaces of inquiry, communication, construction, and expression (Foster & Shah, 2015a; Shah & Foster, 2015). Thus, if teachers are to be inventive in their use of technology in their curriculum, teachers need to be supported to develop the skill set to creatively examine and repurpose technology for educational purposes (Henriksen, Mishra & Mehta, 2015; Mishra, Koehler & Henriksen, 2010). Thus, in order to repurpose games for learning, teachers should be supported in (a) perceiving games in a *novel* way (something that did not exist in this form before), (b) designing curricular experiences using a chosen game in an *effective* manner (something that does the job better than before), and (c) considering the role of the context in choosing and repurposing a games for a specific learning objective in a *wholesome* manner (something that ties with the context). I illustrate this creative view of supporting teachers to use games through an excerpt from my dissertation research (Shah, 2015).

The mixed-methods study investigated the development and assessment of 14 pre-service teachers' knowledge of game-based learning using the Game Network Analysis (GaNA) framework (Foster, 2012) over 11-weeks. The framework includes a focus on the pedagogy and content of games as well as the process for employing game-based learning in classrooms in formal and informal settings (Foster, 2012). GaNA comprises of an analytical lens for game analysis and selection by helping teachers approach the game as a curriculum with constraints and affordances for technology, pedagogy, and content (Foster, 2012). It includes *Play Curricular*

activity Reflection Discussion (PCaRD) model that aids teachers in (a) the systematic incorporation of games in classrooms in order to flexibly accommodate challenges inherent in a typical school structure; (b) the design of learning environments where student engagement, teacher intervention, curricular inquiry are in synergy; and (c) overcoming limitations of the games being used (Foster & Shah, 2015b). GaNA facilitates teachers in designing opportunities for inquiry, communication, construction, and expression to foster transformative learning experiences anchored in the game (Foster & Shah, 2015a). The decisions teachers make during game analysis and game integration are guided by ecological conditions impacting the successful use of GBL experiences. These conditions include social dynamics, organizational and technological infrastructure, and pedagogical culture of the context in which GBL is to be introduced. In this way, GaNA offers one methodological tool kit to use games in new ways.

Creative repurposing of Minecraft for English/Language Arts using GaNA

Max (pseudonym) was a graduate male student who specialized in Secondary education in English/Language. He had no prior training in game-based learning and was interested in incorporating environments such as Minecraft as a way for highschool students to explore elements of good storytelling. Through the 11-weeks, Max was guided to learn about games through direct (playing) and vicarious approaches (researching websites, watching Youtube videos, reading empirical literature), concentrating on the games' content, pedagogical, and technological characteristics (Foster, 2012). Max learnt to play and see games in ways that he had never seen before. He learnt that playing *Minecraft* naturally involved exploring one's narrative experience and learning about cause and effect. Every choice the player made during their individual experience contributed to the final outcome (survival). For instance, if players spent a majority of their time digging holes and searching for minerals, they might not have time to build adequate shelter, and find themselves unprotected from monsters, making them susceptible to death. He believed this example and others he articulated were applicable to students' understanding of literature as narratives and character arcs contain many examples of cause and effect. Max was also able to comprehend that while students may learn from their own mistakes or decisions while playing, *Minecraft* did not explicitly provide opportunities for students to show their understanding of cause and effect as a narrative element. Additionally, there was no feedback from the game regarding this academic content for students to be able to self-correct or self-regulate their actions within the game. For instance, if a player did not survive, the game could not explain why this happened. These were the strengths and the shortcomings of *Minecraft* from the perspective of teaching English, which the instructor could leverage and address respectively by designing learning activities in conjunction with the game.

With this knowledge of the game, Max designed a lesson for students to understand how a character's actions affect a narrative using Minecraft as the curricular anchor creating opportunities for play, curricular activity reflection and discussion (Foster & Shah, 2015b). While the *play* would be naturalistic, Max had planned to identify teachable moments observing how students guided their characters in the world and made decisions for the character. During the *curricular activities* Max wanted to students make connections between the game and academic content. In one of the curricular activities he would engage students in reading different sample stories, identifying at least five examples of cause and effect, and recording them on t-chart graphic organizers. During reflection and discussion activities, Max wanted students to gain additional insights on cause and effect by prompting them to explore how they in their own lives or characters in stories could make different choices in specific situations, leading to different outcomes. Max planned to record insights gained from the P-Ca-R-D activities using *Minecraft* (a) to assess students understanding of cause and effect, and the ways it can affect a narrative, and (b) to plan future PCaRD sessions that focus on strengthening students narrative writing skills.

Looking ahead

Students' lives and the ways they learn in and out of school are being transformed in a Deweyan sense by technology-mediated experiences. Specifically, learners across sites have more opportunities to engage in *inquiry* (through tinkering, playing, experimentation), *construction* (through designing, creating, making, building, producing), *communication* (through mentoring, collaborating with peers, sharing within a community/affinity-based groups) and *expression* (of interest, affect, valuing through artefacts created) (Foster & Shah, 2015a; Shah & Foster, 2014a). This paper argues that working with teachers is imperative to democratize learning with games and other technological pedagogical innovations (e.g. making) in K-12 education. Research on creativity in educational technology offers a useful lens for supporting teachers to unpack *novel, effective, and wholesome* (Henriksen, Mishra & Mehta, 2015) ways to use games and design experiences. Doing so in conjunction with methodological framework like Game Network Analysis (Foster, Shah & Duvall, 2015; Shah & Foster, 2015) is a step in the direction of empowering teachers (a) to facilitate students' understanding of concepts, to support identities and dispositions, and to trigger future trajectories in academic domains and careers, (b) to complement

game-based learning with other theoretical and pedagogical approaches that can be instrumental in supporting knowledge and skills in domains and disciplines that are valued in schools, and (c) to foster interactions between self and learning and the resulting changes in learners' interest and valuing of the content encountered through game playing (Foster & Shah, 2017; Shah & Foster, 2018).

References

Bell, A., & Gresalfi, M. S. (2017). Teaching with videogames: How experience impacts classroom integration. *Technology, Knowledge and Learning*, 22(3), 1–14

Chee, Y. S., Mehrotra, S., & Ong, J. C. (2015). Professional development for scaling pedagogical innovation in the context of game-based learning: teacher identity as cornerstone in "shifting" practice. *Asia-pacific Journal of Teacher Education, 43*(5), 423-437.

Cuban, L. (1986). *Teachers and Machines: The classroom use of technology since 1920*. New York: Teachers College Press.

Eastwood, J. L., & Sadler, T. D. (2013). Teachers' implementation of a game-based biotechnology curriculum. *Computers & Education, 66*(0), 11-24.

Foster, A (2008). Games and motivation to learn science: Personal identity, applicability, relevance and meaningfulness. *Journal of Interactive Learning Research, 19*, 597-614.

Foster, A. (2012). Assessing learning games for school content: Framework and methodology. In D. Ifenthaler, D. Eseryel & X. Ge (Eds.), *Assessment in Game-based Learning: Foundations, Innovations, and Perspectives*. New York: Springer.

Foster, A. & Shah, M. (2017). Games, Science, and Identity Change: Findings From A Year-Long Teacher Professional Development. *In* M. Pivec & J. Gründler (Eds.), *Proceedings of the 11th European Conference on Game-Based Learning* (pp. 173-180), Graz, Austria

Foster, A. & Shah, M. (2015a). The ICCE framework: Framing learning experiences afforded by games. *Journal of Educational Computing Research, 51*(4), 369-395.

