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Cultural practices in networked classroom learning environments

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Abstract This paper presents results of a case study conducted in secondary mathematics classrooms using a new generation of networked classroom technology (Participatory Simulations). Potential for drawing on youths' cultural practices in networked learning environments is explored in terms of opportunities for traditionally underserved students to participate in powerful mathematical discourse and practice. As mediated by the networked technology, the multiple modes of participation and opportunities to contribute to the group's accomplishment of its task served as important avenues for underserved students to bring to bear resources they develop through participating in everyday practices of their communities. The goal is to provide examples of networked activities' potential for leveraging cultural practices of marginalized groups through pedagogy that invites youth to draw on linguistic resources and interaction patterns they develop as members of cultural groups.

Keywords Cultural practices · Networked classroom environments · Mathermatics discourse and practice · Equity · Sociocultural theory · Cultural relevance

Introduction

The following scenario takes place in a large, aging secondary school in a city in upstate New York. The room is crowded, with youths sitting at old desks, several adults circulating among them, and a cart holding a computer, projector, and wireless router. The students, each using a graphing calculator connected to a computer server, control a traffic light in a traffic grid displayed in a projection at the front of the class. They are presented with the following scenario: The mayor of the City of Gridlock is unhappy with the traffic congestion in town and she has commissioned the class to improve the situation. The goal

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is for the students to find ways of optimizing traffic flow for the simulated city. The action proceeds as follows:

Instructor: What is good traffic?
Student 1: The cars is moving—everybody movin'
Student 2: At the same pace
Student 1: What do you mean the same pace, driving like old ladies, I hate people like that!
Student 2: Yeah, I like it when everybody be goin' slow so I can just pass right by them. Yeah, I'll have my Mustang and it'll just be...
Student 3: Good traffic is when I can get to where I need to go in the amount of time I need to get there. *[laughter, "aw," lots of heads nodding]*
Instructor: How about bad traffic, what's that?
Multiple students, overlapping talk: Bad traffic is New York City! It sure is. Ain't nobody ain't movin'. People on bikes. Like in the hood, Jack, on like Gennessee Street *[a local street]*.
Instructor: What are some of the causes of bad traffic?
Multiple students: Too many cars, we need to reduce population, people need to stop having kids, need to take the bus, people need to use roller blades. ...

The computer simulation is run, with students calling instructions to each other as they watch the cars move and try to keep the traffic flowing. Once the cars can no longer move, the instructor leads the class in a discussion:

Instructor: What were some strategies you used to keep traffic flowing?
Student 1: I watched the spaces between cars
Student 2: I changed my light at a constant rate, every 20 seconds
Student 3: What light you know go 20 seconds. Not the one on Dewey Avenue, it be like 4 minutes!
Instructor: What do you want to do for the next run? Remember, the goal is to prevent the gridlock.
Student 3: I think everybody change their light at the same amount of seconds would be good
Student 2: All the lights on the row should be on a certain time *[a strategy of coordinating lights along individual streets]*
Instructor: *[referring to graphs the computer system created as the simulation was running]* What would the stopped cars graph look like if your strategy works?
Student 4: It would look good –
Instructor: What does good mean?
Student 4: It would get on the, it would...on the steady rate *[accompanied by a hand gesture that indicates a negative slope]*
Instructor: So you think it would go down at a steady rate? *[pointing to the projected graph, tracing a line with negative slope]* Okay, let's try it.

In this paper, I examine interactions like the above to understand possibilities for using students' cultural practices as central concerns in the implementation of a new generation of networked technologies[1] in secondary mathematics classes. The goal of the case study

[1] Networked technologies in this case are computers and/or calculators that link individuals so that information can be aggregated and mutually exchanged and accessed, as well as being displayed visually for all to see.

reported here is to support under-represented[2] students' successful participation in technical fields of study. Specifically, I examine opportunities to enhance cultural relevance in the use of HubNet and Participatory Simulations (described more fully below; Wilensky and Stroup 1999). The overarching research question is; in what ways is network-supported classroom activity related to historically derived, community cultural practices? The focus in pedagogy aimed at supporting under-served students' rigorous academic learning leads to my attention to providing access to powerful discourses by connecting them to students' lives (González and Moll 2002; Ladson-Billings 1995a, b; Lee 1995). Thus, features of the above vignette that are of interest to this study include students' flexible use of both formal and informal language (including African American Vernacular English, or what students in this study call 'urban' English)[3], the connections to their lived experience, their coordination of effort, and the collective construction of strategies, knowledge, and meaning to work through the simulated traffic activity. I begin with a brief description of the networked system and the importance of considering cultural practices of non-dominant youth as resources for rather than barriers to learning. I then examine the ways that the multiple modes of participation and opportunities to contribute to the group's accomplishment of its task served as important invitations to under-served students to bring to bear resources they develop through participating in everyday practices of their communities. In particular, I show how collective construction of discourse and practice, as well as particular communicative practices that characterized network activity in this case study (i.e., use of informal language, gesture), invited students' engagement in practices that have links to youths' cultural communities. Finally, I argue that these kinds of linkages are crucial for increasing the inclusive, academically powerful potential of networked classroom activity.

The networked learning environment—Gridlock Participatory Simulation

I focus on mathematics learning and cultural practices in implementation of the HubNet and Participatory Simulations networked classroom system (Wilensky and Stroup 1999) in a large, urban, under-resourced secondary school that serves predominantly African American and Puerto Rican youth. This system is a member of a new generation of technologies that focus on shared construction of mathematics learning (also in this class are SimCalc, Hegedus and Kaput 2003; Texas Instruments' Navigator™ system; ClassTalk, Dufresne et al. 1996) that are quickly making their way into classrooms, and are seen by organizations such as the National Research Council as "one of the most promising technology-based education innovations" (Roschelle et al. 2004, p. 51). The system involves graphing calculators that are connected to hubs that have a wireless connection to a computer that acts as a central server. Students "act out the roles of individual system elements and then see how the behavior of the system as a whole can emerge from these individual behaviors. The emergent behavior of the system and its relation to individual participant actions and strategies can then become the object of collective discussion and analysis" (Wilensky and Stroup 2000, p. 2). In the Gridlock Participatory Simulation that was the focus of this study, each student controls a stoplight at an intersection in a traffic grid. Their collective activity forms traffic flow in a grid, along with real-time graphs of the

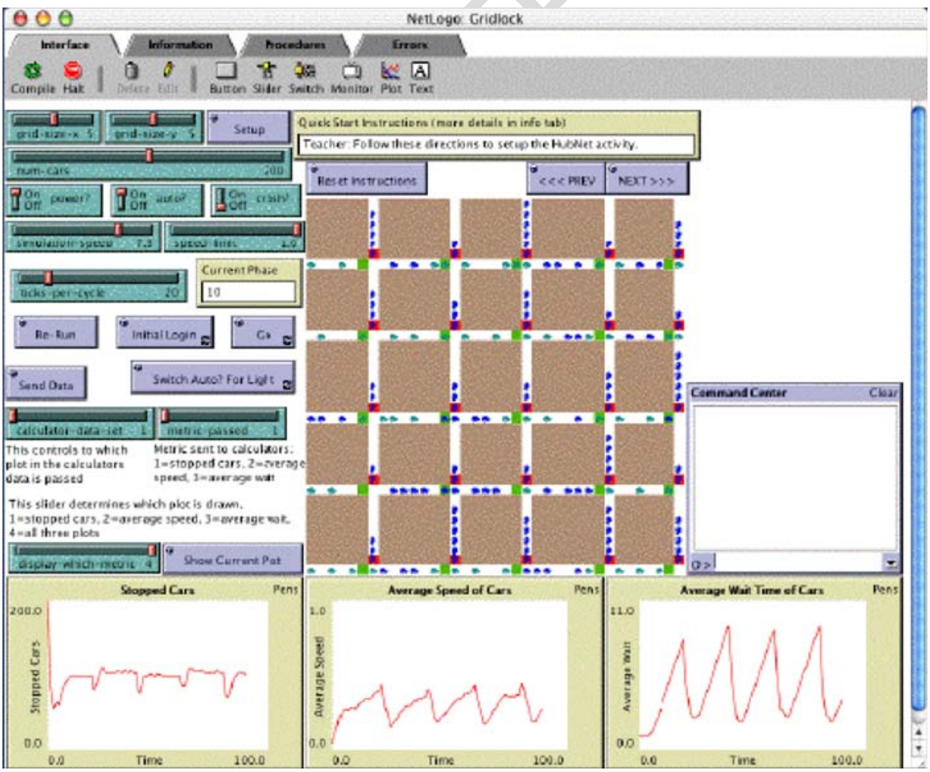
[2] I use varying terms to signal the social position of the youth involved in this work to avoid falling into problems of using a single term such as urban or inner city that may be interpreted to identify these students from a deficit-based perspective.

