PATTERNS OF PARTICIPATION IN NETWORKED CLASSROOMS

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We study the combination of visualization software in the form of SimCalc MathWorlds with wireless Networks on student participation in Algebra classrooms. Such technologies allow students to create mathematical objects or motions on hand-held devices that can be aggregated within parallel software on a teacher's desktop computer then publicly displayed and analyzed. We use work from Linguistic Anthropology to analyze the rich participation frameworks that are evident in such situations, focusing on the shifting roles of speech and physical actions (e.g., gesture and deixis), as students make mathematical meaning at a social level.

FOCUS OF STUDY: VISUALIZATION AND PARTICIPATION

This paper focuses on the present findings of our National Science Foundation funded project investigating the impact on students' participation and engagement in high school algebra classrooms that use a combination of rich visualization software and wireless networks. We use theoretical perspectives from Linguistic Anthropology (Duranti, 1997) to explain new forms of participation frameworks that are evident in our classrooms.

Recent work (Hegedus & Kaput, 2004) developed a series of activity structures with such a combination of technologies to create learning environments that utilized the natural, physical and social set-up of the classroom. Students can create mathematical objects on hand-held devices (such as graphing calculators) and send their work to a teacher computer, which is projected on her whiteboard. Due to advances in wireless communication and interactivity between desktop PCs and hand-held devices, the flow of data around a classroom can be very fast allowing large iterations of activities to be executed during one class. But it is not just an advance in connectivity but in the development and application of curriculum that maximizes such an innovation. Our prior work created activities that allowed students to make functions in SimCalc MathWorlds on the TI-83/84+ graphing calculator that could then be aggregated by a teacher into MathWorlds running in parallel on a PC, using TI's Navigator wireless network. Such an action by the teacher, though, was not done in an arbitrary fashion (i.e., collect all work) but in a mathematically meaningful way. For example, each student is in a numbered group (say 1 through 5), and has to create a position function that can animate an actor (in the **World**) at a constant speed equal to their group number for 10 seconds. So group 2 can use MathWorlds to create a function algebraically (see figure 1), i.e., $y=2x$ on the domain [0,10], or graphically by building a linear function, and dragging a hot spot attached to a line segment with left endpoint at the origin out to (10, 20). When all functions are submitted by the students, or aggregated by the teacher, then a family of functions, $y=mx$ (m=1 to 5)

2006. In Novotná, J., Moraová, H., Krátká, M. & Stehlíková, N. (Eds.). *Proceedings 30th Conference of the International Group for the Psychology of Mathematics Education*, Vol. 3, pp. 257-264. Prague: PME.

will be displayed. This simple activity can be extended into an activity structure that uses group count-off indices in general to distribute mathematical variations across a whole class of students. This latest innovation expects more active participation by students since every student is required to contribute, but not only that, engagement is potentially affected even if a student does not contribute; the aggregate (displayed by the teacher computer) exposes this and, potentially, errors that some students might have made upon analysis of the collection. This is a main working hypothesis and our study has investigated the reality of such a claim.

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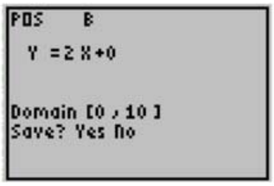
<td>

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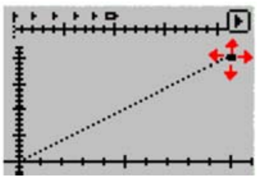
<td>
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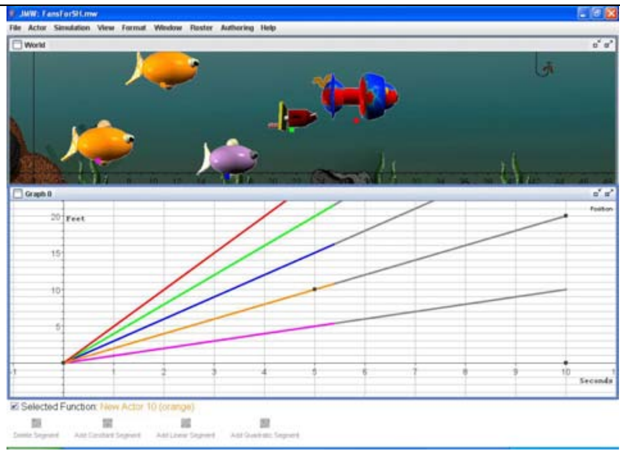
<td></td>
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<td colspan="2">*Figure 1a*: MathWorlds for the TI 83+/84+</td>
<td>*Figure 1b*: Aggregation in MathWorlds for the PC</td>
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Our work has focused on using Linguistic Anthropology to understand the framework of participation in our classrooms and how it changes across activity structures and use of networked classrooms. We present a case study of our work, which analyses one intense classroom episode and the role of such technology. In building on Goffman's work (1981), we are particularly interested in the intersection of both (what we call) the *discourse* and *physical action* spaces, i.e., the role of language, natural, technical and metaphorical, as well as gesture, deixis (e.g., pointing), and posture. We regard these two spaces as intimately linked and so our analysis investigates each of these features to make sense of the impact of the technology on participation and engagement.

METHODOLOGY

Our main study has conducted several common teaching experiments in grade 9 Algebra classrooms across three medium-to-low achieving districts with teachers of varying experience. The teaching experiment consisted of the implementation of a 3-week unit that replaced a chapter and half of material in the text used by the participating schools (Bellman, Bragg, Chapin, et al., 1998). Our participant teachers collaborated with us prior to the interventions to agree on a set of curriculum materials that we had produced with the MathWorlds software that focused on linear functions (y=mx+b form), slope as rate and variation. These materials had been developed over several years and field-tested in a variety of high school and college freshmen classes.