Foster, A. & Shah, M. (2015b). The play curricular activity reflection and discussion model for game-based learning. *Journal of Research on Technology in Education, 47*(2), 71-88.

Foster, A., Shah M., & Duvall, M. (2015). Game Network Analysis: A framework for teaching with games. In M.L. Niess &   H. Gillow-Wiles (Eds.) *Handbook of Research on Teacher Education in the Digital Age* (pp. 380-411). Hershey,   PA: Information Science Reference.

Henriksen, D., Mishra, P., & Mehta, R. (2015). Novel, Effective, Whole: Towards a NEW framework for evaluations of creative products. Journal of Technology and Teacher Education, *23*(3), 455-478

Molin, G. (2017). The Role of the Teacher in Game-Based Learning: A Review and Outlook. In M. Ma & A. Oikonomou (Eds.). *Serious Games and Edutainment Applications Vol II* (649-674). Springer International Publishing

Shaffer, D. W., Squire, K., Halverson, R., & Gee, J. P. (2005). Video games and the future of learning. *Phi Delta Kappan, 87*(2), 104-111.

Shaffer, D. W., Nash, P. & Ruis, A. R. (2015). Technology and the New Professionalization of Teaching. *Teachers College Record* (pp. 1-30).

Shah, M. (2015). *Pre-service Teacher Education in Game-Based Learning: Cultivating Knowledge and Skills for Integrating Digital Games in K-12 Classrooms.* Unpublished Doctoral Dissertation, Drexel University, Philadelphia, PA.

Shah, M. & Foster, A. (2014a). The inquiry, communication, construction and expression (ICCE) framework for understanding learning experiences in games. Special Issue on Applied Research in Immersive Environments for Learning. *International Journal of Virtual and Personal Learning Environments, 5*(2), 1-14.

Shah, M. & Foster, A. (2014b). Undertaking an ecological approach to advance game-based learning: A case study. Special   issue on game-based learning for 21st century transferable skills: Challenges and opportunities. *Journal of   Educational Technology and Society, 17*(1), 29-41

Shah, M. & Foster, A. (2015). Developing and assessing teachers' knowledge of game-based learning. *Journal of Technology and Teacher Education, 23*(2), 241-267. Chesapeake, VA: Society for Information Technology & Teacher Education.

Shah, M. & Foster, A. (2018). Promoting Teachers' Identity Exploration: The Way Forward in Teacher Education for Game-Based Learning. In E. Langran & J. Borup (Eds.), *Proceedings of Society for Information Technology & Teacher   Education International Conference* (pp. 478-486). Washington, D.C., United States: Association for the   Advancement of Computing in Education (AACE).

Silseth, K. (2012). The multivoicedness of game play: Exploring the unfolding of a student's learning trajectory in a gaming context at school. *International Journal of Computer-Supported Collaborative Learning, 7*(1), 63-84.

Squire, K. D. (2010). From information to experience: Place-based augmented reality games as a model for learning in a globally networked society. *Teachers College Record*, *112*(10), 2565-2602

Takeuchi, L. M, & Vaala, S. (2014). Level up learning: A national survey on teaching with digital games. New York: The Joan Ganz Cooney Center at Sesame Workshop.

Defining, Designing, and Documenting Computational Thinking Across K-12 Education

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Abstract: Smartphones, tablets, and laptops are becoming the lenses through which we see, interpret, and interact with the world. As such, for young learners growing up in this technological landscape, being able to recognize the capabilities and limitations of these technologies, think critically about the roles they play in society, and most crucially, to be able to meaningfully participate in this technological culture is essential. Much of the current effort to prepare learners for this future is collected under the umbrella label Computational Thinking, an intentionally vague term comprised of skills and concepts that enable computational inquiry across diverse subject areas and support new forms of creative expression. As part of the effort to bring computational thinking to all, new programming environments, learning platforms, and educational initiatives are being developed and deployed. This paper presents my prior, current, and intended future work towards better understanding the nature of computational thinking and ways to bring it to all learners.

Introduction

Computation is changing our world. In response to the growing need for all students to develop technical and computational literacy skills, new programming environments, learning platforms, and educational initiatives are being developed and deployed to prepare learners for their digital futures. Computational thinking, and its constituent skills, has far reaching applicability, supporting inquiry across diverse subject areas, enabling new forms of expression and creative outlets, and opening the doors to new opportunities for learners in classrooms and beyond. While there is a great deal of activity towards broadly engaging students with computational thinking, many open and consequential questions about how best to accomplish these goals remain.

Broadly, my research seeks to understand how best to support learners in developing meaningful understandings of computational ideas and positive attitudes towards computing. More specifically, I study the design of computational learning environments, looking at the interplay between the representations used, the nature of the learning activity, and the context in which the experience is situated, to make sense of how these aspects collectively shape learners' emerging understanding of powerful ideas in computing. I am particularly interested in understanding how specific features of educational technologies and computational tools make ideas more intuitive and accessible and using these findings to inform the design of new learning experiences. My work lies at the intersection of the Learning Sciences, human-computer interaction, and computational thinking education, with an emphasis on the application of theory to the design and evaluation of innovative computational learning environments. While much of my work focuses on learners developing computational literacy skills, my work extends to using computational environments to deepen learning across an array of disciplines. My research contributes to our understanding of how best to engage people in reasoning about powerful computational ideas and support their ability to develop and apply computational thinking practices. A second contribution of my work is advancing the design of environments and technologies that can broaden participation in computing, bringing learners from diverse and historically underrepresented backgrounds into computing. To date, my research has focused on two main areas: the design of introductory programming environments and the integration of computational thinking into existing subjects as a way to broaden participation in computing.

Designing, understanding, and evaluating introductory programming environments

In my dissertation, I pursued questions on the relationship between the design of introductory programming environments and the knowledge and practices they promote in computer science classrooms. Specifically, I studied the impact of introducing learners to programming through graphical, block-based programming environments (Fig. 1A) such as *Scratch* (Resnick et al., 2009) and *Alice* (Cooper, Dann, & Pausch, 2000), compared to conventional text-based programming languages.

Block-based programming is increasingly becoming the way the learners are being introduced to programming and big ideas in computational thinking more broadly. A growing body of work is finding that the block-based approach is effective at engaging diverse audiences in computing and lowering the barrier to programming (Kelleher, Pausch, & Kiesler, 2007; Maloney, et al., 2008; Ryoo, Margolis, Lee, Sandoval, & Goode, 2013).
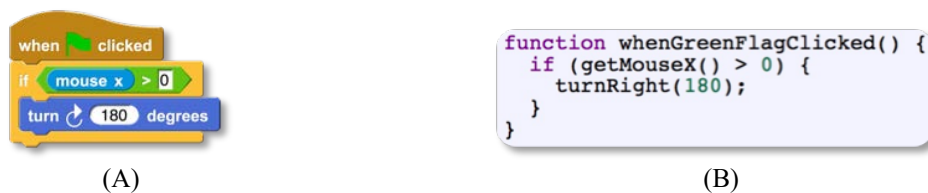
Figure 1. Comparable block-based (A) and text-based (B) programs.