[3] In interviews, students identified the language use as 'urban,' reflecting its use by youth from various cultural communities in Rochester, i.e., African American, Puerto Rican American, European American.

number of stopped cars, average wait time, and average speed over time, all of which are displayed visually at the front of the class (see Fig. 1). Features of the model can be manipulated, including the number of cars and intersections in the grid, cars' speed, and the timing of light changes at computer-controlled intersections. Discussions of the visual display, along with strategies for optimizing traffic flow, involve students in both the creation of and analysis of an emergent, complex dynamic system and multiple, linked representations (three graphs, traffic flow in the grid). Typically, several simulations are run in a class session. The sessions follow a pattern of introducing the system to the students and eliciting the class' ideas about what constitutes good and bad traffic, followed by repeated cycles of running the simulation until gridlock is reached, discussing and analyzing what the resulting graphs reveal about the traffic flow during the simulation, and then choosing strategies for optimizing traffic flow along with predicting what the three graphs will look like if they are successful for the next simulation. Graph analyses involve students in considering, for example, concepts of slope and rate and interpretations of graphs' features and meaning, as well as linking multiple representations to each other and to traffic flow.

Multi-modal participation: Potential for inclusive practice

Prior research with HubNet and Participatory Simulations in secondary mathematics classrooms indicates that networked activity involves important, expanded opportunities to



Q2

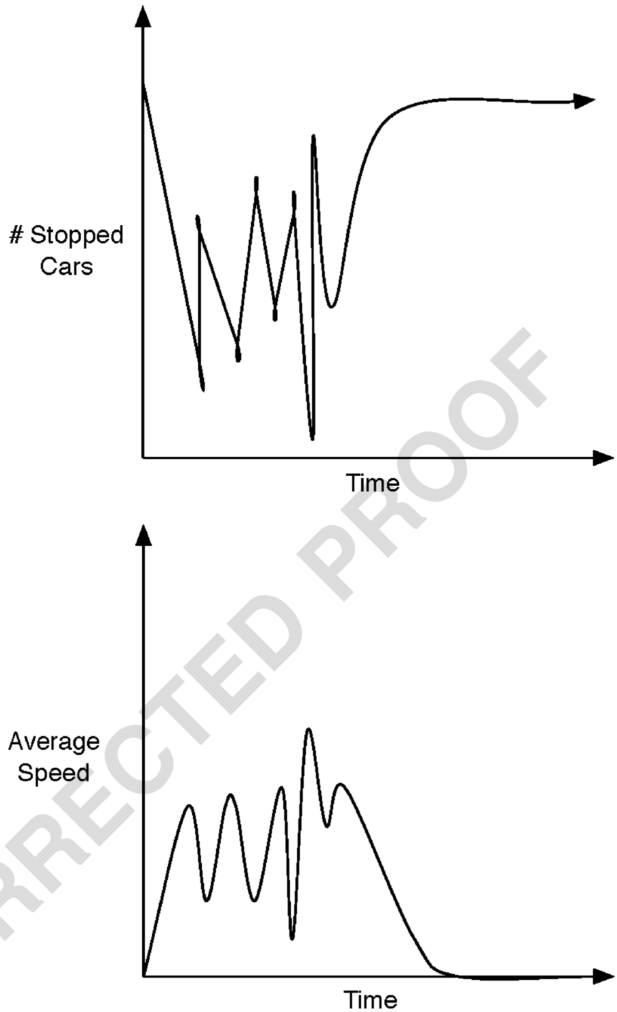
Fig. 1 Projected images of traffic grid and graphs participate in relation to more conventional practice (Author 2004, 2007). Features that offer potentially important avenues for enlarging the types of cultural practices used as resources for learning include: “1) multiple modes of contribution (language, text, physical and electronic gestures); 2) engagement with multiple representations of phenomena (texts, graphs, visual displays of emergent systems, language); and 3) inquiry-oriented discussion and analyses important to the practice of mathematics” (Author 2007, p. 409). The discussions are similar to “metacognitive conversations ... 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” (Lee 2003, p. 48, 49). Our findings indicate that acting on and with the real-time visual display (the projected traffic flow through the grid, emerging real-time graphs of stopped cars, average wait time, average speed in the Gridlock example at the beginning of this paper) and whole-class analysis of the emerging complex system (traffic flow in the grid) are crucial features in increasing the number of students participating, in the class’ engagement in academic mathematical discourse and practices, and in fostering a balance between student and teacher talk (Author 2004; Fig. 2. In addition to these features of the networked activity, the teacher’s questions were critical in fostering a discourse of academic mathematics, i.e., hypothesizing, mathematizing, predicting, visualizing, and linking graphical and other representations (Brenner and Moschkovich 2002). The importance of expansive opportunities for multi-modal participation in powerful mathematics learning found in these results prompted my examination of network-mediated classroom activity in relation to cultural practices of non-dominant youth.

Significance of cultural practices in design of learning environments

Numerous communities call for students living in poverty, girls, and students of color to have access to the discourses of science, technology, engineering, and mathematics (STEM). Some focus on the increasing technological complexity of today’s societies (cf., National Research Council 1996; National Science Foundation 2003; Thom 2001). Others argue that such discourses are discourses of power under-represented students must learn to be able to resist marginalization (Jetter 1993; Ladson-Billings 1997; Moses and Cobb 2001). While many efforts to address these calls emphasize increasing academic achievement in school-based definitions of these disciplines [cf., NCLB 2001 (2002)], others push for students to be given opportunity to engage in practices of professional communities (cf., Ladson-Billings 1997; Newmann et al. 1995). The latter argue that school-based definitions are narrow and simplistic in relation to what is required to participate successfully in STEM professions. Agreeing with these critiques of school practices, this paper responds to calls to provide non-dominant students access to powerful STEM discourses, with particular attention to using students’ cultural practices as important resources for learning (e.g., González et al. 2001; Ladson-Billings 1997; Lee 2003; Warren et al. 2001).

Attention to both powerful discourse and cultural practice is found in a family of approaches that draw on funds of knowledge (e.g., knowledge and skills communities develop through participation over time in local social, economic, political and cultural contexts; Gonzalez and Moll 2002; Moll and Greenberg 1990) and communication and interaction patterns youth construct through engagement in their communities (Lee 1995; Warren et al. 2001). Goals of this pedagogy include students’ achieving academic success, healthy cultural identity, cultural competence, and sociopolitical awareness to not only enable them to engage in powerful discourses of school subjects, but also broader discourses, including STEM communities (Gay 2000; Ladson-Billings 1997).

