Drawing on Diverse Social, Cultural, and Academic Resources in Technology-Mediated Classrooms

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Numerous classroom technologies are being designed to support construction of mathematics and science knowledge (cf., Kaput & Hegedus, 2002; Linn & Hsi, 2000; Soloway et al., 2001; Wilensky & Stroup, 1999), but largely without regard to the social and cultural resources traditionally under-served students bring to classrooms. Carol Lee (2003) notes, "the tremendous funding being invested in the development of such computer-based tools in education may be simply reinforcing current inequities in opportunities to learn, unintentionally widening the achievement gap" (p. 58). There is little hope of attending to that gap if research and development efforts ignore issues of culture. However, with few exceptions (Lee, 2003; Pinkard, 2001), research and design in instructional technologies has not treated underserved students' social, cultural, and academic resources as central considerations.

To build understanding of the influence of culture on technology-supported classroom learning, we turn to a growing body of promising work that treats underserved students' cultural backgrounds and practices as important resources for learning (cf., C. Lee, 2001; Greenberg & Moll, 1990; Gonzalez et al., 1995). Okhee Lee (2003) argues that equity is unattainable if students are not given access to powerful discourses, but that appropriation of discourse is made more difficult if school science (and mathematics) is simply imposed on students. Appropriation is better supported by drawing on students' social and cultural practices as resources rather than as barriers to overcome (cf., Civil & Kahn, 2001; Moll & Gonzalez, 1995). For example, Haitian Creole students' story-telling and argumentation skills have been shown to support their engagement in science (Warren et al., 1992) and irony, satire, and metaphor in African American Vernacular English to scaffold students' analysis of canonical literary works (C. Lee, 2001).

We examine the unique potential of a next-generation networked classroom technology (HubNet and Participatory Simulations, Wilensky & Stroup, 1999) to draw on students' cultural, social, and academic resources to support learning in mathematics. We attend to both (1) content and representations of content; and (2) the participation/interaction of students as dual dimensions of the social space of classrooms. Attending to these dual dimensions highlights " a generative, creative tension between the structuring role of math and science and the structuring role of social activity" (Stroup, Ares, & Hurford, in press). Of particular interest are the following research questions:

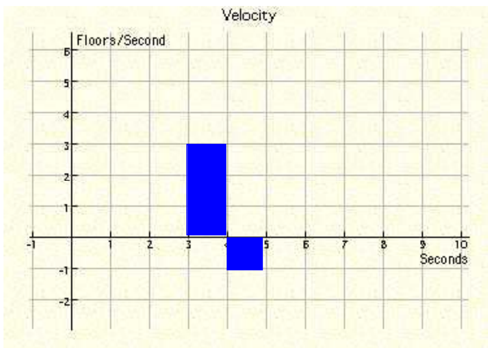
(1) In what unique ways does network-mediated activity scaffold learning for underserved students?
(2) How is mathematical knowledge and practice enhanced through inclusion of underserved students' social and cultural resources in network-mediated learning?

Examining these issues will deepen our understanding of the construction of mathematical content and practice through social interaction. We hope to identify effective ways to begin to close the achievement gaps between cultural, social, and economic groups by broadening the range of tools and knowledge teachers use to allow all students to reach their highest potential.

Network Mediated Learning

HubNet and Participatory Simulations includes a wireless network of graphing calculators, being developed with funding from the National Science Foundation and Texas Instruments (Wilensky & Stroup, 1999, 2000). In Participatory Simulations, participants act as individual agents and observe how the behavior of the system as a whole emerges from their individual behaviors. The emergent results become the focus of in-class discussion and analysis. In the

Elevators Participatory Simulation used in this study, the system collects students' input to individual calculators through the network (arrangement of blocks, Fig. 1, left), and displays the emergent system formed from their collective contributions in an "up front" public space (an array of all students' elevators moving together, along with position and velocity graphs; Fig. 1, right).



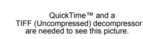


Figure 1. A sample delta blocks arrangement (left) and projected elevators screen, with position and velocity graphs (right).