This is an essential first step in identifying the utility of block-based tools, but follow-up questions looking at how the modality influences emerging understandings and practices had yet to be answered in a systematic way before my dissertation work. In the Learning Sciences, similar questions have been pursued looking at the role of representation in supporting and shaping understanding in mathematics and science domains (Kaput, Noss, & Hoyles, 2002; Sherin, 2001; Wilensky & Papert, 2010). In bringing this lens to the design of introductory programming environments, my goal is to advance our understanding of how and why specific features work and to use those findings to inform the design of the next generation of computational learning environments. The questions I pursued in my dissertation ask how the block-based modality affects learners' emerging understandings of core programming concepts and if and how concepts learned and practices developed in block-based tools carry over to more conventional text-based programming languages. To answer these questions, I designed a quasi-experimental, mixed-methods study across three high-school computer science classrooms, with each class following the same curriculum, but using a different programming environment (Weintrop, 2016). I created both the curriculum and the programming environments used in the study. I conducted two iterations of this design-based research study in successive school years in an urban, public high school, using findings from year one to inform the design of the programming environments and curriculum for the second. Both iterations included the design and implementation of three modes of two different introductory programming environments that differentially support block-based, text-based, and hybrid block/text approaches to programming (Fig. 2). The environments I created were based on Snap! (Harvey & Mönig, 2010) in year 1 (Fig. 2A) and Pencil Code (Bau et al., 2015) in year 1 (Fig. 2B).
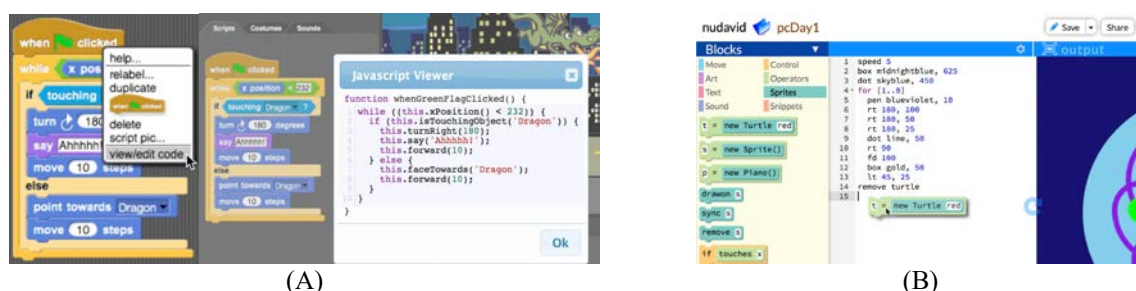
Figure 2. Two iterations of hybrid blocks/text environments from my dissertation study.

My dissertation shows that modality matters. One contribution of this work is the finding that students working in the block-based form outperformed their peers who used an isomorphic text-based versions (Weintrop & Wilensky, 2017b). Further, analyses of students answering questions on central computing concepts in either block-based or text-based modalities show that students' ability to answer questions differed by modality, with student performing better in block-based contexts across a number of implementations and languages (Weintrop, Killen, & Franke, 2018; Weintrop & Wilensky, 2015). In following students as they moved from introductory environments to a professional programming language (Java), we found the differential learning outcomes that occurred in the introductory tools did not better prepare learners for later computer science instruction (Weintrop & Wilensky, Under Review). This presents a new set of research questions about how to support learners in transitioning from introductory to professional tools, a line of work I intend on pursuing. A second contribution of this work is the creation and evaluation of two hybrid programming environments (Figure 2) that blend features of block-based and text-based environment (Weintrop & Wilensky, 2017a).

Broadening participation by integrating computing across the curriculum

The second focus of my research is on exploring ways to broadening participation in computing through the design of accessible computational learning experiences that are easily implemented in existing classrooms. In particular, I am looking at ways to integrate computational thinking into existing mathematics and science

classrooms (Pei, Weintrop, & Wilensky, 2018; Weintrop et al., 2016). The motivation for this approach is threefold: (1) it builds on the symbiotic relationship for learning between computational thinking and mathematics and science domains, (2) it addresses practical concerns of reaching all students and having proficient teachers, and (3) it brings science and mathematics education more in line with contemporary professional practices in these disciplines. By integrating computational thinking into existing classrooms, this work contributes a novel, easily adoptable, and scalable strategy for engaging diverse populations in computing that is theoretically grounded, practically feasible, and fits within existing educational infrastructure. To date, the focus has been on high school mathematics and science classrooms and focused on learners and curricular materials. I am currently in the process of expanding the scope of this integrative approach to include English Language Arts and other humanities and artistic subjects. Additionally, I am working on a project studying pre-service teachers to understand what existing knowledge resources they possess that can be used to help them integrate computational thinking into their teaching. In doing so, the hope is to develop approaches to help teachers draw on their prior experiences with computing and technology to advance the goal of bringing computational thinking instruction to all learners.

References

Bau, D., Bau, D. A., Dawson, M., & Pickens, C. S. (2015). Pencil Code: Block Code for a Text World. In *Proceedings of the 14th International IDC Conference* (pp. 445–448). New York, NY, USA: ACM.

Cooper, S., Dann, W., & Pausch, R. (2000). Alice: a 3-D tool for introductory programming concepts. *Journal of Computing Sciences in Colleges*, *15*(5), 107–116.

Harvey, B., & Mönig, J. (2010). Bringing "no ceiling" to Scratch: Can one language serve kids and computer scientists? In J. Clayson & I. Kalas (Eds.), *Proc. of Constructionism 2010* (pp. 1–10). Paris, France.

Kaput, J., Noss, R., & Hoyles, C. (2002). Developing new notations for a learnable mathematics in the computational era. *Handbook of International Research in Mathematics Education*, 51–75.

Kelleher, C., Pausch, R., & Kiesler, S. (2007). Storytelling alice motivates middle school girls to learn computer programming. In *Proc. of the SIGCHI 2007* (pp. 1455–1464).

Maloney, J. H., Peppler, K., Kafai, Y., Resnick, M., & Rusk, N. (2008). Programming by choice: Urban youth learning programming with Scratch. *ACM SIGCSE Bulletin*, *40*(1), 367–371.

Pei, C. (Yu), Weintrop, D., & Wilensky, U. (2018). Cultivating Computational Thinking Practices and Mathematical Habits of Mind in Lattice Land. *Mathematical Thinking and Learning*, *20*(1), 75–89.

Resnick, M., Silverman, B., Kafai, Y., Maloney, J., Monroy-Hernández, A., Rusk, N., … Silver, J. (2009). Scratch: Programming for all. *Communications of the ACM*, *52*(11), 60.

Ryoo, J. J., Margolis, J., Lee, C. H., Sandoval, C. D., & Goode, J. (2013). Democratizing computer science knowledge: transforming the face of computer science through public high school education. *Learning, Media and Technology*, *38*(2), 161–181.

Sherin, B. L. (2001). A comparison of programming languages and algebraic notation as expressive languages for physics. *International Journal of Computers for Mathematical Learning*, *6*(1), 1–61.

Weintrop, D. (2016). *Modality Matters: Understanding the Effects of Programming Language Representation in High School Computer Science Classrooms* (Dissertation). Northwestern University, Evanston, IL.

Weintrop, D., Beheshti, E., Horn, M., Orton, K., Jona, K., Trouille, L., & Wilensky, U. (2016). Defining Computational Thinking for Mathematics and Science Classrooms. *Journal of Science Education and Technology*, *25*(1), 127–147.

Weintrop, D., Killen, H., & Franke, B. (2018). Blocks or Text? How programming language modality makes a difference in assessing underrepresented populations. In *Proc. of International Conference on the Learning Sciences 2018*. London, UK.