Fig. 2 Graphs of number of stopped cars and average speed over time



This study extends important work that attends to networks' implementation in demographically heterogeneous classrooms, e.g., Hegedus and Kaput 2003; Wilensky 2003 by attending specifically to the fact that students bring varied cultural practices and resources to the task of learning. As Wilcox (1988) notes, "many popular educational reforms are likely simply to rearrange the appearance of classroom interaction, leaving the substance of what takes place in the classroom largely untouched. This is because the reforms are conceptualized and introduced with little understanding of the powerful cultural influences at work in the classroom" (p. 303; cited in Panofsky 2003, p. 422). Further, Lee (2003) cautions that ignoring those influences may actually reinforce inequities in classroom learning and achievement. She bases her caution in the fact that evaluation of computer-based educational tools' impact has not considered that different cultural groups will approach and/or interact with them differently, based on cultural norms and models that influence goals, values, and beliefs about such tools' use in learning. There is little hope of improving under-represented students' preparation in STEM disciplines and transforming classroom teaching and learning through technology if research and development efforts ignore issues of culture, given what we know about its profound influence in learning (Bruner 1996; Lave 1988; Papert 1980; Vygotsky 1987). Q3

The case study presented here addresses both the heterogeneity of classrooms and the potential affordances of next-generation networked technologies for leveraging the cultural resources under-represented students bring to classroom learning. Cultural practices as resources for learning are explored first, followed by the study design and findings. The concluding sections explore implications for inclusive pedagogies in technology design and classroom practice more broadly.

Cultural practices as resources for learning

The notion of cultural practices used here acknowledges that culture is complex, multidimensional, and constructed through engagement in everyday, historically inherited activities of communities (Civil and Kahn 2001; Moll and Greenberg 1990; Scribner and Cole 1981). In this sociocultural theoretical framework, cultural practices are understood to include ways of interacting, using language and tools, and reasoning. They also involve patterned ways of interrelating with children and adults; communicating information, ideas and emotion; and approaching tasks. As a result of participation in communities' activities, youth develop "repertoires of practices" that influence their interactions in varying settings (e.g., home, school) and that serve as resources for learning, whether that learning is at school or elsewhere (Gutierrez and Rogoff 2003, p. 22).

Drawing on cultural practices in network-supported pedagogies in this case means:

- using the cultural practices of students as valuable, legitimate resources for learning;
- treating use of those practices as central issues in implementation; and
- scaffolding students' learning of rigorous academic content by drawing on those practices in service of generative learning, or learning that engages students in productive and creative activity, characterized by increased personal and collective agency (Author 2005).

Increased agency is viewed as important in supporting under-represented students' cultural competence in their communities of origin and their successful development of powerful discourses.

Importantly, artifacts like computers, calculators, and language are examined for their mediating role in human activity and interaction. Tools themselves cannot shape activity. A sociocultural perspective pays attention to artifacts-in-use: "the agent of mediated action is seen as the individual or individuals acting in conjunction with mediational means" (Wertsch 1998, p. 33). Cultural tools are never "mere" artifacts because, by virtue of people's use of them in service of achieving a goal, they inevitably shape the activity by influencing the means by which goals are achieved (Cole 1996). Further, by virtue of their being used and modified over time in goal-directed activity, artifacts are also changed. Finally, as explored in more depth in the findings section, artifacts have a dual nature, meaning that they are both ideal (thinking tools used to make sense of phenomena and interactions) and material objects (e.g., graphs, traffic flow in the display). Cole's (1996) conceptualization of artifacts as a nexus of internal and external activity is important here, providing a way to examine artifacts in use as they shape and are shaped by mental and other activity.

Communication, interaction, and language

Examination of mediating artifacts can illuminate the nature of the evolving relations among the cultural resources students bring to bear in classroom learning, uses and roles of tools as mediating means that shape activity and interaction, and the emergent outcomes of those activities. As Lee (2003) notes, "With the new opportunities for forms of representation and communication afforded by new computer-based technologies, it may well be quite useful for designers to consider the implications of this work for communication opportunities within computer-based environments" (p. 44). However, the communication, interaction, and language use patterns people employ differ depending on the setting, audience, and purpose (Bahktin 1986; Gee 2005). Especially for traditionally underrepresented students whose home/community language use is often devalued, out-of-school communication and interaction styles may be markedly different from those they utilize in classrooms (Heath 1983). As a result, research and practice that examine the affordances of drawing on heterogeneous communication and interaction patterns offer valuable guidance for supporting inclusive, network-mediated activity.

Seminal work on expanding the kinds of communication and interaction patterns valued in classrooms is found in research by Rosebery et al. (1992, 2001), who identified important connections between Haitian Creole students' skills in argumentation and story-telling and inquiry in science. In literacy, Lee's (2001, 2003) Cultural Modeling Project draws on linguistic features of African American Vernacular English, including "use of metaphor and... satire, irony, and shifts in point of view" (Lee 2001, p. 100), to scaffold students' literary analysis of canonical texts. In work on educational technologies, Pinkard (2001) and Lee (2003) also attend to curriculum, using curricular resources their students had significant prior knowledge about; specifically, clapping routines ("Miss Mary Mack," Pinkard 2001, p. 20) and "signifying dialogue, lyrics from rap and R&B music, or videos" (Lee 2003, p. 48) to either focus students' analysis of texts or ground students' development of literacy skills. Pinkard's (2001) *Rappin' Reader* and *Say Say Oh Playmate* computer-based learning environments and Lee's (2003) modified *Collaboratory Notebook* (Edelson and O'Neill 1994) served to engage students in rich, culturally relevant text environments (both print and pictorial, as well as audio and video); to provide them flexible tools for thinking, visualizing, hypothesizing, and analysis; and as sites for production of text.

The research I report here extends prior work by focusing on the notion that cultural practices are invoked in response to features of activities that invite their use. Webster, Wiles, Civil and Clark (2005) offer an example of culturally responsive mathematics pedagogy in a Yup'ik Native American community that is helpful in understanding the role of curricular and pedagogical designs. They do not claim a direct transfer of community cultural practice and norms for communication and interaction into classroom activity, but show how a culturally responsive curriculum and the teacher's pedagogy can work together with students' community-based funds of knowledge and ways of interacting to create an inviting, safe space for students to learn rigorous mathematics. Building on such findings, this study focuses on the role of network-mediated mathematics pedagogy in encouraging students to bring to bear cultural practices whose roots may be in often-denigrated, under-appreciated communities.

Lee (2003) notes that:

> Finally, I want to respond to an often cited critique of culturally responsive approaches—that is, that it is cumbersome, if not impossible, to address the breadth of cultural diversity,

> for example, within the United States. In this case, computer-based technologies offer unique opportunities. Computer-based tools can provide underlying architectures that allow for multiple forms of modeling, of ways that learners can represent their understanding, and multiple routes for interactivity and appropriation. (p. 58)

The networked classroom system examined in this study provides such architecture. To build understanding of the potential provided by these networks in mathematics education, the possibilities for drawing on varied cultural practices and resources as valuable and necessary are examined in terms of opportunities to participate in powerful mathematical discourse and practice.

