Paper Title Conceptualizing and Operationalizing Equity Focus in Designing Computational Thinking–Integrated Science and Mathematics Curricula

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Purpose

What does equity-focused curriculum design mean for curricula that are integrated with Computational Thinking? Are we designing for equitable participation? Is our conceptualization of equity deep enough? Does it address social inequities and injustices that affect student classroom participation? How do our gender, racial, ethnic, educational, and other identities support and limit us from designing to support equitable participation? These are just a few of many questions that we, a co-design collective, have been grappling with for the past several months. The co-design collective includes authors of this paper and others, who are teachers and researchers, that are involved in devising ways to foreground equitable participation. We take the stance that learning is a cultural process and attending to the design of learning environments and pedagogical practices that foreground equitable participation is vital to support learners' disciplinary engagement and learning (Nasir et al., 2006; Bell et al., 2017).

The collective grew over the past several years through creating science and mathematics high school curricula that are integrated with Computational Thinking (CT) (Authors, 2016; Authors, 2017; Authors, 2019). In recent years, we have adopted a co-design or participatory design approach (Penuel, 2019) for creating such CT-integrated curricula (Authors, 2019; Authors, 2020).

We present a new strand of the work that focuses on characterizing ways to foreground equitable participation in CT-integrated curricula. Particularly, our study focuses on how teachers characterize equity in the context of CT and grappled with the above questions around equitable participation in the context of co-designing CT-integrated curricula through analysis of two interviews and modifications to an existing CT-integrated curriculum.

Theoretical Frameworks

Integrating CT in Science and Mathematics

Wilensky, Horn, and colleagues have argued that CT integration in science and mathematics classrooms affords: (a) authentic participation in disciplinary practices, (b) pedagogical effectiveness of computational tools, and (c) increased participation in computational fields through the inclusion of women and historically minoritized groups (Wilensky, Brady & Horn, 2014; Weintrop et al., 2016). Our approach to integrating CT in high school science and math classrooms is designing and teaching curricula that are enriched with CT activities by hosting teacher professional development programs that engage teachers and researchers in the collaborative design of CT-integrated curricula (Authors, 2019). The project aims to increase access to CT practices, tools, and ideas by empowering teachers to effectively integrate CT-infused content into their classrooms. Importantly, these classrooms serve a wide range of students across a variety of racial/ethnic, class, and socioeconomic backgrounds (See Table 1).

Co-Designing for Equity-Focus in CT-Integrated Curricula

Although we reach a diverse set of students, we can do more to apply a critical equity lens to improve participation in CT and disciplinary learning for all students. Because culture and sociohistorical inequalities impact learning processes and outcomes (Gutiérrez & Jurow, 2016; Gutiérrez & Rogoff, 2003), we focus on intentional design of CT-integrated learning environments that support equitable participation. We use repertoires of practice to characterize culture as a dynamic way in which people participate in cultural practices (Gutiérrez & Rogoff, 2003; Nasir et al., 2014). Accordingly, Nasir and colleagues argue that learning is a "culturally heterogeneous process of engagement in repertoires of practices" (2006, p. 699). To engage

students in CT practices in culturally meaningful ways, CT-integrated curricula must be designed to connect to lived experiences of all students in order to support equitable participation.

We used a collaborative co-design approach to identify ways for creating and teaching CT-integrated curricula that foreground equitable participation. Co-design, a collaboration between teachers and researchers, positions all participants as experts (DiSalvo et al., 2017; Penuel, 2019; Schuler & Namioka, 1993). This practice allows for teachers to (1) learn about CT from researchers and (2) empowers teachers to redesign their curricula through the integration of CT tools and practices (Authors, 2019; Authors, 2020). Importantly, co-design allows for a teacher-led project (Authors, 2020) and, in the case of our present study, it developed a co-design collective focused on equity. This collective engaged in a project to characterize equity-focused approaches to CT-integration. In this paper, we seek to understand how partnering teachers grappled with equity in the context of CT-integrated curricula. Specifically, we investigate:

How is equitable student participation conceptualized and operationalized in CT-integration through a co-design process?

Methods & Data Sources

The presented data is a part of a multiyear Design-Based Research project (Design-Based Research Collective, 2003) aimed at integrating CT in science and mathematics classrooms (Authors, 2020). A co-design collective of three researchers (first, second and seventh authors) and four teacher partners, who had previously co-designed CT-integrated curricula, participated in this study. The participating teachers taught in urban and suburban schools in the Midwestern United States (See demographics of the schools in Table 1). The teacher cohort included three science teachers (pseudonyms: Lori, Kate, and Sarah) and one math teacher (Jason). Additional teacher and researcher demographics are included in Table 2.