Weintrop, D., & Wilensky, U. (2015). Using Commutative Assessments to Compare Conceptual Understanding in Blocks-based and Text-based Programs. In *Proc. of the Eleventh Annual International Conference on International Computing Education Research* (pp. 101–110). New York, NY, USA: ACM.

Weintrop, D., & Wilensky, U. (2017a). Between a Block and a Typeface: Designing and Evaluating Hybrid Programming Environments. In *Proc. of the 2017 Conference on Interaction Design and Children* (pp. 183–192). New York, NY, USA: ACM.

Weintrop, D., & Wilensky, U. (2017b). Comparing Block-Based and Text-Based Programming in High School Computer Science Classrooms. *ACM Transactions on Computing Education (TOCE)*, *18*(1), 3.

Weintrop, D. & Wilensky, U. (Under Review). How Block-based, Text-based, and Hybrid Block/Text Modalities Shape Novice Programming Practices.

Wilensky, U., & Papert, S. (2010). Restructurations: Reformulating knowledge disciplines through new representational forms. In J. Clayson & I. Kallas (Eds.), *Proc. of Constructionism 2010*. Paris, France.

Doctoral Consortium

Fabric-based Computing: New Materials for Learning Computer Science

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Abstract: When embroidering fabric into tessellation structures, crafters sew algorithmic patterns and program folding mechanics. Fiber crafts could become an alternative context for computer science education. This research aims to understand computational concepts and practices of fiber crafts and the uncharted computational products and learning processes they foster.

Vision

Inclusive of weaving and electronic-textiles (Buechley, 2006), fabric manipulation is a compelling yet uncharted context for reinvigorating the historical connections of fiber crafts and computing. Fiber crafts that incorporate the algorithmic patterns into fabric to create three-dimensional textures could become an alternative context for learners to intimately (and perhaps more profoundly) engage with Computer Science Education (CSEd). The goals of my dissertation are to research three aspects of fiber arts: (1) the computational concepts and practices, (2) the emergent computational forms of CSEd, and (3) the range of design process(es).

Through design, materials become "objects-to-think-with" for learners to internalize inherent ideas of physical objects through understanding their own bodily actions (Papert, 1980). New computational materials, like fiber crafts, therefore have the potential to create new and transform existing learning opportunities. New materialist theories can extend constructionist assumptions beyond material mediated internalization by flattening hierarchies among materials and people and negotiating learning through routines and variations (Barad, 2003). This relates to fiber crafts because artifacts form through human movement, and changes in movement can produce changes in the performed computation. My dissertation draws on the framework of Goode and Chapman's (2016) CS curriculum that includes concepts (e.g., algorithms) and practices (e.g, debugging) that map on to observable aspects of fiber crafts (e.g., defining input/output commands).

Pilot studies showed fabric manipulation as a compelling context for computing, including practicing core computational concepts (e.g., intuiting algorithms, defining conditionals), and demonstrated that in fabric, participants performed pre-computational practices. Crafters became an intimate part of live computational performances instead of controlling a computer. This kindled questions about which CS concepts and practices are inherent to fiber crafts and which computational forms and learning processes they produce.

I will investigate these areas in the context of a fiber-crafts public school course for youth (age 11-13) through qualitative and performative analyses (Barad, 2003) of video data, think alouds, and artifacts. The analyses will include iterative coding for computational concepts and practices, graphic abstractions of material computational expressions, tracking routines and variations in computational units, aesthetic deliberations (e.g., integrating patterns), and what facilitates or prohibits them (e.g., fold and movement potential) to demonstrate design process(es) during computationally relevant moments. This dissertation aims to contribute to scholarly efforts that investigate fiber crafts for disciplinary learning, extend material-mediated conceptions of learning by theorizing learners as part of computational products, and expand CS learning processes. This promises implications for broadening participation in CS and for integrating low-cost computation into low-resourced settings, which could have ramification for gender representations and rupture inequities within CSEd.

New materialist theories are new to the Learning Sciences. To help advance my dissertation, I seek to solicit methodological guidance to better align my analytical techniques and theoretical framework, and to explore implications of my work for the Learning Sciences.

References

Barad, K. (2003). Posthumanist performativity: Toward an understanding of how matter comes to matter. *Signs: Journal of Women in Culture and Society*, 28(3), 801-831.

Buechley, L. (2006, October). A construction kit for electronic textiles. In Wearable Computers, 2006 10th IEEE International Symposium (pp. 83-90). IEEE.

Goode, J., & Chapman, G. (2016). Exploring computer science, version 7.0. Computer Science Equity Alliance. Retrieved December 29, 2017 at http://www.exploringcs.org/for-teachers-districts/curriculum.

Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas*. New York, NY: Basic Books.

Supporting Undergraduate Bioscience Learners in Problem-Solving Process Skills Using a Technology-Enhanced Learning Environment

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Abstract: Problem-solving process skill is required to solve various open problems in genetics, and most often learners make the mechanical application of this skill without a comprehensive conceptual understanding. To address this difficulty, I am planning to develop a TEL environment which will be based on dynamic variable manipulation, system-generated appropriate and dynamic feedback, etc. for teaching this skill. Through a series of empirical studies, this research aims to design and evaluate the TEL environment.

Vision

Undergraduate bioscience and medical learners learn genetics since it is a compulsory foundational course in their curriculum. Learners are required to identify and justify the patterns of inheritance behind various biological phenomena. To identify these inheritance patterns, they have to solve problems which are either cause-effect problems (closed problems) or effect-cause problems (open problems) (Orcajo & Aznar 2005). Learners solve these problems by connecting theoretical knowledge with practical they do in the lab (Crews et al. 1997).

Experts solve these kinds of problems by performing a series of skills that can be grouped into problem representation, problem-solving and problem analysis (Orcajo & Aznar 2005). Problem representation requires them to qualitatively analyze the problem and propose a hypothesis. Problem-solving needs them to do steps like the design of a resolution strategy (analysis of problems in parts or resolution of a simpler case, study the problems using tables, graphs, percentages, etc.) and resolution (application of concrete cases with numerical data). Lastly, problem analysis includes steps to interpret the results according to hypothesis and theoretical framework used. These steps are often unclear to non-experts/learners as to why they are doing these steps.

However, learners' difficulty as reported in literature includes the mechanical application of common problem-solving process steps without a comprehensive conceptual understanding of these steps (Karagoz & Cakir 2011). So there is a need of teaching this skill explicitly to the learners. Therefore to provide an authentic learning environment for problem-solving process skill, I propose a Technology-Enhanced Learning (TEL) environment: Geneticus Investigatio (GI) as part of my doctoral research.

The proposed TEL environment will be based partly on the theory of anchored instruction (Crews et al. 1997). The learning environment will have a problem context similar to problems faced by researchers. Further learning material and activities in the environment will serve to "anchor" the subsequent learning which will also encourage exploration. I have used the TELoTS framework which gives step by step guidelines to identify, characterize steps and design learning activities for TEL environment (Murthy et al. 2016).

A classroom study with 22 undergraduate bioscience learners (convenience sampling) was conducted with this initial version of TEL environment to further inform the redesigning of the learning environment. Through this study difficulty faced by learners were triangulated from the individual interviews which were conducted with the learner and are being addressed in the second version of TEL. I am thinking to evaluate my TEL system from learning, engagement and interaction perspective and would like to discuss my research questions and respective data collection and analysis method for re-designing and evaluating my learning environment.