Case study design

Setting

The study was conducted in a large secondary school (~2200 students) in Rochester, NY, a city that ranks 11th in the US for per capita poverty. The school has a heterogeneous demographic profile (60% African American, 26% Hispanic, 12% white, 3% Asian, Native American, Alaskan, and Pacific Islander; 36% free or reduced lunch; 11% English language learners). In 2004 and 2005, the graduation rate was less than 40%; that number had not changed by 2007. Three teachers participated in the study. It is important to note that they were working hard to support their students' success, including the expansion of conventional practice, in an under-resourced school and in an environment of high stakes accountability that was putting pressure on the mathematics department to compartmentalize and standardize the curriculum while also emphasizing test taking. Given the policy and demographic context, as well as the school's achievement profile, the school serves as an important setting for examining the ways that networked activity might offer important opportunities to engage in powerful mathematical discourses by drawing on cultural practices that are not often viewed as resources.

From 2004 to 2007, my research team spent two consecutive days per month in their classes over the course of the academic year. Data from eight mathematics classrooms were analyzed for this paper. The classes were algebra, integrated mathematics (algebra, geometry, trigonometry), and mathematics competency (pre-algebra, algebra), class sizes ranged from 7 to 28, and classes ran for 42 minutes. Students were sophomores, juniors and seniors (second, third, and fourth year). We report analyses of field note data taken over 20 class sessions and video data from 4 class sessions during which we implemented the Gridlock Participatory Simulation, described in detail below. The use of video was important in enabling the analysis of gesture, verbal intonation, and non-verbal activity, all of which enriched the analysis of cultural practices. In addition, 9 focus group interviews with a total of 42 students (2–6 students per group) complete the data corpus.

Because our work with the teachers was in the beginning phases, two graduate students (both former classroom teachers) and I had primary teaching responsibilities, with the teachers chiming in as they saw fit and felt comfortable. Table 1 presents the Gridlock lesson[4], and shows that a key element is posing questions to the class that invite students to, for example, ground the activity in their own experience, strategize together, predict what effects implementing their strategies will have on the three measures of traffic flow, and

[4] See Stroup and Wilensky (2004) for classroom activities for Gridlock and other Participatory Simulations. Q1

Table 1 Gridlock activity lesson plan

Activity lesson plan
Describe task: The Mayor has commissioned a report about traffic flow downtown. Today and tomorrow, class works with Gridlock Participatory Simulation that has each student control a traffic light at an intersection in a traffic grid. The report has to recommend how to optimize traffic flow
Draw on prior experience: Discussion questions–What makes 'good' traffic? 'Bad' traffic? What is involved, and how might we measure it?
Start simulation and allow class to explore, noting how long it takes to reach gridlock
Discussion questions—What strategies were you using? What were you trying to accomplish? What strategies do you want to use on the next simulation? (record suggestions on chart paper)
Class implements new strategy in simulation; note time to gridlock
Discussion questions—How well did your strategy/ies work? How can you tell? What do you want to do this third time? (connect to actual traffic, for example, timed phased lights downtown)
Discussion questions—What do these graphs mean? How do they relate to traffic flow? How do they relate to each other?
Small group task—use chart paper to draw graphs of good and bad traffic, write the story of the graphs, and propose a strategy for optimizing traffic flow

evaluate the results of their collective efforts by analyzing and linking the graphical representations of those measures. Also central to the lesson is the use of multiple modes of participation, i.e., whole class, small group, independent work, and discussion; writing, graphing, and physical and electronic gestures. Features of the networked system *and* our pedagogy shaped the activities and interactions in the classrooms, thus the focus on network-mediated activity and artifacts in use. Further, we did not focus on cultural relevance explicitly in our pedagogy; the focus was on engaging students in the construction and analysis of a complex dynamic system. Attention to cultural practices came in with the analysis of the data, given our observations of differences in language use and interaction patterns in networked and non-networked classroom activity and prior findings, presented above, that pointed to potential affordances for cultural relevance.

Analytic techniques

I focused on the activities and interactions of students, teachers, and researchers-as-instructors. The case is comprised of the eight classrooms in which students, teachers, and researchers-as-instructors engaged in the Gridlock PartSim. Field note and video data gathered over the 24 sessions were examined using Gee's (2005) activity building task as a framework for analysis. That task involves determining how language is used to make meaning of and create a situation. Importantly, this involves examining ways that people "build and rebuild our worlds *not just through language*, but through language used in tandem with actions, interactions, non-linguistic symbol systems, objects, tools, technologies, and distinctive ways of thinking, valuing, feeling, and believing" (p. 10, emphasis added). Questions asked of the data include, "What is the larger or main activity (or set of activities) going on in the situation? What sub-activities compose this activity (or these activities)? And, what actions compose these sub-activities and activities" (Gee 2005, p. 111)? In particular, data were examined to understand how the classes approached and engaged (main activities) in the Gridlock PartSim, what interactions with people and the network made up those approaches and engagements (sub-activities), and what actions (e.g., utterances, strategies, role-playing, etc.) comprised those interactions. The goal was not to document change in response to our implementing the Gridlock Participatory Simulation, but to characterize the relations among people, the network, and activity as the simulations proceeded.

Links from the above analysis to literatures on practices of the particular cultural groups represented among the students in the case study classes were examined to explore opportunities for students to bring to bear practices of their communities. For example, interactional and mathematical work accomplished through the use of "urban" language and of efforts to come to collective understanding of models of traffic flow were examined in light of research on African American Vernacular English (Smitherman 1977), communalism in African American communities (Boykin 1986; Ladson-Billings 2007), *personalismo* in Latino/a cultural communities (Santiago-Rivera et al. 2002), and social networks in Puerto Rican and Mexican American communities (Antrop-González and De Jesús 2006; González and Moll 2002).

Semi-structured focus group interviews with students provided information about students' experiences and perceptions of networked activity. Questions focused on what they thought was different in their classrooms when we brought the networked technology in, relationships among their in- and out-of-class ways of interacting and the networked activities, and whether and how the activities helped them learn mathematics. While the questions themselves provided *a priori* categories, analyses within categories were guided by the ethnographic question, "what's going on here?" Three doctoral students and I used a constant comparative method for analyzing interview data, following Strauss and Corbin (1998). All of us analyzed the same transcript independently, discussed codes and themes to come to consensus, and independently coded another common transcript, at which point we reached 93% inter-rater agreement. Further analyses were conducted separately, using the scheme we had constructed together.

The findings regarding the main and sub-activities are organized around two central tenets in culturally relevant pedagogy: rigorous academic learning and links to students' community cultural practices. First, the two main activities are presented, including excerpts from representative data and analysis of interactions and mathematical activity. In keeping with my analytic approach that explored links to cultural practice literature relevant to the findings, the subsequent sections weave together data, analysis, and literature to describe opportunities for pursuing cultural relevance in network-mediated pedagogy. Findings regarding students' perceptions follow.

Findings

The two, related main activities that characterized the network-mediated activity were coordination of efforts and co-construction of mathematical discourse and practices. Table 2 lists the main activities that characterized network-mediated activity, along with sub-activities that comprised them. The term *coordination* captures the distributed nature of that activity, with no one person orchestrating groups' activity. Instead, a collective sense characterized these interactions, with both individually and collectively constructed visual representations in the real-time display along with verbal directions, pleas, and prompts serving to mediate the joint efforts of students. This is not to say that there was always agreement as to the direction of the activity or strategies by which to accomplish tasks, but that overall coordination of effort was a main activity at the group level.