Among others, qualitative understandings of the mathematics of change (Kaput, 1994; Stroup, 1996, 2002) that start from the integral and then move to the derivative are goals of this activity. Features of this system that may offer avenues for enlarging the social, cultural *and* academic practices used as resources include: 1) multiple modes of contribution (language, text, physical and electronic gestures), 2) multiple representations (texts, graphs, visual displays of emergent systems, language), and 3) inquiry-oriented discussion and analyses, "in which students are supported in making public the strategies they are employing as well as the evidence and reasoning they are using, … [and] where instructional conversations are not solely directed by teachers' intentions" (C. Lee, 2003, p. 48, 49).

Examining ways to draw on the varied, often untapped, resources available in heterogeneous classrooms can support important advances in classroom technology development by pinpointing features of their design and use that can become culturally responsive and that support the achievement of underserved students. Further, it can provide important information to teachers as they consider whether and how to incorporate networked and other classroom technologies into their teaching.

Methodology

We focus on social activity, discourse, networked technology, and learning in a sociocultural theoretical framework (Vygotsky, 1987). Learning is viewed as being mediated by social activity involving both people (teachers, peers) and tools (networked technology). Further, learning involves co-constructing mathematical knowledge and meaning through appropriation of discipline-specific content, discourses and practice. Discourse analysis (Gee, 1999) enables us to analyze students' appropriation of the content, discourses and practices of mathematics as a discipline. We situate that appropriation within the social space of classrooms that is formed by the intersection of dual dimensions of 1) social and cultural resources, and 2) content and representations. Thus, network-mediated learning in the social space of the classroom is shaped by the dynamic, mutually constitutive roles of mathematics-specific content and representations, *and* participation and cultural resources in learning (Stroup, Ares, & Hurford, 2004, in press).

Setting

Approximately 50% of the students in the high school in which this study was conducted were Hispanic, 21% African American, 25% European American, and 4% Pacific Islander, Native American, and recent immigrants from a variety of countries; those demographics were reflected in the two classes that participated. One of the two classes had 17 students; the other had 15. The teacher, Sylvia (a pseudonym, as are all names), was a European American, veteran mathematics teacher with 15 years of experience. She was interested in using networked classroom technology to support her commitment to problem-based instruction, and as complementary to her regular Interactive Mathematics Program (IMP; Fendel, Resek, Alper, & Fraser, 1997) curriculum. The two sessions taught by her but with different students were video-taped, one when the network was in use and another when it was not. Analyses centered on characterizing classroom activity both with and without the networked technology.

Quantitative analysis of classroom talk

Whole-class talk was coded by one researcher as to the type of comment or question contributed by Sylvia or students (e.g., invitation to explain, observation), drawing on the work of Brenner and Moschkovich (2002) on everyday and academic mathematics, but including codes that emerged as important as well. A second researcher used the scheme to evaluate its usefulness, add emergent codes, and delete codes. The two researchers arrived at the final coding scheme through a process of discussion, independent coding, checks of inter-rater reliability, and more discussion. The final inter-rater reliability check yielded 71% agreement. Frequency diagrams were constructed to examine how the numbers of comments or questions within categories changed over the course of each class session, to examine teacher versus student contributions, and to conduct cross-session analyses.

Qualitative analysis of classroom Discourse

Transcripts of videotapes were analyzed to identify patterns of participation, and use of social, cultural, and academic resources. Following Moschkovich (2002) and Gee (1999), we used the following questions for Discourse analysis [Discourse defined as "ways with words, feelings, values, beliefs, emotions, people, actions, things, tools, and places that allow us to display and recognize characteristic *whos* doing characteristic *whats*" (Gee, 1999, p. 19)]:

- *Discourses:* What Discourses are involved and produced in this situation? What Discourses are relevant (or irrelevant)? What systems of knowledge and ways of knowing are relevant (and irrelevant) in the situation? What Discourse practices are students participating in that are relevant in mathematically educated communities or that reflect mathematical competence?
- *Activity building:* What is the larger or main activity going on in the situation? What sub-activities compose this activity? What actions compose these sub-activities and activities?
- *Resources:* What are the multiple resources students use to communicate mathematically? What sign systems are relevant (and irrelevant) in the situation (e.g., speech, writing, images, and gestures)? By what means are they made relevant (and irrelevant)?