References

Crews, T. R., Biswas, G., Goldman, S., & Bransford, J. (1997). Anchored interactive learning environments. International Journal of Artificial Intelligence in Education (IJAIED), 8, 142-178.

Ibáñez Orcajo, T., & Martínez Aznar, M. (2005). Solving problems in genetics II: conceptual restructuring. *International Journal of Science Education*, 27(12), 1495-1519.

Karagoz, M., & Cakir, M. (2011). Problem-solving in Genetics: Conceptual and Procedural Difficulties. *Educational Sciences: Theory and Practice*, 11(3), 1668-1674.

Murthy, S., Iyer, S., & Mavinkurve, M. (2016). Pedagogical Framework for Developing Thinking Skills using Smart Learning Environments. *Learning, Design, and Technology: An International Compendium of Theory, Research, Practice, and Policy*, 1-49.

Knowledge Places: Embedding Knowledge in the Space of the Classroom

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Abstract: This research investigates a novel approach to supporting classroom learning communities through ubiquitous computing and embodied interaction. Specifically, this work embeds community knowledge within the physical space of the classroom, with the aim of mediating opportunistic inter-group interactions instigated through proximity.

Vision

In a learning community approach to education (Bielaczyc & Collins, 1999) the whole classroom of students assumes "collective cognitive responsibility" (Scardamalia, 2002) for its progress, often creating a community knowledge base consisting of user-contributed content, semantic tags, votes, and other social information. While some research has investigated knowledge building environments, most designs have adopted a cloud-based interaction paradigm for contributing to and accessing emerging community knowledge. Cloud-based designs can be successful in promoting learning (Slotta, 2013), however, getting young learners to attend to and leverage the community's knowledge can be challenging. There are many reasons cited for this, including lack of interest, lack of awareness of the potential value of community knowledge, difficulty in formulating queries to access knowledge contributions, the granularity of contributions, and the dominant role of peer discourse and collaboration in daily classroom activity, particularly for younger learners. While these scaffolds do complement students' individual interactions with the cloud-based knowledge base, they leave in place a somewhat monolithic cloud as the repository of their collective work. The goal of this research is to explore the potential for moving the knowledge base into the space of the classroom. Supporting the construction of an emergent knowledge base in which students' physical location within the classroom and co-location with other students serves to mediate the filtering, access to, and applications of community knowledge – through the technology paradigm of ubiquitous computing, in which physical objects, surfaces, and spaces embody digital information. This approach, "Knowledge Places" (KP), decomposes the community knowledge base into a collection of thematic (disciplinary) units which are semio-spatially mapped (Roschelle & Pea, 2002) onto demarcated locations distributed around the classroom. This necessitates students' physical movement among those KP sites in order to contribute knowledge or otherwise access their peers' contributions through a "performant query," analogous to the way the Embedded Phenomena designs (Moher, 2006) require movement to investigate shared objects of inquiry. Ultimately, Knowledge Places seeks to bring learners into close contact with the aggregated community knowledge associated with a particular topic at each KP site and to bring learners into physical proximity with peers who share an immediate interest in a given topic for the purpose of fostering productive disciplinary discourse (Engle & Conant, 2002).

References

Bielaczyc, K., & Collins, A. (1999). Learning communities in classrooms: A reconceptualization of educational practice. *Instructional-Design Theories and Models: A New Paradigm of Instructional Theory*, *2*, 269–292.

Engle, R. A., & Conant, F. R. (2002). Guiding Principles for Fostering Productive Disciplinary Engagement: Explaining an Emergent Argument in a Community of Learners Classroom. *Cognition and Instruction*, *20*(4), 399–483. http://doi.org/10.1207/s1532690xci2004_1

Moher, T. (2006). Embedded phenomena: supporting science learning with classroom-sized distributed simulations. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 691–700. http://doi.org/10.1145/1124772.1124875

Roschelle, J., & Pea, R. (2002). A walk on the WILD side: How wireless handhelds may change computer-supported collaborative learning. *International Journal of Cognition and Technology*, *1*(1), 145–168. http://doi.org/10.1075/ijct.1.1.09ros

Scardamalia, M. (2002). Collective cognitive responsibility for the advancement of knowledge. *Liberal Education in a Knowledge Society*, *97*, 67–98.

Slotta, J. D. (2013). Knowledge Community and Inquiry: New Opportunities for Scripting and Orchestration. *OISE-University of Toronto*, 1–15.

Computation, Constructivism, and Curriculum Design

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Abstract: Existing methods for automating curriculum design have had limited impact over the past fifty years. I propose two ways to potentially get around this limitation: developing adaptive content selection policies that are robust to different conceptions of student learning and taking an orthogonal approach to automated curriculum design that uses learner-generated solutions to help students learn.

Vision

From the mechanical teaching machines of the early twentieth century to intelligent tutoring systems and the wave of massive open online courses (MOOCs) in recent years, many have been motivated by the dream of personalized, adaptive instruction for all students. To achieve this dream, learning scientists and educational technology researchers have largely focused on rule-based systems that rely on extensive domain and psychology expertise. To do adaptive content selection, these systems use simple forms of rule-based AI (possibly combined with constrained machine learning algorithms). While this approach has led to the development of successful intelligent tutoring systems with high quality content, (1) such systems use a very limited form of adaptive content selection, and (2) developing such systems can be very costly. In contrast, some researchers are now starting to apply black box machine learning algorithms to do adaptive content selection. However, in my dissertation I will show through a comprehensive literature review that these approaches have had relatively limited impact.

Instead, I hope to demonstrate that combining insights from both approaches can help in automating curriculum design. In particular, I focus on three aspects of automated curriculum design: content creation, content curation, and adaptive content selection. I propose a number of methods for impactful, cost-effective automated curriculum design that combine machine learning, human computation, and principles from the learning sciences.

First, I will describe how reasoning about model mismatch (i.e., the fact that our statistical models of student learning do not accurately describe student learning) can help point out limitations in existing approaches [Doroudi and Brunskill, 2017] and help in creating more robust adaptive content selection policies [Doroudi et al., 2017].

Second, I will show experiments that demonstrate how we can leverage the work that students naturally do to create new content in a cost-effective way [Doroudi et al., 2016]. In doing so, I will take motivation from the constructivist philosophy of education, whereby I view learner-generated solutions as being a projection of students' constructions on the written plane, which can then be used to inform other students as they construct their own understandings.

Third, I propose to demonstrate how using machine learning (in particular, multi-armed bandits) can help curate the best content among a pool of learner-generated solutions that continues to grow over time.

Finally, I propose to show how we can use learning science principles to constrain the search for good content selection policies. In particular, I hope to show that constraining adaptive content selection algorithms with insights from the expertise reversal effect can help improve upon strictly black box approaches to adaptive content selection that disregard what we know about student learning.

References

Shayan Doroudi and Emma Brunskill. The misidentified identifiability problem of Bayesian Knowledge Tracing. In Educational Data Mining, pages 143–149. International Educational Data Mining Society, 2017.

Shayan Doroudi, Ece Kamar, Emma Brunskill, and Eric Horvitz. Toward a learning science for complex crowdsourcing tasks. In Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems, pages 2623–2634. ACM, 2016.