Table 2 Main activities and sub-activities, or interactions involving language, tools, and other resources that made up the main activities of coordination and co-construction

Activities
Main activities
Coordination of effort, with no apparent leader; a collective coordination
Co-construction of mathematical objects, discourse, and practice
Sub-activities
Use of informal language to reason, communicate mathematically
Use of physical gesture to communicate mathematically
Use of graphical representations to communicate mathematically
Use of electronic gesture to participate, communicate mathematically
Linking representations to each other and to real world phenomena
Experiential resources (experience with city traffic)
Strategizing at individual and group level, and connecting kinds of reasoning (e.g., agent and aggregate)

Q7

Coordination of efforts

The excerpt below from transcribed and field noted video data is representative of the interactions involved in coordination when the Gridlock Participatory Simulation was running and when the classes discussed the outcomes of their efforts. Students and teachers were highly engaged during these episodes, calling out to each other when traffic was flowing and contributing ideas during the analysis of their results. Important to note are their collective efforts to keep traffic flowing smoothly and the many suggestions for changes to make to the model to do better with the next run of the simulation:

Student 3: Oh! Somebody needs to change!
Student 6: I ain’t goin’ no where
Student 2: Change your light, HHH! (each intersection is identified by a trio of letters)
Student 1: We’re stuck here, HHH!
Student 3: Look at the traffic at HHH!
Teacher: We need HHH to turn to green
Student 5: Got it
Student 8: YYY is too blood!
Student 6: SSS you gotta find a space to open up!
Student 10: Look at our graphs!
Student 2: Who’s MMM? YYY?

[Students continue with the simulation until Gridlock occurs and cars can no longer move. N asks about students’ strategies, and then what they want to do for the next simulation. One student suggests that they work together. Another student suggests leaving a gap so the cars do not back up at intersections. Students suggest speeds for cars and want all three graphs showing (Fig. 3). They decide to reduce the number of cars and the speed. Q4 When simulation is started again, the same pattern of calling out to each other to change lights ensues.]

The contributions above were spread across numerous students, so that control of the group’s efforts was distributed among participants. The students’ coordination of effort was supported by the combination of interacting with the dynamic interactive medium (traffic flowing through grid; emerging, real-time graphs), communication among individuals, and

Q2

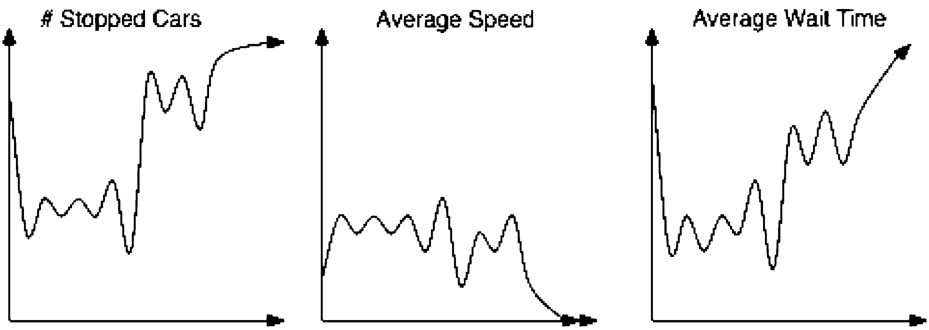


Fig. 3 Three metrics of traffic flow. *X*-axes represent time

individual and group strategies. The comments, "WE need HHH to change" and "look at OUR graphs" indicate a group ownership of the activity. The strategies–everyone working to leave a gap, collective agreement to reduce cars and speed–also pinpoint efforts to coordinate activities in service of avoiding Gridlock.

Corroborating prior findings (Author 2004, 2007), the projection of the traffic system and the emerging graphs provided a dynamic, co-constructed object that focused the group's efforts, and served as a tool for coordination and thinking. Very concretely, the technology itself provided ways to contribute to the emerging system, contributions required by the Gridlock PartSim for the activity to proceed. The instructor's prompting of the whole class analysis of their coordinated efforts, as well as the invitation to determine what to modify in the model and which strategies to implement, was also important. As a mediating artifact, then, the networked activity (technology and instruction) fostered the group's coordination of efforts and provided the opportunity for them to work collectively.

Across all 24 classes, these kinds of interactions typified groups' efforts. Several strategies aimed at coordination emerged (e.g., "We all need to work as a group and figure out which lights need to turn red and green at the same, because right now we're all doin' our own thing"), including changing lights at regular time intervals, synchronizing intersections, and matching person-controlled light changing with computer-controlled intersections' patterns.

Co-construction

It is in this main activity that the nature of the mathematics involved in most obvious. Groups co-constructed both mathematical objects (e.g., traffic flow in the system, graphs of the number of stopped cars, average speed, average wait time) and mathematical discourse and practice (e.g., strategizing at both individual and collective level, analyzing and linking representations to each other and to the traffic flow, use of language and physical gestures to communicate mathematically). Two excerpts are included that illustrate the sophisticated conceptual understanding the classes' developed together and the nature of the network-mediated learning.

The first excerpt, transcribed from a class with nine students, is representative of collective construction of interpretations of and linkages among mathematical representations; in this case, the graph of stopped cars and the movement of the cars in the grid. Just prior to this exchange, students had implemented a strategy of changing their lights at regular intervals, beginning with all the lights in a particular row being the same color. This segment of their discussion focused on interpreting the meaning of the graphs of stopped cars and average speed:

> Instructor: Right, so, is there anything about this graph that may tell us that we did pretty good for a while?
> Student 3: How long we were going.
> Instructor: Yeah, good, how long we were going. How can we tell we're gridlocked?
> Students: The cars don't move. By the line. When it goes straight. At the end. *(overlapping talk, pointing toward graphs in upfront display)*
> Student 4: When it goes straight at the end (*pointing to the graph of number of stopped cars)*.
> Instructor: When it goes straight up here, so that means all cars are stopped? (*pointing to the same graph)*
> Students: Yes.
> Instructor: So what's this mean down here? *(pointing to the graph of average speed)*
> Student 7: All cars stopped,
> Student 6: They're not movin'
> Student 8: The speed decreases (*moving hand in a downward sweeping motion)*
> Student 9: The speed! It stays the same.
> Student 7: It stays the same.
> Instructor: And what is the speed?
> Student: Zero. Nothing. Stopped *(overlapping talk)*
> Instructor: So what's the relationship between these two graphs?
> Student 5: One is higher and one is lower *(motioning with hands, holding one up and one down relative to each other)*.
> Student 3: They look the same.
> Student 8: If you turn one upside down, they look the same (*turning hand from palm down to palm up)*.
> Instructor: Talk to me about in the real world. This is stopped cars, this is average speed. This is high, this is low.
> Student 9: They stopped at the same speed, at the end they stopped at the same speed.

In this episode, the students and instructor constructed understanding of how the graphs related to the motion of the cars in the grid. The horizontal segments of the two graphs were connected to the time during which all the cars in the system were stopped and Gridlock reached ("The cars don't move. By the line. When it goes straight."). Together, the group worked to connect the graphs to each other as well, linking the shapes and their meaning to each other ("If you turn one upside down, they look the same," "at the end, they stopped at the same speed"). Their discussion built on a variety of individual contributions as they developed a collective story of the graphs' meaning. The networked technology served a dual mediating function in this co-construction by providing the tools to both create and interpret the traffic flow and the graphs, while the discussion mediated their linking the movement of cars in the grid to the graphs and their collective construction of the meaning of the graphical depictions.