Findings

This section is organized in terms of Discourses produced, activity building, and resources, followed by examination of the dual dimensions of the social spaces that emerged in the two class sessions.

Discourses

A Discourse of school mathematics problem solving was produced in the IMP activity, while a Discourse of dynamic systems thinking was the product of the Participatory Simulation. [Dynamic systems thinking "focus[es] not on the elements of something, but on the relationships or interactions between the elements … shifting from a concern for detail complexity to a concern for dynamic complexity: concern for dynamic relationships, rather than fine distinctions" (Ramsey & Ramsey, 2002, p. 99).] The problem solving Discourse was characterized by the more mechanical aspects of mathematics (e.g., order of operations, converting fractions to decimals) being embedded in a task, in this case, determining the profit ferry owners made by transporting white settlers moving to the Western US and their wagon trains across the Kansas River. Thus, contextualizing formal mathematics and embedded arithmetic were the focus (Ares, Stroup, & Schademan, 2004). We use the term 'school math' because the ways of knowing involved were teacher- and textbook-dominated, as evidenced by the nature of students' contributions (largely procedural) and Sylvia's invitations (see Table 1), which constituted 62% of the coding.

Table 1. Nature of Students' Contributions and their Teacher's Invitations

IMP problem	Elevators Participatory Simulation
Students' Contributions	
Explanation (21)	Observe/describe (19)
Fill-in-blank answer (21)	Prediction (12)
Report result (16)	Request clarification (11)
Perform procedure (14)	Explanation (10)
Add precision (11)	Visualize (8)
	Evaluation (8)
Sylvia's Invitations	
Invite performance (18)	Invite prediction (14)
Invite explanation (16)	Invite elaboration (8)
Known-answer question (12)	Invite performance (6)
Invite elaboration (8)	Invite explanation (5)
Invite clarification (7)	Invite clarification (4)
Invite contribution (5)	Invite contribution (4)
Invite evaluation (4)	Invite play (2)

However, an important exchange in the IMP lesson drew on students' knowledge of the broader world, providing an opening for drawing on social and cultural resources. The profit formula included a wage of 40 cents per hour for the ferry operator. A student remarked, "That sucks." Sylvia asked whether there were people making that little now, and what would be a fair wage today, which precipitated a discussion of varying wages around the world, including students' own pocket money. Here, though relatively briefly, students' social resources were fodder for critical connections between mathematics in school and the world. The dynamic systems thinking Discourse involved in the Participatory Simulation was characterized by students and Sylvia exploring relationships among position and velocity graphs, and among those representations and the motion of the elevators. Here, the focus was on predicting and describing relationships, and development of increasingly sophisticated understandings of those relationships. The following exchange is representative:

Sylvia: I'd like to hear from some of you about what you think we're gonna see up front when they send all these up. .

Lydia: At the point where all of our graphs are going up and down at the same time on the…

Sylvia: …This little section? [*pointing to the worksheet plot of blocks*]

Lydia: yea, on that little section all of the ah line graphs will go up the same amount and down the same amount. [*uses hands to indicate simultaneous movement]*

Sylvia: Um. So what's it gonna look like up there? On the graph. [*pointing to the public display*]

Jose: Parallel.
Lydia: They'll be parallel [*uses arms to demonstrate parallel lines]*.
[once the simulation was run]
Sylvia: What, what's happening right here? [*points to position graph*]
Brian: Jaime.
Sylvia: What else is happening?
Jaime: No no. Everyone goes crazy again?
Sylvia: That's true. Everyone does kind of go crazy again, or do their own thing. What's happening right here? [*points to an intersection of two lines on the position graph*].
S: Someone went up and then stopped.
Sylvia: But I mean this very point, right there.
Jaime: They're crossing?
Sylvia: What does it mean?
Jaime and Lydia: They're on the same floor.
Jaime: For that second.