Shayan Doroudi, Vincent Aleven, and Emma Brunskill. Robust Evaluation Matrix: Towards a more principled offline exploration of instructional policies. In Proceedings of the Fourth (2017) ACM Conference on Learning@ Scale, pages 3–12. ACM, 2017.

Using Multiple Embodied Representations to Support Learners in Making Connections Across Modeling Activities

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Abstract: My research aims to help students see familiar cultural practices, such as dance, as a resource in understanding scientific concepts and building bridges from their everyday lives to disciplinary norms. I build on the previously successful Science Through Technology Enhanced Play (STEP) mixed-reality learning environment that combines motion-tracking technology with a computational simulation and provide learners the opportunity to use dance, a fun and familiar practice for all participants, to share their understanding from STEP and why it matters to them.

Vision

Embodied theories of learning highlight the processes in which expressive gesture and body movement act as key representational resources (Abrahamson & Sánchez-García, 2016). The role of the body in learning is well-studied in laboratories and formal environments, but the potential for using familiar embodied activity to help bridge between out of school practices and scientific ones is understudied and under-utilized. The goals of my dissertation are to: (1) support science learning across contexts by connecting multiple representations that leverage the body; (2) expand participation in science by studying how embodied representations can support the engagement of students from diverse backgrounds in science activities across learning contexts, and; (3) explore how dance, a familiar and popular form of embodied activity, might connect their informal experiences with science.

My dissertation builds on evidence that early elementary students can construct explanatory and predictive models. While existing literature suggests young children are capable of sophisticated modeling practices, focus is predominately on modeling by *individuals* and models as *visual* representations. By contrast, my dissertation will address this gap by investigating two forms of models that are instead *collective* and *embodied*: participatory models (Danish, 2014) and ensemble dance. Collective embodied models are powerful tools for cooperative and coordinated reasoning as they ask learners to move and think relative to each other. For example, in a participatory model learners physically enact parts of a complex system and in doing so learn its mechanisms and rules. Similarly, in an ensemble dance individuals move together in locally valued and mutually understandable ways to co-create shared meaning.

Students, ages 6-8, participating in a performing arts summer program will progress through a five-week sequence of modeling activities to explore the relationship between macroscopic states of matter and microscopic particle behaviors. Each activity is divided into two parts. In the first part, students will engage in embodied scientific modeling, which targets exploring and learning science concepts. Then, during the second part, students will be asked to choreograph and perform a dance to represent what they learned and why it matters to them. Thus, students will be building on local dance practices and personal connections to make sense of the science, affording an opportunity to engage in science in a way that is both fun and familiar. The participatory modeling activities build on the previously successful Science Through Technology Enhanced Play (STEP) mixed-reality learning environment that combines motion-tracking technology with a computational simulation (Danish et al., 2015). Dance-based activities will be co-designed with local performing arts instructors and focused on the genres and techniques of dance the students are already interested in and engaging with.

Analysis will focus specifically on how interactional mechanisms (e.g., talk and embodied action) are assembled to evaluate the rules of science, representational infrastructures, and social participation. Through this in-depth analysis of the video data, I aim to locate the representational resources that support learners' movement from disciplinary to dance-based embodied representations (and back again), and what is learned during this process. Given the importance of connecting science with students' everyday lives, my dissertation will advance designing for learning across disciplines and settings by leveraging the body as a primary representational pathway.

References

Abrahamson, D., & Sánchez-García, R. (2016). Learning is moving in new ways: The ecological dynamics of mathematics education. *Journal of the Learning Sciences*, *25*(2), 203-239.

Danish, J. A. (2014). Applying an activity theory lens to designing instruction for learning about the structure, behavior, and function of a honeybee system. *Journal of the Learning Sciences*, *23*(2), 100-148.

Danish, J. A., Enyedy, N., Saleh, A., Lee, C., & Andrade, A. (2015). Science through technology enhanced play: Designing to support reflection through play and embodiment. *Intl. Society of the Learning Sciences.*

Why Can't We All Just Get Along?: Focusing on Socioemotional Climates to Understand Emotions in Collaborative Learning

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Abstract: This study aims at identifying and understanding the socioemotional processes that groups of students use while engaging in collaborative learning. I will also compare the processes of two extreme groups (one with high and one with low meta-emotional judgments).

Vision

In this study, I aim to address gaps in the social regulation of learning literature and improve collaborative learning practice by better understanding the phenomena of socioemotional climates. These are a group's collective emotional state, defined by the overwhelming presence of either positive or negative emotions (Bakhtiar, Webster, & Hadwin, 2017). Currently, most of the literature focuses on socioemotional interactions and tensions; research is still lacking regarding the emotion regulation strategies students use and the types of talk they engage in while working together. The goal of this research is to determine what regulation strategies and talk types groups use and how each of these differ between groups that rated their socioemotional climate as more positive and less positive.

Measuring socioemotional climates remains a challenge in the current literature. Meta-emotions are feelings, or perceptions, about feelings and are primarily studied at the individual level (Pekrun, Goetz, Titz, & Perry, 2002). Therefore, a group's collective meta-emotional judgments about their emotions can be used to represent their socioemotional climate (Bakhtiar et al., 2017). Importantly, socioemotional climates evolve over time; the group members become more interdependent, with individuals' states influencing others in a reciprocal manner. For this reason, short-term studies on socioemotional climates may not accurately depict development of the social processes.

The purpose of this study is to understand the different social processes of socioemotional climates. Specifically, I intend to investigate two research questions: **RQ1**) What socioemotional regulation processes and talk types did groups use in a project-based learning environment? **RQ2)** How do these strategies and talk types differ between groups who rated their meta-emotional judgments as low and high?

Participants are second-year graduate pharmacy students ($n = 150$) completing a required project-based learning course on problem solving and innovative solutions in pharmacy at a university in the southeastern United States. During this course, we piloted an app that another student and I created, *Collabucate,* with six groups of student volunteers ($n = 29$), recording their two-hour weekly meetings (i.e., two per week for seven weeks). Using log data from the app (i.e., weekly ratings of their feelings about collaboration), I calculated the groups' average meta-emotional judgments to serve as their ranking for their socioemotional climate. After identifying the groups with the overall highest and lowest ratings for comparison purposes, I will code both verbal and non-verbal data during each of the group meetings for socioemotional regulation strategies, interactions, and talk types. I will primarily use deductive coding, but for those topics less prevalent in the research, I will use inductive coding.

To answer RQ1, I will conduct a code mapping analysis (Saldaña, 2016) for socioemotional regulation and talk types. For each social process, I will map codes using a three-step iterative process in which I will place codes into categories, categories into themes, and finally themes into theory. In the last step, I will look for patterns in the strategies and talk types used by students. To better understand the data and answer RQ2, I will conduct a thematic analysis using the analytic memos (Saldaña, 2016) from our coding to compare the qualitative differences between the types of codes used in these two groups.

Preliminary findings have shown that the group with the lowest meta-emotional judgments began the course with average ratings, decreasing to the lowest overall scores. Conversely, the group with the highest meta-emotional judgments maintained a high rating over time. Notably, these groups differed in the strategies and types of talk they used (e.g., the high self-rated group engaged in talk types that resulted in more positive responses). Although the high self-rated group identified slightly fewer tensions, both groups identified *progressing despite different personalities and working styles* as a tension most frequently.

References

Bakhtiar, A., Webster, E. A., & Hadwin, A. F. (2017). Regulation and socio-emotional inter-actions in a positive and a negative group climate. *Metacognition and Learning*, 1-34.

