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The Study of Mathematics and Numeracy as Public and Spatial Exercise

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Abstract: This study of networked classroom activity proposes that a resource-rich point of view is powerful in increasing the engagement of marginalized students in mathematics classes. This work brings attention to the values, beliefs, and power relations that pervade numeracy practices and adds attention to mathematical dimensions of social spaces. Findings show that the multiple modes available to communicate mathematically, to contribute, and the inquiry-oriented discussions invited students to draw on a variety of expressive modes to engage with complex mathematical concepts. Spatial analysis illuminates the relations among reproduction and production of knowledge, as well as the social space that characterizes the networked classroom activity. They also reveal the affordance of emergent, transformed social spaces for youth's use of a variety of social and cultural displays in producing mathematical knowledge. Students extended notions about social space by adding attention to affective features of classroom and school activities.

Keywords: Mathematics, social, status, student, numeracy.

1. Introduction

This study contributes to the literature that illuminates the successful participation of marginalized students in secondary mathematics classes. With this perspective, rather than focusing on the barriers such youth may face classroom exam interactions that foster their engagement in powerful mathematics learning. This can be done as an exploration of mathematics in terms of social practice that is linked to critical geographies focus on social space.

Throughout the paper varied terms are used to refer to youth and communities that have and continue to be subject to societal inequities as a way to trouble the use of language such as urban and at-risk languages that cover deficit assumptions about people and places. Similar stances are evident in related literature reviewed here. For example, Moschkovich [1] juxtaposed three theoretical postures to examine how each would guide the analysis of two Latina students' construction of understanding and communication about properties of rectangles and about slope. In that article, she illuminated what was learnt and what was missed in adopting the theories, principles, arguing that a sociocultural lens provides ways to understand linguistic and interactional resources the participants were drawing upon that were missed in vocabulary acquisition and social construction of meaning perspectives. This analysis is approached similarly in that it is an exercise in examining what we see when we take a social spatial theoretical position and use its central tenets to analyse classroom activity and interaction.

Here in this paper, findings are presented from a study of mathematical practices of high school youth in the northeast US, building on work in New Literacy Studies or NLS [2, 3]. In this framework, literacy is seen as "literacies" or literacy practices, which are undertaken for specific purposes and bound within social, historical, and cultural contexts [4]. In addition to literacy, this framework changes the ways that we think about other disciplines, including mathematics and science. For many, mathematical and scientific practices can no longer be separated from the larger contexts in which they occur. For example, borrowing from and expanding upon the work of NLS, Calabrese Barton [5] and Ortiz [6] focus on the science practices of urban youth from critical feminist science perspectives to centre youths' experiences and perspectives and to uncover science-related resources they develop in everyday life.

Similarly, Baker [7] and Baker and Street's [8] pioneering work has enriched our understanding of what counts as mathematics. Their differentiation between numeracy and mathematics highlights the embedded nature of mathematics in everyday life:

Numeracy, then, is taken as the broader term, including both everyday practices and educational aspects, both of which may have a mathematical dimension. Mathematics, then, we take to be a more specialised and abstract set of practices, usually the domain of professional practitioners of both mathematicians in universities and mathematics educators in both Higher Education and schooling. ([9], p. x)

As such, mathematical activity not only involves content, but also involves values and beliefs, context, and social and institutional relations ([9], p. 17). These dimensions shape what kind of numeracy gets done in particular situations. Their work provides important impetus for our explorations of numeracy as social practice in relation to the creation of classroom social spaces that have mathematical and cultural dimensions as central features.

This present paper work contributes to the social turn in mathematics education research [7, 9]. Exploring this social turn is informative for deepening the understanding of numeracy that is inevitably constructed as students and teachers make meaning in classrooms. Such work has given rise to views that stress the dynamic, emergent nature of disciplinary content, discourse, and practices that ensue from individuals' and groups' action and interaction (cf., [1, 10]). The focus on social construction in mathematics has included recognition that examining both every day and schooled mathematics practices is critical to understand mathematics learning and teaching and to inform both pedagogy and policy (cf., [7, 11–14]). Attention to both every day and school activity is important to mathematics education research because it broadens the contexts in which mathematics learning is considered to occur. The contribution of this present analysis to this work is bringing attention to the values, beliefs, and power relations that infuse numeracy practices and adding attention to mathematical dimensions of social spaces. Further, it is shown that numeracy practices shape and are shaped by the social space of the classroom.