The ways of knowing that were relevant here and across the whole activity involved shared construction of understanding, where student's individual elevator's motions served as examples for exploration and construction of, for example, an informal metric for speed, and the graphical representations were examined for "how we did" in coordinating activity, lending a collective sensibility to this Discourse. The shared construction and collective sense invited more participation by students, evidenced by the finding that 57% of codes were attributed to Sylvia.

Activity building

In the IMP class, textbook-centered, step-by-step work through procedures for solving the profit problem was the main activity, while movement between individual creation and collective exploration of emergent mathematical objects was the main activity of the Participatory Simulation. The sub-activities that composed the IMP main activity included responding to known-answer questions with fill-in-the-blank answers, reporting results, and talking through the steps of procedures (e.g., converting fractions to decimals), balanced somewhat by explanations of procedures or why the formula "made sense" (see Table 1). The sub-activities that supported the Participatory Simulation main activity involved interpreting graphical representations, i.e., predicting and visualizing position and velocity graphs based on the arrangements of elevator floors, and observing/describing real-time development of graphs and elevators' motion (see Table 1). Important opportunities to draw on social and cultural resources of students were also in evidence, as Sylvia issued open-ended invitations: "you can do whatever you want on either side of this (required arrangement)," and, "do something interesting." Thus, students were invited to contribute social and academic resources (explorations, understandings) in creative, even playful ways to the group's efforts.

Resources

Discourses were made relevant through the use of tools or cultural artifacts, especially the textbook in the IMP class and the networked system activities and technology in the Elevators class. In addition, both activities drew on English and Spanish language, text (book for IMP, worksheet for Elevators), peers and Sylvia, calculators, and mathematical symbols (profit formula, graphs). However, the real-time public display in which students could identify their own and others' contributions, physical and electronic gestures (e.g., using arms to indicate parallel lines, individual elevator motion), and multiple representations of relationships were additional, unique resources available in the Participatory Simulation. Through the use of gesture, multiple representations, and public display, diverse ways of knowing were involved in the situation, inviting contributions of both social and academic resources, in addition to cultural resources embodied in language.

Dual Dimensions of Social Space

We examine two dimensions of the social space of the classrooms -- 1) content and representations, and 2) participation, including using of social, cultural and academic resources – to address the research questions. Comparative analyses help us pinpoint unique ways in which network-mediated activity may scaffold learning for underserved students, and how mathematical knowledge and practice may be enhanced through inclusion of underserved students' social, cultural and academic resources in network-mediated learning.

Content and representations

Not surprisingly, the content involved in each class session was markedly different (see Table 2). Both sessions engaged students in learning important content, though the variety was greater in the Elevators activity. In addition, the wider variety in the representations available for students to make sense of content in the Elevators session expanded the social space along one of the dimensions of interest, providing opportunity for students to explore multiple relationships among variables of interest. Finally, the nature of those contributions and the content addressed were such that students had much more latitude to act, given the focus in the IMP activity on mostly textbook-determined progression through a more constrained task.

Participation including use of resources

While there was considerable overlap in the types of resources available and used in both class sessions, the Elevators session did offer additional tools and avenues for participation, expanding the social space along the participation dimension of the classroom. The technological capabilities of HubNet and design of the Participatory Simulation that allow individual inputs to be collected and displayed as a real-time emergent, evolving system represented a unique activity structure in which students could identify themselves and others as individual elements, and examine the nature of a complex interaction of elements. Students were invited to both contribute and draw on diverse social, cultural, and academic resources in the situation, as they used gesture, text, language, and images as resources in their exploration.