Pekrun, R., Goetz, T., Titz, W., & Perry, R. (2002). Academic emotions in students' self-regulated learning and achievement: a program of qualitative and quantitative research. *Educational Psychologist, 37*, 91-105.

Saldaña, J. (2016). *The coding manual for qualitative researchers (3ʳᵈ ed)*. Sage. Los Angeles.

Collaborative Writing in Higher Education: Investigating the Implementation of CSCL Tools and the Role of Prior Individual Experiences and Preferences

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Abstract: This research project aims to contribute to the understanding of the complex process of collaborative writing by taking into account the different individual, collaborative, and contextual variables and the interaction between them. The use of Computer Supported Collaborative Learning (CSCL) tools such as collaboration scripts and group awareness tools to scaffold students during collaborative writing are investigated.

Vision

Collaborative writing (CW), an omnipresent activity in higher education settings, is known as a highly complex process. It is frequently unstructured and tends to involve multiple roles, subtasks, and activities which all can be performed iteratively (Lowry, Curtis, & Lowry, 2004). Moreover, there are individual, collaborative, and contextual components at work, as well as interactions between all these components and factors (Van Steendam, 2016). On the one hand, various studies have shown that the way groups tackle this complex task differ and have pointed at the difficulty of developing truly CW (e.g. Lowry, Curtis, & Lowry, 2004; Onrubia & Engel, 2009). Next to this text construction process, process regulation is also indicated as an important, related collaborative process during CW (Van Steendam, 2016). On the other hand, individuals may have different ideas on how to write a text. First, there are different individual approaches towards writing (e.g. writing beliefs, White & Bruning, 2005) which can be related to CW processes and outcomes (e.g. Cuevas et al., 2016). Secondly, the way students act in CW activities and conceive CW differs (see e.g. Noël & Robert, 2004; Marttunen & Laurinen, 2012). Thirdly, the Script Theory of Guidance (Fisher et al., 2013) highlighted the important role of learners' internal scripts to understand their actions in the collaboration.

Despite this complexity, there is a lack of profound research on these CW processes and their relation with product quality. In addition, the relation with individual factors has been underexposed and no previous study has investigated internal CW scripts. Therefore, this research project has two main goals. First, to unravel the complex process of CW and the role of individual prior experiences and preferences within the scope of CW tasks. Second, to investigate the opportunities of CW technologies and the use of CSCL tools such as collaboration scripts and group awareness tools to scaffold students during CW.

References

Cuevas, I., Mateos, M., Martin, E., Luna, M., Martin, A., Solari, M., … Martinez, I. (2016). Collaborative writing of argumentative syntheses from multiple sources: The role of writing beliefs and strategies in addressing controversy. *Journal of Writing Research, 8*, 205–226.

Fischer, F., Kollar, I., Stegmann, K., & Wecker, C. (2013). Toward a script theory of guidance in computer-supported collaborative learning. *Educational Psychologist*, *48*, 56–66.

Lowry, P.B., Curtis, A., & Lowry, M.R. (2004). Building a Taxonomy and Nomenclature of Collaborative Writing to Improve Interdisciplinary Research and Practice. *International Journal of Business Communication, 41*, 66-99.

Marttunen, M., & Laurinen, L. (2012). Participant profiles during collaborative writing. *Journal of Writing Research, 4*, 53-79.

Noël, S., & Robert, JM. (2004). Empirical Study on Collaborative Writing: What Do Co-authors Do, Use, and Like? *Computer Supported Cooperative Work, 13*, 63-89.

Onrubia, J., & Engel, A. (2009). Strategies for collaborative writing and phases of knowledge construction in CSCL environments. *Computers and Education, 53*, 1256–1265.

Van Steendam, E. (2016). Editorial Forms of Collaboration in Writing. *Journal of Writing Research, 8*, 183-204.

White, M.J., & Bruning, R. (2005). Implicit writing beliefs and their relation to writing quality. *Contemporary Educational Psychology, 30,* 166-189.

The Effects of the Productive "Visible-Annotation Tool" (P-"VAT") for Collaborative Knowledge Construction on Higher-Order Interaction and Collaborative Outcome

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Abstract: This abstract reports a design-based experimental study that evaluates the effects of the revised tool (P-"VAT") on higher-order interaction and level of collaborative outcome. To achieve this purpose, research was carried out to revise the previous version of the VAT through comparison of the effects of two types of learning strategies in P-VAT. Results will lead to in-depth and systematic verification of the research questions.

Research background and vision

With the proliferation of network technologies, computer-supported collaborative learning (CSCL) is currently being implemented at all levels of education (Fu, Aalst, & Chan, 2016). In particular, an asynchronous online discussion tool is a valuable means of engaging students for the knowledge construction in the complex task. Many researchers have designed asynchronous discussion tools with various functions (Fransen, Weinberger, & Kirschner, 2013). Regrettably, however, the realization of the productive learning process from the precise sharing of ideas to the successful integration of diverse ideas has proven to be difficult in educational practice (Kirschner & Erkens, 2013). Despite the increase in research on various scaffolding strategies for CSCL, there is still a lack of effort in designing scaffolding, especially considering the sequential nature of the knowledge construction process (Rienties, Giesbers, Tempelaar, & Lygo-Baker, 2012; Shin et al., in press). In addition, given that the fundamental goal of CSCL is learner-centered reflective thinking, some strategies should be provided in a form that increases the autonomy of the learner (Ludvigsen, 2016). Toward these issues, this study suggested that the successful completion of complex tasks requires a productive CSCL environment that combines several scaffolding strategies implemented at different phases of knowledge construction (Resier, 2004). This study aims to improve the previously proposed VAT by providing a negotiation script during the opinion-sharing phase and combining peers' feedback activities to enable learner-directed flexible interaction during the problem-solving phase, thereby fading internalized negotiation scripts (Bouyias & Demetriadis, 2012). In particular, productive VAT (P-VAT) as the improved tool focused on problem solving phase can promote a reflective discourse based on dynamic interaction and then can lead to a fruitful collaborative solution. Through these effects, P-VAT will help to realize productive knowledge construction from building exact common ground to describing the fruitful solution through the higher-order interaction. In addition, the study expects to contribute to the field of CSCL research by combining, within a series of productive knowledge construction processes, key scaffolding strategies that have been shown consistently to be important to CSCL.

References

Bouyias, Y., & Demetriadis, S. (2012). Peer-monitoring vs. micro-script fading for enhancing knowledge acquisition when learning in computer-supported argumentation environments. *Computers & Education*, 59(2), 236-249.

Fransen, J., Weinberger, A., & Kirschner, P. A. (2013). Team effectiveness and team development in CSCL. *Educational Psychologist*, 48(1), 9-24.

Fu, E. L., van Aalst, J., & Chan, C. K. (2016). Toward a classification of discourse patterns in asynchronous online discussions. *International Journal of Computer-Supported Collaborative Learning*, 11(4), 441-478.

Kirschner, P. A., & Erkens, G. (2013). Toward a framework for CSCL research. *Educational Psychologist*, 48(1), 1-8.

Ludvigsen, S. (2016). CSCL towards the future: The second decade of ijCSCL. *International Journal of Computer-Supported Collaborative Learning*, 11(1), 1-7.

Reiser, B. J. (2004). Scaffolding complex learning: The mechanisms of structuring and problematizing student work. *The Journal of the Learning Sciences*, 13(3), 273-304.