1.1. Spaces as Social Constructions

At first rouge, space may seem static (as in classroom space with its requisite desks, tables, chairs, and so forth, staying largely unchanged over decades, particularly in under resourced schools serving nondominant students). However, following theorists including Soja [15], Harvey [16], and de Certeau [17], it is proposed that contrary to this rigidity, social space is actually dynamic and volatile. For example, cities are made up of spaces that are constructed and differentiated based on physical, social, and historical dimensions:

[they] are marked by socially constructed boundaries that divide areas geographically along racial, ethnic, class, and religious lines. Chicago, New York, Boston, and Toronto, to name a few, all have designations such as “South Side” or “Upper East Side” that mark those spaces and their inhabitants as different from those in others parts of the city. ([18], p. 1)

Through this kind of socio spatial differentiation, people are located within particular spaces and inscribed with particular social orderings of who they are, what they can do, and how they can be. On another scale, youth experience school spaces as different from neighbourhood spaces due to the physical arrangements of people and things, the kinds of actions and talk that are treated as legitimate, and the norms for social relations among children and adults. Finally, in school and classroom spaces, youth are positioned in relation to both the teacher and the discipline of mathematics as, among other things, producers or, more often, receivers of knowledge. This attention to social positioning is important in considering the numeracy learning of traditionally underserved youth, as access to opportunities to engage in rigorous learning depends in important ways on their and their teachers’ views of the goals and aims of school as a space learning for particular students (e.g., aligned with their goals and practices or alien to them).

Treating space as a social construction leads us to consider the practices through which spaces are created, how people are positioned in various spaces, and the implications for agency and learning. In this paper, we examine numeracy as a social practice that creates social space, considering in particular its productive nature, or how it is implicated in the construction of space that has social, historical, cultural, and mathematical dimensions, all of which are infused with relations of power [9]. Appropriate questions to consider when looking at practices with an eye toward spatial analysis include the following. How are numeracy and social practices changing classroom social space? Why and into what is this space changing as a result of youths’ engagement in numeracy practices?

This approach is found in promising in its attention to agency and to the variety of ways in which people engage in numeracy practices, as well as the connections among school, home, and community practices that have mathematical activity as central features (cf., [9, 11, 19, 20]). A social practice view provides a unique perspective on pedagogical issues, given the focus on practices and activities that make up everyday interactions (both in and out of classrooms). Taking on a spatial theory lens extends such work (i.e., funds of knowledge, [12]; culturally relevant pedagogy, [21]; and cultural demonstrating, [22]) by highlighting the intersections of social, cultural, historical, and physical dimensions of numeracy learning. In this study, we explore work with a networked classroom technology (described below) that requires collaboration among students, fosters generative learning, and transforms both the mathematical content and student-teacher roles [18]. Examination of such practices has the potential to widen the types of practices invited into classroom mathematics activity. As shown in earlier research

[23], these activities can be crucial in building on practices of students that are often undervalued or excluded from mathematics teaching and learning in school.

2. The Context

The numeracy practices in an urban high school's mathematics classes are examined using a networked technology designed to leverage the power of groups in rigorous, generative learning. The networked technology is Hubnet and Participatory Simulations (PartSims; [24], a member of a class of technologies that focus on shared construction of mathematics learning (e.g., SimCalc MathWorlds [25]; Texas Instruments Navigator system). The system involves graphing calculators that are connected to hubs that have a wireless connection to a computer which functions as a central server. In PartSims, 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 behaviour of the system and its relation to individual participant actions and strategies can then become the object of collective discussion and analysis. ([26], p. 2)

Traffic flow in a traffic grid, spread of disease, and the motion of elevators are examples of phenomena explored in PartSims, while the content involved includes but is not limited to linear, trigonometric, and exponential functions; regression; equivalence; rates of change; graph analysis; and modelling. PartSims provide opportunities for youth to be central actors and producers of mathematical discourse and practice. They are important to our examination of social practices and spaces that emerge from youths' activities and interactions, highlighting that youth are active agents in creating practices and social spaces. This view of students is in stark contrast to the conventional classrooms that position them as recipients of norms, practices, and discourses, at the mercy of adult and institutional exercises of power. It is also a productive arena for examining the creation of social space because youth have ample opportunity to interact and to exercise agency as to what mathematics is explored as well as how the exploration proceeds, transforming classroom practices to those that invite participation by more students and less control by teachers.