The following excerpt captures groups' uses of the real-time emerging graphs to judge both their efforts to avoid Gridlock and their predictions of what their strategies would produce, as well as their moves to consider more general relationships among the graphs and the traffic flow. Prior to this exchange, students had chosen a strategy of changing their lights every 5 s and predicted that, if their strategy worked, the graph of stopped cars would drop and stay low and fairly steady, and that the graphs of average speed and wait time would rise but then level off in the middle of the graph:

> Student 3: At least it was going down, you saw that? [referring to emerging graph of stopped cars, hand swooping down]
> Student 5: We got it got it at a constant rate! Dddddd
> Student 2: It's a good method though, right?
> Student 3: Y'all was makin' mad traffic down there, look
> Student 1: My theory was right, mister [as Gridlock happens again]
> Instructor: So what can you tell me about the relationship between these two graphs? This one's up here this one's down here, why's that? [pointing to the graphs of number of stopped cars and average speed]
> Student 3: They go hand in hand, they got like a direct relationship. If people
> Student 2:...it was it has to do with each other because the amount of cars stopped causes the speed to decrease [one hand moves up, the other moves down]
> Instructor: How does that all relate to this graph of average wait time?
> Student 2: If you have a lot of stopped cars, they're going to be going slow [drops hand down], so your average time is going to take a lot longer [hand moving up] than it would if there were more cars moving.

During the simulation, the group used the dynamic representations to gauge how well they were implementing their strategy ("at least it was going down," "we got it at a constant rate," "it's a good method," hand swooping down to accompany observation of emerging stopped cars graph). They used the representations to evaluate their progress and linked the graphs' properties to their definition of good traffic flow. During the post-simulation analysis, they linked the representations to each other, translating between them to work out the relationships among them and to traffic flow ("they go hand in hand," "the amount of cars stopped causes the speed to decrease"). Student 2, in the final lines of the excerpt, successfully linked all three graphs to each other and used them to generalize the relationships among them and traffic flow. Also important in this exchange was the movement to more formal mathematical language and reasoning ("direct relationship," linking number of stopped cars to increasing average wait time). They talked about themselves being 'in' the graph ("We got it at a constant rate," "Y'all made mad traffic down there").

All the excerpts above are also representative of invitations to students to draw on gesture and informal language, developing conceptual understanding before moving to formal symbolization and vocabulary. For example, we found consistent use of words such as "level," "smooth," "steady," "going down and staying down," to describe how graphs of the number of stopped cars and of average speed should look if traffic flow was good. Important connections among graphical representations and real-world phenomena were being made, and thinking with the tools of mathematics was fostered. Gestures that represented students' thinking and interpretations were also commonly found (e.g., hand swooping down to indicate negative slope and decreasing number of stopped cars, hands moving in opposite directions to illustrate inverse relationship). These complemented or augmented their discussion to illustrate their understanding. Across all the classes, instructors then built on those contributions to move to more formal discussions of slope and rate ("where in the graph is the average speed decreasing the fastest?" "in formal language, going up fast refers to the slope"). It is important to note that the practices we documented involve types of mathematical reasoning (e.g., agent and aggregate reasoning, Wilensky and Stroup 2000; strategizing, abstracting, hypothesizing), and are not simply using language and tools in ways that mathematize situations. Mediated by the networked activity, powerful conceptual understanding is evident in the students' graphical analysis, understanding built through interactions that included important links to youths' community cultural practices, as shown next.

Main activities' links to cultural community practices

The focus on groups' cooperation and shared construction that characterized the two main activities is central to the networked activity (both system design and related classroom activities). Coordination and co-construction are also features of pedagogies designed to leverage communities' cultural practices, where "teachers encouraged a community of learners rather than competitive individual achievement" (Ladson-Billings 1997, p. 480). In a related vein, the collective construction of stories in native Hawaiian communities (Au 1980a), *confianza* or mutual trust and networks of relations in Mexican communities in Tucson, AZ (Greenberg and Moll 1990; González et al. 2001), and call and response traditions in African American churches in Chicago (Moss 1994) feature co-construction and coordination, practices these communities have developed over time and in particular social, cultural, historical contexts[5]. Also, Boykin and colleagues have documented extensively the role of communalism in urban African American communities, arguing that this practice differs from the conventional focus in schools on individualistic/competitive practices (1986, 1995, 2005). Flores (1993) traces similar practices in Puerto Rican communities in the US, citing the close proximity both geographically and in terms of social positioning in the US of African Americans and Puerto Ricans as influences that foster cross-group influences on cultural practices. Finally, Antrop-González and De Jesús (2006) and Santiago-Rivera et al. (2002) describe the value Puerto Rican youth and families tend to place on communal rather than individualistic cultural models that value high-quality interpersonal relationships that support individuals' confidence and self-respect (*familismo* and *personalismo*). Thus, findings regarding the two main activities (along with language use, explored below) point to a potential congruence between network-mediated activity and cultural practices of communities in which our students participate (majority African American and Puerto Rican American). The two main activities, then, represent an important potential in networked activity in that they draw on resources of these cultural communities.

The multiple modes available to communicate mathematically and to contribute as well as the inquiry-oriented discussions invited students to draw on a variety of expressive modes to accomplish their collective task. Language, gesture and mathematical representations used to communicate mathematically were predominant sub-activities in coordination and co-construction (see Table 1). It is through these sub-activities that additional support for the claim that features of networked activity represent opportunities for increasing cultural relevance is found. Explored next, these sub-activities add depth and specificity to our understanding of the opportunities involved.

[5] This is not to say that all members of those communities engage in such practices, or that, for example, African American communities in New York engage in the same or similar practices as communities in Chicago. It is to make, following Gutierrez and Rogoff (2003), "a shift from the assumption that regularities in groups are carried by the traits of a collection of individuals to a focus on people's history of engagement in practices of cultural communities" (p. 21). Such an approach resists both essentializing to entire populations and locating such practices as traits within individuals.

Language use and interaction patterns in cultural communities

Communities' language use and ways of interacting have long been recognized as practices that bind people together across time and that serve as critical sources of group identity and coherence. As critical resources, they can be extremely influential in either inviting or excluding students in classroom interactions, providing key avenues for students' motivation to engage in learning activities. Lee (2003):

> calls on designers explicitly to draw on community-based norms for discourse. ... norms for who can talk, how, when, and about what help to construct roles for participants to play. Lack of congruity with community-based norms for talk (including use of different national languages—such as Spanish; language varieties—such as African–American Vernacular English [AAVE]; or registers) has been shown to result in lack of participation in classroom talk. (p. 47)

Language varieties are not simple constructions that involve only linguistic structures and rules. Heath's (1983) classic ethnography of language learning in three different communities makes clear that they develop in social, political, cultural, and economic histories, and in interaction with each other. Norms for communication are themselves cultural practices, and thus also involve values, beliefs, and expectations for speaker and hearer roles. While classroom technologies cannot by themselves open up the kinds of language use and interaction patterns invited into learning activities, features of the design and use of them can be examined for the potential to treat community-based linguistic and interactional practices as legitimate and powerful resources.

Evidence of that potential in network-mediated activity is included in language use such as that captured in the following field note excerpts of students' coordinating their efforts:

> Somebody messin' me up here.
> Who's 11? (intersections were designated by numbers)
> 18, gotta move.
> 19, change to a different stop light.
> Well, I ain't movin' at all. I'm mad.
> Can't see those numbers.
> Thank you, thank you, God. I'm finally moving.
> ...
> There we go...get through...I put that red light...oooh...change...I'm gonna change 7 thru 9...15, 15, 15..."
> I'm gitting backed up. Number 14...let my people go through please... Thank you... go...go...go...go...yeah go...stay there...go...go ...number 2, number 5. I'm good. Nobody complaining about me. I wonder why? I'm just good. I was gitting it, did you all see me...did we beat the freshman yet? If everyone here was like me, we'd be phat.