Rienties, B., Giesbers, B., Tempelaar, D., Lygo-Baker, S., Segers, M., & Gijselaers, W. (2012). The role of scaffolding and motivation in CSCL. *Computers & Education*, 59(3), 893-906.

Shin, Y., Kim, D., Jung, J., (in press). The effects of representation tool (Visible-annotation) types to support knowledge building in computer-supported collaborative learning. *Educational Technology & Society*

Exploring the Definition and Measurement of Collaborative Problem Solving

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Abstract: Current CPS constructs and assessments designed to provide insights regarding proficiency with CPS skills have focused largely on the CPS skills required for temporary teams to solve problems in situational or temporary contexts. My research is focused on designing and measuring a construct that addresses the more longitudinal aspects of team effectiveness and to better understand the role that behaviors and cognitive skills play in influencing both the team effectiveness and task effectiveness aspects of CPS.

Vision

Collaborative problem solving (CPS) is an important 21st century skill, required for success along the entire Kindergarten to Career continuum. Students are expected to collaborate and solve problems from the playground to the classroom. Collaborators in the workforce are tasked with building teams and solving problems across a wide range of fields, and in both formal and informal settings.

My research aims to build on the current state-of-the art work developed by groups such as PISA (OECD 2017) and ATC21s (Hesse, Care, Buder, Sassenberg, & Griffin, 2015) to design a construct and tasks that include and measure a more comprehensive range of behaviors and skills, and to then validate this construct and these tasks against real-world outcomes, using real-world contexts. My goal is that the insights gleaned from this work will inform the ability of those working in the learning sciences to build better instruments for the classroom and in doing so provide more authentic, meaningful, and actionable insights regarding proficiency and progress with these skills for learners and teachers than the field has been able to provide previously.

To this end, I have developed a construct model of CPS that addresses aspects of team effectiveness and task effectiveness as supported by a range of behaviors and cognitive skills, and aligned with real-world outcomes. This new model is designed to provide insights about the ability of an individual, as well as a team, to succeed in more authentic, complex, and real-world contexts. This new model was used to create tasks designed to elicit a range of both behaviors and cognitive skills required to support both team and task effectiveness in an online, game-based, CPS assessment, "Circuit Runner." Four consecutive studies have been designed, and two completed, to explore the validity of both the framework and the assessment tasks.

The CPS I and II studies focused on administration of different iterations of the "Circuit Runner" game to different populations with the inclusion of additional instruments (e.g., pre-and a post-survey, CPS-focused situated judgment test (SJT), HEXACO-IR self-report survey) to explore the measurement of CPS skills across instruments. Five subskills from the CPS construct were measured within the game (e.g., perspective taking, persistence, strategy, goal orientation, problem feature awareness) with three of those sub skills measured in the SJT (e.g., perspective taking, strategy, problem feature awareness). Correlation and further data analytics provided the preliminary confirmation that these are valid and reliable measures. We continue to explore the insights provided by the data in the game.

The CPS III study will be similar to CPS I and II and include a 'post' version of the game played at a later date to explore tracking of these skills over time. CPS IV Study involves the administration of a Team Effectiveness Peer Review Tool (TE-PRT) designed to measure the comprehensive set of Team Effectiveness components of the CPS construct at both the individual and team levels, both within and across teams. The goal is an expanded exploration of the skills with varying types of instruments within and across teams, over time, and with the additional insights provided by real-world individual and team performance metrics.

My hope in sharing my current work with the learning sciences community is to glean insights that might inform construct, task, or study design. I would also benefit from a greater understanding of the perceptions of the learning science community regarding the importance/limitations of measurement of complex skill sets such as CPS and the advantages/disadvantages of employing technology for these purposes.

References

Hesse, F., Care, E., Buder, J., Sassenberg, K., & Griffin, P. (2015). A framework for teachable collaborative problem solving skills. In Assessment and teaching of 21st century skills (pp. 37-56). Springer Netherlands.

OECD. (2017). PISA 2015 Assessment and Analytical Framework. OECD Publishing. https://doi.org/10.1787/9789264281820-en

Making Energy Easy: Interacting With the Forces Underlying Chemical Bonding Using the ELI-Chem Simulation

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Abstract: We developed and explored four increasing levels of embodied interaction as atoms to support chemistry students in grasping the forces and energy changes involved in chemical bonding. Current results show an increase in students' conceptual understanding in all four levels with the highest learning gain among students who felt the forces using a haptic device.

Vision

This study seeks to develop and explore high-school chemistry students' conceptual understanding regarding forces and energy involved in chemical bonding. Having no access to the molecular world and lacking the force-based explanation of chemical bonding, students rely on incorrect interpretations and intuitive heuristics, such as the 'octet-rule', i.e. eight electrons in the outer energy level (Taber, 2002). Most of them view chemical bonds incorrectly as attached solid spheres for which energy is needed to bring them together, or as coiled springs that release energy when relaxed (Boo, 1998).

We designed and developed an Embodied Learning Interactive environment, ELI-Chem, to alleviate these difficulties: (1) ELI-Chem removes the abstraction by providing bodily experience with the molecular level as proposed by embodied learning theory (Barsalou, 1999); and (2) ELI-Chem is based on a mathematical simulation of attraction-repulsion forces between atoms, supporting a force-based teaching approach (Nahum-Levy et al., 2007; Taber, 2002).

ELI-Chem offers sensory-motor experiences of the attraction and repulsion forces while two atoms approach and move apart, at four increasing degrees of embodiment: (1) *observing videos* that involves no action; (2) *using a mouse* to move an atom in the simulation; (3) *using a joy-stick* that moves a greater distance than the mouse; and (4) *using a haptic device* at greater distance and greater force than the mouse. The first non-interacting degree is a comparison group for the rest. The working hypothesis is that more intense physical experience with the underlying electrical forces provides a stronger foundation for understanding energy changes during chemical bonding and related concepts such as chemical stability or bond-length.

The participants are forty-eight 12th grade chemistry students, 12 in each group. The study is framed as pretest-intervention-posttest design. Main concepts addressed: repulsive and attractive forces, chemical stability, and energy released/required.

Findings show that there was an increase in students' conceptual understanding in all four groups. Three groups - video, mouse and joystick - were indistinguishable in their learning effects. From an explanation based on the 'octet rule' depicting the atoms as static "touching" balls that energy is required to approach them, all groups turned to consider the dynamic balance between attraction and repulsion forces. Adding haptic information to create a multimodal experience of chemical bonding resulted with increased learning gain, indicating on the use of sensorimotor schemes in the building of a more accurate mental models and representations.

References

Barsalou, L. W. (1999). Perceptions of perceptual symbols. *Behavioral and Brain Sciences, 22*(04), 637–660.

Boo, H. K. (1998). Students' understandings of chemical bonds and the energetics of chemical reactions. *Journal of Research in Science Teaching, 35*(5), 569-581.

Nahum-Levy, T., Mamlok-Naaman, R., Hofstein, A., & Krajcik, J. (2007). Developing a new teaching approach for the chemical bonding concept aligned with current scientific and pedagogical knowledge. Science Education, 91(4), 579-603.

Taber, K., & Coll, R. K. (2002). Bonding. In J. K. Gilbert, O. De Jong, R. Justi, D. F. Treagust, & J. H. Van Driel (eds.). *Chemical Education: Towards Research-based Practice* (pp. 213-234). Kluwer Academic Publishers.

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