In the first phase of our study, Author 1 conducted 20-minute informal interviews with each teacher to understand their conceptualizations of equitable participation in CT-integrated curricula. The second phase included four co-design sessions over the course of one month. The goal of these co-design sessions was to modify an existing lesson designed to introduce students and teachers to integrated CT practices (Authors, 2017). Modifications to this lesson served two purposes: 1) to create an equity-focused introductory lesson on CT-integrated curricula, and 2) to understand teacher operationalizations of equity for this study.

Four weekly co-design sessions included discussion and feedback from teachers and researchers. In between sessions, teachers worked asynchronously on revisions to their lessons and provided feedback to their co-design partner. Teachers tracked their work by writing design memos which included questions designed to support the co-design process and capture data about the modification process (See sample Design Memo in Figure 1). Each teacher produced one modified equity-focused CT-integrated lesson and participated in a post-interview which was tailored to understand their modifications and how they operationalized their ideas about equity to make those modifications.

We conducted qualitative analysis of interview transcripts from Phase 1 and Phase 2 and Design Memos to understand how teachers conceptualized their ideas about equity in the context of classroom teaching and operationalized those ideas in CT-integrated curricula. Phase 1 utterances (n=48) were coded by four researchers to identify teacher conceptualizations. Codes were discussed to ensure agreement. Teacher conceptualizations of equity refer to teachers' ideas of equitable participation in classroom learning. Design Memos and Phase 2 interviews were analyzed to characterize how teachers operationalized their ideas in curriculum design. We

developed case studies of four teachers (Yin, 2009) to investigate conceptualizations and operationalizations of equity-focus in CT-integrated curricular design.

Results

In this section, we present cases of two teachers to discuss their understandings of equity from the perspective of CT-integrated curricular design. We discuss their expressed ideas regarding supporting equitable participation (conceptualizations), their curricular design strategies reflected in their modifications to an existing introductory CT lesson, and their expressed views and reasoning for those modifications (operationalizations). See Table 3 for all teacher operationalizations, conceptualizations, and modifications.

Jason. In the first phase of our study, Jason believed that equity-focused curricula should be designed to both support participation of students of color and educate white students on issues of equity. He raised questions such as, "*How is our old stats curriculum not serving our students of color, and how can it better serve students of color, and, on top of that, how is our old curriculum not educating white students on some of the equity issues that exist in our community?"* This demonstrates that Jason was thinking about equity-focus from two perspectives – cultivating a learning experience that enables equitable participation for his students of color and addressing existing power structures that play out in the classroom.

As a part of his modifications, Jason incorporated opportunities for student collaboration in Lesson 0. For example, he added instructions for students to discuss their answers with one another (See Figure 2). According to Jason, these modifications were important because, "*With the lens of my two black male students, the big things that I, the big changes, I wanted to make were giving them time to discuss with a partner. And I think that sometimes their voice gets lost in the classroom as a person of color, and so I wanted to make sure that I wasn't the voice dominating the room as a white male."* Jason operationalized equity in CT-integrated curriculum by making changes that increase the participation of his focal students, two Black males, while recognizing his positionality as a white man. His attention to power dynamics in the classroom is directly aligned with his initial conceptualizations of equity.

Lori. During Phase 1, Lori highlighted the value of *relevancy* in the science classroom. She specifically discussed using place-based relevancy as a pedagogical tool. For instance, she described adding an example of life expectancy discrepancies across the city in which her school is situated in a recent lesson on health disparities. As she explained, "*I specifically call out like health disparities… like [a midwestern city] was – the study just came out – the largest life expectancy gap in the nation."* This shows that her conceptualization of equity prioritized relevancy, specifically place-based relevancy.

In her revised Lesson 0, Lori replaced a simple model of an atom used at the beginning of the lesson with a model of snowfall accumulation (See Figure 3). As she describes, "*The first thing I changed was kind of that intro model. Instead of using the atom, I used the snowfall accumulation. Because in our region, right, that's something that everybody has seen and everybody is used to, and it felt like a really easy on-ramp to talking about models which are oftentimes kind of scary."* In other words, she believed that snowfall would be a more relevant, and thus accessible, model for an introductory static model to compare with a dynamic interactive computational model. Through this modification, Lori operationalizes equity in the content of CT as providing place-based relevancy to provide a more accessible introduction to CT to the students in her classroom. Similar to her initial perceptions of equity, relevancy is an integral component of Lori's understanding of equity.