Table 2. Content addressed in two class sessions

IMP lesson	Elevators Participatory Simulation
Order of operations; converting fraction to decimal notation, minutes to hours; substitution and evaluation of numbers for variables; rounding; profit formula; mathematizing variables and relationships among variables in profit formula; symbolizing	Change in amount; abstracted time; graphical representation of time and position; the significance of parallel position-time graphs, parallel and intersecting lines; coordination of graphs with motion; a sense of the constant of integration; visualization, prediction, explanation of graphical representations of position and velocity; extending mathematical reasoning beyond what was visible; and the initial emergence of a metric for rate

Conclusion

The results emerging from this study point to the potential for networked technologies to be culturally responsive in design and use. The Elevators class session involved increased variety of avenues for engaging content and representations, and each other, expanded social space, broadening opportunities to serve under-served students by enlarging the ways of knowing and systems of knowledge treated as important resources for learning. Further, our findings indicate that mathematical knowledge and practice may be enhanced by diversifying classrooms' academic, social and cultural resources, and drawing on those of under-served students. The point also needs to be made that connections to the world outside school in this case were stronger in IMP; the strengths of the IMP problem solving approach in inviting some diversity in experience is clear. Still, the variety of ways of acting available in the Participatory Simulation was larger than in IMP as enacted. Our findings indicate that looking closely at classroom activity can identify some existing features of networked technology design and use that have potential to better support under-served students' mathematical learning, especially in terms of academic and social resources. However, cultural practices proved to be much more difficult to pinpoint. We argue that this is due to the limits of looking only in classrooms. To move to truly culturally relevant classroom technology design and use, exploration of social, academic, and especially cultural practices of under-served students must be done across contexts, including peer and home communities, to identify those that can be important in supporting rigorous mathematical learning. This is partly or largely due to schools' historical and ongoing under-appreciation and misunderstanding of the practices of under-served students. They are often viewed as lacking, and their families and communities have been viewed through a deficit model. Until we move outside the structure of schools and traditional approaches to technology design, we will be missing important opportunities to enlarge the social space of classrooms in ways that serve all students.

Selected References

Ares, N., Stroup, W., & Schademan, A. (2004, April). Group-level development of powerful discourses in mathematics: Networked classroom technologies as mediating artifacts. Paper presented at the meeting of the American Educational Research Association, San Diego, CA.

Brenner, M.E., & Moschkovich, J.N. (Eds.) (2002). *Everyday and academic mathematics in the classroom.* Reston, VA: National Council of Teachers of Mathematics.

Kaput, J., & Hegedus, S. J. (2002). Exploiting classroom connectivity by aggregating student constructions to create new learning opportunities. Paper presented at the 26th Conference of the International Group for the Psychology of Mathematics Education, Norwich, UK.

Gonzalez, N., Moll, L.C., & Tenery, M.F. (1995). Funds of knowledge for teaching in Latino households. Urban Education, 29, 443-470.

Lee, O. (2001). Culture and language in science education: What do we know and what do we need to know? Journal of Research in Science Teaching, 38(5), 499-501.

Lee, C.D. (2003). Toward a framework for culturally responsive design in multimedia computer environments: Cultural modeling as a case. Mind, Culture, and Activity, 10(1), 42-61.

Linn, M. C., & Hsi, S. (2000). Computers, Teachers, Peers: Science Learning Partners. Mahwah, Lawrence Erlbaum Associates.

Pinkard,N.(2001).Rappin' Reader and Say Say Oh Playmate: Using children's childhood songs as literacy scaffolds in computer based learning environments. *Journal of Research on Computers in Education, 25*(1), 17-34.

Ramsey, D.C., & Ramsey, P.L. (2002). Reframing the perfectionist's Catch-22 dilemma: a systems thinking approach. *Journal for the Education of the Gifted, 26*(2), 99-111.

Roschelle, J., Kaput, J. J., & Stroup, W. (2000). SimCalc: Accelerating students' engagement with the mathematics of change. In M.J. Jacobson, & R.B. Kozman (Eds.), Innovations in Science and Mathematics Education: Advanced Designs for Technologies of Learning (pp. 47-75). Lawrence Earlbaum Associates, Mahwah, NJ.

Stroup, W., Ares, N., & Hurford, A. (in press). A dialectical analysis of generativity: Issues of network supported design in mathematics and science. Mathematical Thinking and Learning.
Wilensky, U., & Stroup, W.M. (1999).