Ten different students contributed the utterances above, so that no one person or few people were orchestrating the activity. The use of informal language to manage efforts at avoiding gridlocked traffic relied on what Lee (2003), citing Smitherman (1977), identifies as features of African American Vernacular English: "verbal inventiveness, unique nomenclature, rhythmic, dramatic evocative language, sermonic tone, [and] cultural references" (p. 54). Potential for changing norms is seen above in talk often associated with African American churches (Thank you, thank you, God; let my people go) and youth culture (I ain't movin'; we'd be phat). Much more work is required to understand more fully the implications and affordances of students' language use and patterns of interacting in network-mediating mathematics learning. In addition, drawing on students' cultural practices was not done with explicit intent, but was instead a result of instructors' letting the interactions unfold without intervening. However, students indicated in their focus group responses that they felt comfortable talking and interacting in ways more like they did outside class when engaging in the networked activities than during 'regular' classroom activity. Similar findings in Ladson-Billings' (1992b, c) study of a successful teacher of African American students involved her "encourag[ing] students to use their home language while they acquired the secondary discourse (Gee 1999) of 'standard' English. Thus, her students were permitted to express themselves in language... with which they were knowledgeable and comfortable. ... students [became] not only facile at this 'code-switching' (Smitherman 1981), but could better use both languages" (Ladson-Billings 1995a, b, p. 161). In the findings reported here, use of 'urban' language was important in students' building conceptual understanding of the mathematical concepts and relationships involved while also serving as a bridge to more formal mathematical language use and understanding. As they noted in interviews, the increased comfort lead to an increased focus on learning. Their perspectives, explored in more depth next in the paper, add strength to the speculation that network-mediated activity may involve important possibilities for networked pedagogies that leverage community cultural practices.

Students' insightful perceptions

Students' insights into their network-mediated learning and interaction complemented and corroborated our analysis of field note data, and also extended it. Focus group interview data revealed connections to the main activities in students' responses about being able to work together and to help each other. When asked what was different when we brought the technology in, they cited the focus on collective activity and our regular use of small group work to complement the whole-class discussions and activities as important in supporting their learning. Numerous statements such as, "you communicate with one another," "it's better it's like say Lewis will help me instead of the teacher ... it's better 'cause I think we're all going to understand better if another student teaches us," and "we were always together more and yeah we all like to work together" indicate the value students put on cooperation. This value was tied by them directly to learning, and positioned students as people who know and can teach. In a setting where students from this school's communities are often demeaned, that positioning is important in inviting them to participate and contribute to rigorous learning.

Freedom in networked classroom climate Students extended our notions about the nature of the networked environment by adding attention to affective features of classroom learning. Freedom to interact and act (this includes hands-on learning, opportunity to help each other), and a relaxed and joyful learning atmosphere were the primary themes that spoke to affective elements of network-mediated activity. I stress here that the data show that students were not emphasizing fun for fun's sake, but were speaking of a learning environment that had an affective dimension that supported their focus on the task at hand. Many of their responses pointed to the changed classroom climate, for example:

> Boy: 'cause your level of comfort, you become *with* each other—it's like when you in the classroom and you work it out one way or another but like that [networked]

> activity it was just like everybody was having fun so it's like–kind of like forget where you at but you don't—it just means everybody having fun
> Girl: more like having fun—it's better to have your mind busy—so much tension in the classes here–if it's so strict because then you won't want to do nothing cause you're all mad and they [teachers] got an attitude—you don't want to learn like that—you want to have fun. Fun and freedom were tied directly to learning in these data, so that students were not saying simply that the networked activities were enjoyable, but that they invited them to engage in learning the mathematics involved. In addition, they characterized networked activity as inviting and engaging within a school context that they often found hostile or constraining. Our observations in areas outside the school corroborated the notion of tension. Uniformed sentries were numerous, hallway video cameras recorded movements and interactions, and assistant principals with walkie-talkies circulated, giving a sense of being under surveillance and strict control. The atmosphere is similar to that reported for many urban schools that serve marginalized populations, with disproportionately strict discipline (cf., Townsend 2000) and adults and students often distrusting each other (cf., Valenzuela 1995; Yeo 1997). The more relaxed atmosphere the students described in networked activity was important in terms of allowing a focus on learning, rather than on contestation, tension, and conflict. As one student remarked, "yeah it makes you want to save math for friends."

Freedom to participate is critically important in terms of inviting students to be themselves, to not feel constrained to be a certain kind of person. Students indicated that, during the networked activities, they felt able to relax, "because really you know, when you're doing the technology you're not really worried about it [surveillance] because it's like your time to do the technology piece ... and we'll be talking like we're going home." The colloquial vocabulary, overlapping speech, pacing of talk, and playful use of language seen in the above excerpts are characteristic of the ways we observed youth interacting and talking in the 'commons area' where we had weekly research meetings. The value students placed on broadening the modes of interaction and communication was tempered by the ways they talked about the situational nature of interaction and their concerns that the ways they talked with and interacted with friends were not necessarily appropriate for classrooms—"you want to show you know how to act," "the teachers wouldn't know what we were saying," "there is a time and a place for everything." Students clearly recognized that they had developed repertoires of ways of using language and interacting that were situational. Still, the interview data indicate that networked activities allowed them the freedom to choose from this repertoire to use the language that served them best in understanding and participating.

Discussion and conclusions

In these Gridlock PartSims sessions, coordination and co-construction, built on the multiple modes available to contribute, to communicate mathematically, and to draw on the strengths of group construction of mathematical discourse and practice, were shown to be important features of networked activity. Interactions like these, mediated by the network's technical and intellectual tools, are important to building powerful mathematical discourse and practice. In addition, network-mediated activity provided opportunities to non-dominant students to bring to bear important cultural practices as resources for mathematics learning.

Thus, two central principles of culturally relevant pedagogy—links to community cultural practices and rigorous academic learning—were found to be integral to the networked activities. The following discussion of the roles available to students, their positioning in relation to mathematics discourse and practice, and the resources on which they could draw points to rich possibilities for inclusive networked pedagogies. Challenges to normalized classroom practice, particularly that found in urban, under-resourced schools, follow. I conclude with possibilities for future research in culturally relevant networked pedagogies.

Roles and positioning While the instructors' approaches to teaching reflected in the data were fairly traditional in terms of directing the discussion of the traffic flow, graphs, and strategies or predictions, the networked system and activity offered students a different kind of role than individual, passive responders. Unlike systems such as computer-aided design software (Stake 1991) or Geometer's Sketchpad (Jackiw and Bennet 1995) that involve more solitary efforts, each student contributed to the construction of dynamic representations. Those representations were created and acted on through the collective efforts of students. Also, Kaput (1998) argues that static representations such as textbooks' representations and notations are traditionally used in many math classrooms in ways that set up a one-way relationship between mathematics and experience, denying students any control of either. He notes that in acting on and with dynamic representations, "These kinds of affordances turn a fundamental representational relationship between mathematics and experience from one-way to bi-directions" (p. 258, 259). In this kind of relationship, students can take on roles as active agents whose generative activity positions them as productive, creative contributors to mathematics discourse and practice. They become knowledge producers rather than consumers.

Cultural and other resources Thurston (1994) argues that our facility with language is important not just for mathematical communication, but also as a tool for thinking mathematically. Work by Cook et al. (2008), Inpen et al. (1995), and Goldman-Segall (1998) show the importance of gesture in supporting mathematics and other learning, with non-verbal movements, particularly of hands and arms, serving as ways to communicate understandings that cannot yet be articulated verbally. Such facility is clearly in evidence in the Gridlock PartSims, with students articulating their notions of traffic flow and interpreting graphs in everyday but powerful language as well as gesture. The fluid use of informal language and gesture to negotiate strategies and to link and translate across multiple representations allowed the groups to think together mathematically, and helped them make sense of the system. Further, the link to youths' cultural communities found in the main activities of coordination and co-construction, built on the sub-activities of language, gesture, and use of representations to communicate mathematically, is evidence of the potential to respond to Lee's (2003) call to "designers explicitly to draw on community-based norms for discourse ... as anchors for instruction" (p. 47). This expansion of norms for classroom discourse may support the construction of learning environments where school-based discourses and those of youths' "social worlds [are] blended, making the boundaries between these worlds porous and movement between these worlds fluid. It is in this new discourse space that new forms of participation [are] legitimized, thereby extending the repertoire of resources accessible to all students" (Barton 2007, p. 24). Of course, more empirical evidence from community studies in Rochester will be needed to make the claim that networked activity is directly linked to particular groups' practices. The point here is that the data indicate that there are important possibilities worth pursuing.