Scholarly Significance

The co-design process supported teachers' operationalizations of their ideas about supporting equitable participation for learning using CT. Interviewing teachers about their co-designs, as a methodology, provided key insights on their beliefs and perceptions of equity-focus in CT. While there is an increased interest in designing equity-focused curricula, we need to understand how teachers design for equity-focus in CT-integrated curricula specifically. Researchers and practitioners can learn from the methods utilized in this study in order to understand teacher conceptualizations of equity in the context of CT.

Our preliminary findings suggest that the design modifications of our co-design collective are primarily focused on accessibility and relevance in the context of designing CT-integrated curricula, which suggests that teachers focused on connecting CT to the lived experiences related to accessibility and relevance. As discussed in our findings section, Jason conceptualized equity as combatting power dynamics in the classroom and made modifications to address this by providing more opportunities to share their ideas in class. While this suggests attention to systemic issues of race, we do not yet know if his modifications are sufficient in combating structural racism and anti-Blackness.

Since our co-design sessions were not designed to explicitly address issues of social inequality and injustice, teacher operationalizations of equity as expressed through their modifications to a CT-integrated curriculum were oriented towards accessibility and relevance. Unless there is an explicit focus on a wider spectrum of equity – ranging from accessibility and relevance to calls for social justice – it is possible that teachers will continue to focus on relevance and accessibility and not social justice. As we grapple with the questions mentioned in the introduction of the paper, we hope future co-design sessions can explicitly address combatting existing power dynamics – such as structural sexism, racism, and anti-Blackness – so that teachers can expand their conceptualizations and operationalizations about equity-focus in the context of CT towards justice.

Table 1. Demographics of the Schools

School	**Teacher(s)**	**Race Demographics**	**Free/Reduced Price Lunch**	**Individualized Education Plans**	**English Language Learners**
Evergreen High School	Jason, Kate	45.8% White, 26% Black, 18.7% Hispanic, 5.8% Asian, 3.3% Multi-racial	34.7%	11%	5.1%
Lakeview High School	Lori	3% White, 69% Black, 25.8% Hispanic, 0.8% Asian, 0.4% Multi-racial	62.5%	5%	2.3%

Sycamore High School	Sarah	5.5% White, 8.8% Black, 82% Hispanic, 1.8% Asian, 1.1% Multi-racial	89.9%	21%	24.3%

Table 2. Teacher and Researcher Demographics.

Teacher and Researcher Demographics	
Researchers	White woman
	South Asian (brown) man
	East Asian woman
Teachers	White man
	White woman
	White woman
	White woman

Table 3. Teacher Conceptualizations and Operationalizations of Equity in CT-Integrated Curricula.

Teacher	Teacher Quotes	
Jason	*How is our old stats curriculum not serving our students of color, and how can it better serve students of color, and, on top of that, how is our old curriculum not educating white students on some of the equity issues that exist in our community?*	Conceptualization
	With the lens of my my two black male students, the big things that I, the big changes, I wanted to make were giving them time to discuss with a partner. And I think that sometimes their voice gets lost in the classroom as a person of color, and so I wanted to make sure that I wasn't the voice dominating the room as a white male.	Operationalization
	• Changing the wording of the questions • Adding opportunities for collaboration • Adding relevancy to a math/statistics class	Most important changes identified by teachers in

		Design Memo
Sarah	*I'm thinking from this special education lens not so much from gender equity and those kinds of things, so it's interesting to me because it's it's much broader.*	Conceptualization
	I split up some of these questions, because they were all kind of stuck together, and my experience with special education kids is it becomes overwhelming, and you can't answer more than one question at a time. So I split them up.	Operationalization
	● Language and phraseology ● Choosing a phenomenon that is common to many	Most important changes identified by teachers in Design Memo
Lori	*I specifically call out like health disparities… like [a midwestern city] was – the study just came out – the largest life expectancy gap in the nation.*	Conceptualization
	The first thing I changed was kind of that intro model. Instead of using the atom, I used the snowfall accumulation. Because in our region, right, that's something that everybody has seen and everybody is used to, and it felt like a really easy on-ramp to talking about models which are oftentimes kind of scary.	Operationalization
	● Providing access point for all with snowfall model ● Adding real world scenario with tree density ● Adding local relevance & opportunity to predict changes in environment & determine questions to ask to learn more ● Providing more visuals throughout	Most important changes identified by teachers in Design Memo
Kate	*I definitely…. I was really conscious of trying not to make anyone 'other'. And the whole first quarter was basically 'biodiversity isn't good' so we're starting from a standpoint of diversity is good.*	Conceptualization
	The last few questions on page three are really thinking about the different populations of people, and how population density plays [a role in COVID spread] into those areas, so they can even see in Evanston where people are more closely packed, there's a higher spread.	Operationalization