The particular PartSim that is the focus of this paper is Gridlock, which involves each student individually controlling a traffic light at a specific intersection in a traffic grid and working collectively to optimize traffic flow (more extensive description of the activity is included below). The numeracy involved includes the mathematics of variation and change, working with positive and negative numbers, graph analysis, and connections to traffic flow in the city in which the classroom is situated. Gridlock is appropriate for conducting a multidimensional exploration of the construction of social spaces. For example, students work with multiple, linked representations (i.e., graphs of number of stopped cars, average wait time, and average speed), as well as tasks that require whole-class coordination and collaboration to be successful. Gridlock is also rich with mathematical discourse and practice, including representations, visualization, language, and gesture serving to mediate learning and interaction. In addition, Gridlock involves rich mathematical content and reasoning in ways that are similar to SimCalc [25, 27]: "underlying ideas of calculus (variable rates of changing quantities, the accumulation of those quantities, connections between rates and accumulations, and approximations) are taught … and are rooted … in children's everyday experiences" ([28], p. 289).

Important for this study are the following: connections among (1) discourse and practice and (2) mathematical content and reasoning are central to the recently adopted Common Core Curriculum Standards for mathematics [29]:

The Standards for Mathematical Content are a balanced combination of procedure and understanding. Expectations that begin with the word "understand" are often especially good opportunities to connect the practices to the content. Students who lack understanding of a topic may rely on procedures too heavily. Without a flexible base from which to work, they may be less likely to consider analogous problems, represent problems coherently, justify conclusions, apply the mathematics to practical situations, use technology mindfully to work with the mathematics, explain the mathematics accurately to other students, step back for an overview, or deviate from a known procedure to find a shortcut. In short, a lack of understanding effectively prevents a student from engaging in the mathematical practices.

The emphasis on understanding as a critical starting point for introducing students to more formalized content in mathematics is exactly what Gridlock and other PartSims are designed to do. As seen in the findings reported below, foundational understandings of concepts and mathematical representations were built across all the events and classrooms we studied, preparing students for rigorous mathematics learning.

Beyond mathematics classrooms, understanding the mathematics of change and variation is important for many topics in the curriculum beyond algebra and calculus. As discussed earlier, social sciences, economics, and history increasingly rely on dynamic models to understand complex phenomena. Interactive media that simultaneously present qualitative and quantitative representations are potentially useful in many fields for helping learners bridge between experience and abstraction ([28], p. 291).

Both the widely applicable mathematics involved and the grounding in personal experience production can alter classroom social spaces that are ripe with opportunities to exercise agency and learn powerful mathematics. As Soja [15] notes, "It is precisely this possibility of meaningful spatial [and content] transformation that gives to the production of space a significant practical and political dimension" (p. x), a dimension that we view as critically important in research involving underserved youth. The transformed social space and access to rigorous mathematics are particularly salient for urban schools serving students of color, where expectations of students and provision of resources are often low [21, 30, 31].

The paper is organized as follows: the theoretical framework is explained in terms of what we can gain by looking at numeracy practices as creating social spaces, particularly in understanding youth engagement in numeracy events, or "occasions when numeracy activity is integral to the nature of the participants' interactions and their interpretive processes" ([9]; p. 20). Spatialized and spatializing practices [32] are proposed as useful tools in understanding and explaining sociocultural processes involved in youths' engagement in numeracy activity in their mathematics classes at school. We present findings from our study in high school mathematics classrooms in Rochester, NY, and conclude with a discussion of implications for research and pedagogy.

3. Theoretical Framework

In this study, work is done to particularize examinations of social space to numeracy activity in classroom contexts involving youth from nondominant groups. In this paper, it is drawn on particularly on de Certeau and Harvey [16, 17] in conceptualizing social space involving knowledge/discourse, technologies (e.g., symbol systems, calculators, and curricula), and practice (Foucault (1986) and Bhabha (1994) are also informative along these lines.). Across all these conceptualizations, space is a social sphere that is constructed through peoples' material and ideal activity.

Following Street, Baker, and colleagues [7, 9, 33], this study begins with the starting point of the social and cultural practices involved in numeracy events; where those practices are viewed as activities that create space that has social, political, historical, cultural, and mathematical dimensions. From this view, such activity shapes and is shaped by discipline-specific ways of speaking, interacting, acting, and using analytical and physical tools. Numeracy practices, then, emerge from interactions involving both numeracy—language, representations, symbolic and notational systems, forms of argumentation—and the contexts in which numeracy activity is taking place (e.g., classroom, grocery store, and engineering team). Integral to those contexts are the power relations that permeate them, given that participants are accorded differing status in relation to content and to each other in different contexts.