Challenges to conventional classroom practice I aligned this work with critiques of often narrow and simplistic school-based approaches to teaching STEM disciplines. Work on the knowledge-producing practices of STEM practitioners clearly presents a challenge to how mathematics practices are often constructed in schools. Across such diverse fields as physics (Ochs et al. 1994), engineering (Larsson et al. 2002, medicine (Latour and Woolgar 1979), software development (e.g., Faraj and Sproull 2000), industrial product design and manufacturing (Adler 1995), and the physical sciences (e.g., energy physics, geophysics, space science; Chompalov and Shrum 1999), informal and formal language, diversity in roles, use of multiple representations of phenomena, and action on representations in interaction with team members characterizes their work. Such practices are much broader and more varied than those often focused on in school mathematics classrooms, involving teams of people that draw on varied expertise and collective efforts to accomplish complex tasks. In pursuing cultural relevance, rigorous learning should involve more than school-based notions of disciplinary practice and content, as those are not sufficiently rich to foster students' success in powerful STEM discourse and practice. This study demonstrates that rather than being grounded in school-based definitions of mathematical discourse and practice (individual, procedural, dominated by paper and pencil tasks), network-mediated activities' opportunities for students' dynamic engagement in conceptual, collective activity are more akin to practices of professional communities.

The potential in network-mediated pedagogy for more expansive, culturally relevant practice also lies in contrast to mathematics teaching found often in schools with demographic and achievement profiles that are similar to the one in which this study was conducted. Stodolsky and Grossman's (2000) study of teachers responding to rapidly increasing demographic diversity of their students report that, "math teachers generally consider their subject to be sequential, requiring topic coverage in a set order; math is also perceived as relatively static with knowledge viewed as cut and dry and subject to little change" (p. x). Further, Ladson-Billings (1997), in responding to the notion that culturally relevant teaching is "just good teaching" (p. 697), refers to a pedagogy of poverty (citing Haberman 1991) often found in schools serving students of color and those living in poverty. That pedagogy focuses on "giving information, asking questions, giving directions, making assignments, monitoring seatwork, reviewing assignments, giving tests, reviewing tests, assigning homework, reviewing homework, settling disputes, punishing noncompliance, marking papers, and giving grades" (1991, p. 290) ... "taken together and performed to the systematic exclusion of other acts, they have become the pedagogical coin of the realm in urban schools" (p. 291). In contrast, this study's and prior analyses show that specific elements of network mediated activity are important to fostering students' engagement with what Kaput (1998) terms the "dynamic interactive medium" (p. 262)–the upfront display of real-time emerging graphical representations and the complex dynamic system that students controlled and created. This medium invited them to act on and with mathematical representations of traffic flow. Such action is critical in rigorous mathematical learning and participation in a powerful practice and discourse, rather than more rote, procedural learning often found in settings like the school in which this study's classes are situated.

Future directions This is not to ignore that there are constraints involved; students' mixed responses to whether their mathematics learning was easier or harder in network-mediated activity are clear evidence of the challenges some perceived. Two important findings from the interview data point to challenges in network-mediated activities, and they are critically important given that they are students' perspectives on their own learning. Students had varying responses to how the networked activities supported or hindered their learning, especially the sometimes chaotic nature of the exchanges among students, and students opting out when the class couldn't cooperate. For some, the experience was distracting: "Not saying the calculators distract me ... you trying to stay in the game instead of paying attention—letting the person teach you how to do it." When asked whether and how the networked activities helped them think about mathematics, some responded in the negative. Most did speak about the activities helping them think about the phenomena that grounded mathematical activity, specifically traffic for the Gridlock PartSim. Thus, they cited that they did think differently about traffic (noticing patterns they hadn't thought about before).

While these are important connections to real world phenomena, this begs the question, if students don't recognize the activities as explicitly related to mathematics learning, are they learning mathematics? On the one hand, a challenge is to be more explicit with students (and their teachers) about the mathematics content and mathematical thinking we observe them engaging with in the networked activities. On the other hand, their responses make very obvious the limitations of school mathematics in relation to STEM community practices. Students in these classes said that school math (versus everyday math) was calculations, proofs, numbers, equations; geometry, algebra, calculus; observation, associations, analyzing; and working alone, as well as a requirement that was useless, boring, confusing, and scary (though a few students expressed their appreciation of the subject). The dramatic difference between students' views and STEM practices is another challenge to address, both in networked activity and in 'regular' classroom teaching and curriculum, as has been advocated by the National Council of Teachers of Mathematics (2000) and the American Association for the Advancement of Science (1989).

This is preliminary work that needs to be elaborated and deepened to explore the kinds of mathematical thinking and understanding students are developing, so the work presented here that focuses more on activities can be complemented with work on reasoning and performance or achievement. Taking up these challenges, the examination of practices that travel across contexts, though they are transformed in response to differing features of contexts, is important in inclusive pedagogy because it fosters consideration of resources students develop in their home and peer communities. Those resources, such as language and interaction patterns, are central to their cultural identities, cultural competence in their communities of origin, and to their academic success. Analyzing the ways in which use of networked technologies can draw intentionally on cultural practices as learning resources is critical to those technologies' influence in today's classrooms. Of course, all classrooms involve cultural practices and things such as the flexible use of language, gesture and representations; collective construction of meaning occurs in classroom activity that is not network-mediated. However, looking at how the space of activity and participation is opened up uniquely in networked activity will increase the likelihood that cultural practices may be drawn upon in classrooms implementing the networked classroom technologies under study here and becoming widely available to schools.

Finally, efforts to increase participation in STEM learning are often directed at all learners, rather than centering on particular cultural groups, producing supposedly generalized strategies to increase participation and success. However, scholars examining the use of communities' cultural practices argue that, given the fact that communities develop repertoires of practices through historically derived communication, interaction, and other patterned activity (Gay 2000; González and Moll 2002; Gutierrez and Rogoff 2003; Lee 2001), generalization is impossible. An important move to make, I believe, is to follow Brenner's (2005) lead and not claim that these networks are good for "all students," but to show the ways that they support learning of specific groups. As Lee (2003) notes:

> The dominant cognitive research literature on educational design rarely specifically addresses the significance of whether players are African American, Puerto Rican, Mexican American, or Laotian, whether those players are speakers of English or persons for whom English is a second language or who speak a "nonstandard" variety of English. However, I argue that who these people are, how they culturally identify themselves, is not an irrelevant consideration in our design decisions. (p. 58)

Focusing efforts on the repertoires of practice of particular communities of interest has a better chance of improving mathematics teaching and learning, and to realizing the potential of networked classroom technologies. Recipes for design and use are not the goal here, and could be dangerous in the same ways that prescriptions for pedagogy based on cultural learning styles often came to be (e.g., Gutierrez and Rogoff 2003). The goal, instead, is to provide examples of ways to draw on cultural practices of marginalized groups through pedagogies that treat such things as language varieties, communicative modes, and interaction patterns as critical resources in fostering students' and groups' increased agency and future success.

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