	• The connection to their own lives and those of people in different communities around the world • The focus on invitations for information shows students that I value their input more than that I demand it • Used a model for a phenomenon with which students are almost certain to have direct experience	Most important changes identified by teachers in Design Memo

Figure 1. Sample Design Memo

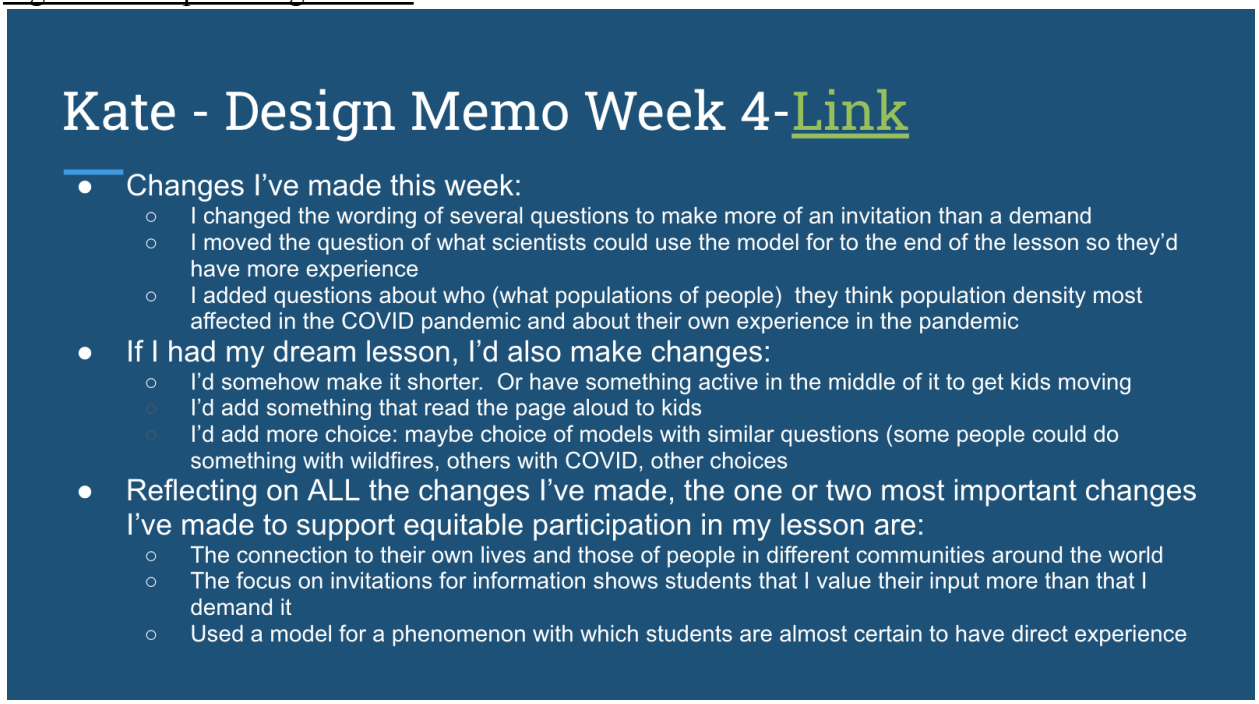


Figure 2. Jason's Lesson 0 Modification

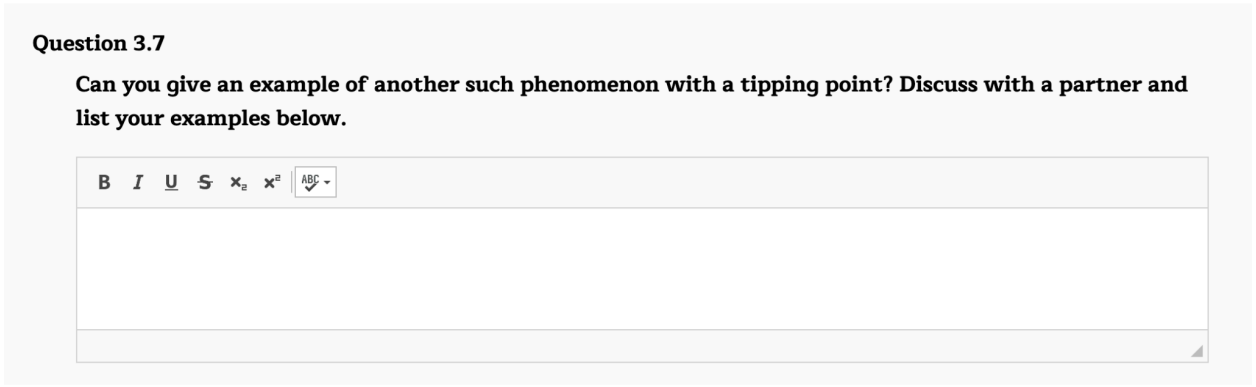
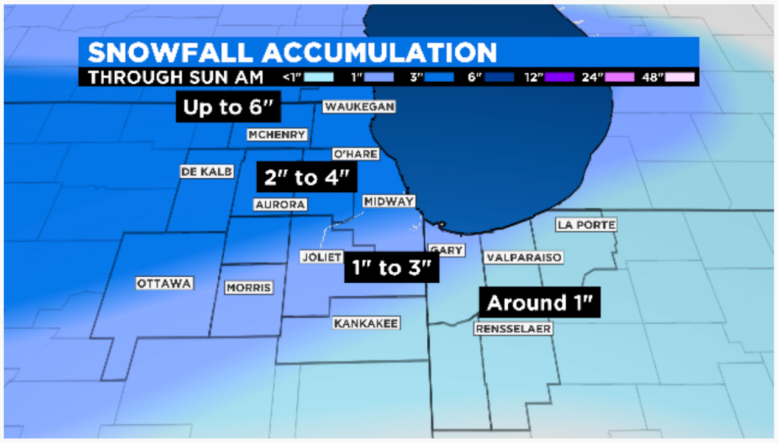


Figure 3. Lori's Lesson 0 Modification

Question 1.1

We use scientific models all the time. Look at the the picture below. **Can you tell what it is a model of?**



Enter your response

References

Authors and colleagues (2016)

Authors and colleagues (2017)

Authors and colleagues (2019)

Authors and colleagues (2020)

Bang, M., & Vossoughi, S. (2016). Participatory design research and educational justice: Studying learning and relations within social change making.

Bell, P., Horne, K. V., & Cheng, B. H. (2017). Special Issue: Designing Learning Environments for Equitable Disciplinary Identification. *Journal of the Learning Sciences*, *26*(3), 367–375.

Design-Based Research: An Emerging Paradigm for Educational Inquiry. (2003). *Educational Researcher*, *32*(1), 5–8.