Additional attention is added to the creation of social space through practices that shape the kinds of activities and modes of participation treated as appropriate or legitimate in particular places involving particular people [15, 19, 34]. Such practices also shape the kinds of interactions, social relations, and knowledge that result. In addition, the ways in which everyday activity inserts dynamism, mutability, and challenge into dominant norms are made explicit. This complements Street et al.'s [9] work on the content, context, values and beliefs, and social and institutional relations involved in numeracy events and practices not only by looking at relations among, for example, school and home numeracies, but also by uncovering the ways that those spaces are both produced and potentially transformed. Street and colleagues' works are instrumental in making explicit that there are power relations and differential valuing of particular practices, that is, school numeracy over home or community numeracy practices. However, social spatial theory gives us a way to examine in some detail how those power relations and values come to be.

3.1. Spatialized and Spatializing Practices

Building on earlier work on spatialized and spatializing practices ([15, 32]), it is brought together theories of social practice and social space in that discourse/knowledge, practice, technologies, and space are treated as operating in a mutually constitutive relation with each other. Spatialized practices are those that are often viewed as "natural" or appropriate, based on historical, political, and social notions; these practices largely reproduce social space (e.g., teachers' and students' compliance with desks arranged in rows and the resulting reproduction of traditional teacher/student relations). Engagement in them is largely unreflective. Certain paths and actions are presupposed for particular places and people (e.g., teachers move mostly at the front of the classroom and determine who speaks and about what; students remain seated and respond when asked to speak); their practices are spatialized [15].

Spatializing practices, on the other hand, are those involved in appropriation and production of space. de Certeau [17] gives an example of such modification of the existing practices and built environments, treating an act of walking in a city as

… a process of appropriation of the topographical system on the part of the pedestrian (just as the speaker appropriates and takes on language); it is a spatial acting-out of the place (just as the speech act is an acoustic acting-out of language); and it implies relations among differentiated positions. (p. 97-98)

4. Methods

How are numeracy practices changing classroom social space? Why and into what is this space changing as a result of youths' engagement in numeracy practices? Given our theoretical framework, ethnographic style methods are appropriate. LeCompte and Schensul [35] note that ethnography uses everyday practices as a lens for interpretation as well as exploring the socio political and historical nature of phenomena. Rather than testing hypotheses, it is sought in this paper to understand numeracy practices involving urban youth and the meanings numeracy has for them. To do so, we need not only to observe numeracy practices, but also "to start talking to people, listening to them and linking their immediate experience out to other things that they do as well" ([9]; p. 19).

5. Networked Classrooms

The chosen classrooms were important for this study because youth had more control of the content and processes of learning and activity than it is seen in their "regular" classroom sessions. Also, the nature of the mathematics involved engaged students (and teachers) in the production of rich mathematical discourse and numeracy practice, giving us insights into the ways that youth can play a part in spatializing practices that transform mathematics classrooms as social spaces.

5.1. Data Sources and Analytic Techniques

Videotapes of two sessions of Gridlock PartSim classroom activity and interviews with 93 students comprise the data corpus. We chose to focus on two sessions because of (1) the exploratory nature of our study, (2) the aim of ethnography to provide thick descriptions [37], and (3) the high quality of the video and audio. There were twenty-eight students in one class and ten in the other. The interviews included but were not limited to specific questions about Gridlock; other questions addressed other PartSims and more general impressions and advice students would share.

Interview data were analyzed by university researchers as supplementary to the above analyses and helped heighten our understanding of participants' perspectives of numeracy practices. Three researchers analyzed the same interview transcript independently, discussed our coding, analyzed another transcript independently, and reached consensus through further discussion.

6. Findings

This paper findings are organized in two sections. The first section presents the analysis of the numeracy practices found in the networked classroom activity, including the mathematics and the control of symbols, signs, and knowledge. The second section focuses on the analyses of spatialized and spatializing practices involved in the creation of social spaces, along with students' experiences and perceptions of numeracy practices as personal, political, and value-laden. The latter helped illuminate issues of power and ideology in numeracy practices associated with Gridlock.

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