DiSalvo, B., Yip, J., Bonsignore, E., & Carl, D. (2017). *Participatory design for learning* (pp. 3-6). Routledge.

Gutiérrez, K. D., & Jurow, A. S. (2018). Social Design Experiments: Toward Equity by Design. In M. Cole, W. Penuel, & D. K. O'Neill (Eds.), *Cultural-Historical Activity Theory Approaches to Design-Based Research* (1st ed., pp. 79–112). Routledge.

Gutiérrez, K. D., & Rogoff, B. (2003). Cultural Ways of Learning: Individual Traits or Repertoires of Practice. *Educational Researcher*, *32*(5), 19–25.

Nasir, N. S., Rosebery, A. S., Warren, B., & Lee, C. D. (2006). Learning as a Cultural Process: Achieving Equity Through Diversity. In *The Cambridge handbook of: The learning sciences* (pp. 489–504). Cambridge University Press.

Penuel, W. R. (2019). Co-design as infrastructuring with attention to power: Building collective capacity for equitable teaching and learning through design-based implementation research. In Collaborative curriculum design for sustainable innovation and teacher learning (pp. 387-401). Springer, Cham.

Schuler, D. & Namioka, A. (1993). Participatory design: Principles and practices. Hillsdale, NJ: Erlbaum.

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.

Wilensky, U., Brady, C. E., & Horn, M. S. (2014). Fostering Computational Literacy in Science Classrooms. Commun. ACM, 57(8), 24–28.

Yin, R. K. (2009). *Case study research: Design and methods* (Vol. 5). sage.