Each class was recorded with two digital cameras, one focused on the teacher and the whiteboard space where MathWorlds was projected and the other positioned at the front of the class focused on the students using a wide-angled lens to pan out and observe whole class dynamics as well as small group interactions. Both cameras were used as roaming cameras when the class was involved in small group work. The camera placement and focus is largely guided by our research questions and inquiry on the types of participation and engagement exhibited in class both from a linguistic and physical perspective. Our rich inter-related datasets allow us to examine the impact of the technologies from a teaching and learning perspective. This paper focuses on analyses of some of our classroom video data.

APPLICATION OF LINGUISTIC ANTHROPOLOGY

We will first outline briefly the theoretical perspectives of Linguistic Anthropology and then use them to unpack the impact of the technology on participation, engagement and learning using vignettes from our classroom intervention described above. Linguistic anthropology combines the study of language and culture as one of the main sub-fields of anthropology. Linguistic anthropology is "*not just interested in language use but language as a set of symbolic resources that enter the constitution of social fabric and individual representations of the world*" (Duranti, 1997, p.2). Researchers in the field see the subjects of their work, speakers, as **social actors** that are members of complex, interacting communities. Our analysis has profited from this theoretical perspective as to study the interactions and learning cycles within the SimCalc Networked classroom but we cannot only focus on the use of language but the interactions and physical expressions that occur between students based upon the publication and representation of their work in a social workspace. The computer software, projected onto a whiteboard display, becomes an "active participant" as much as any human in the classroom, as a harvester, presenter and facilitator of students' mathematical work.

Analysis 1. Production Formats

A key contributor to the field of linguistic anthropology who primarily focused on participation structure is Goffman. We focus on one aspect of his work to analyze the new forms of participation evident in our connected classrooms. Goffman (1981) argues that a person can identify themselves in three ways in a discussion, (i.e., the pronoun "I" can refer to three distinct roles) namely, **animator** (person who gives voice to a message that is being conveyed), **author**, one who is responsible for the sentiments or words being expressed, and **principal**, person whose beliefs are being expressed. One person could have all three roles, but they can often be separate, e.g., a press release from the Whitehouse where the President (as Principal) might have a speech written for him (an Author) that is delivered by a spokesperson (an Animator). These three roles constituted what he called a **production format** of an utterance. In addition to roles of speakers, he determined two terms for "hearers"—**ratified participants** (those entitled and expected to be part of the communicative event) and **non-ratified participants**. This leads us to understanding not only what speakers know and want but also how speakers design their speech in the on-going evaluation of the recipient(s). This is described by the notion of **recipient design** (Duranti, 1997, p.299). The design of speakers and hearers is called the ***Production Format***. We are especially interested how within this format students choose to participate whether they are ratified or not and what role the technologies play in this process.

This structure has helped us unpack the communicative complexities that appear to evolve in a networked classroom. What is fundamentally new for us is the role of the *aggregation space* where students' contributions are displayed in a public display space. We analyze an episode from one of our classrooms. The students are working on an activity we call "arrows":

You and your partner will start at different positions. You are positioned G (your Group-number) away from 3 feet. The person with the odd count-off # will start to the right of 3 feet. The person with the even count of # will start to the left of 3 feet. You and your partner must meet at 3 feet at the same time. You and your partner will determine the amount of time you will travel for. The group CANNOT travel for the same amount of time, only you and your partner can. You must create a linear expression for your motions.

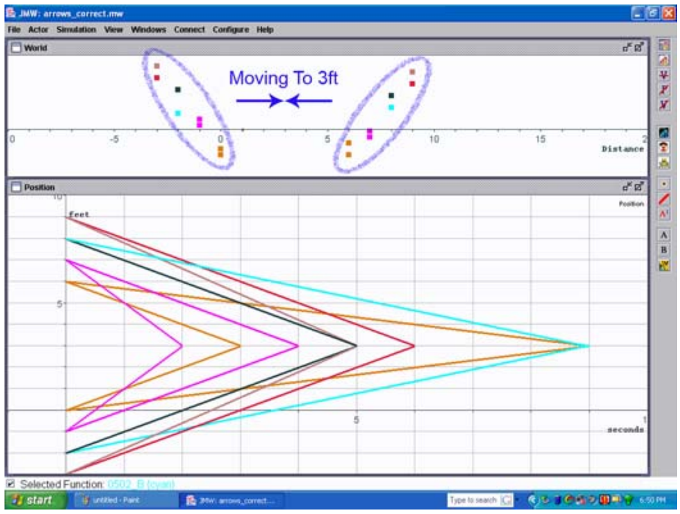

Figure 2: Arrows following a correct aggregation in MathWorlds

Figure 3: Classroom Setup

After their work has been collected into MathWorlds on the computer, they begin by looking at the view of the **World** where the animations of all their graphs occur (see Figure 2 for a correct set of contributions). The first error in the world is the starting position of two students, Jess and Alyssa. They should have started at -2 and 8 feet, respectively (see Cyan colored dots in figure above). Instead, they both began at zero. When the motion is run, two students do not stop at three. They also do not travel for the same amount of time. There is some debate among the students as to how to correct the motion of these actors. Robert (R) and Kirsten (K) believe that the actors have a domain that is incorrect (see figure 3). Kirsten then suggests that maybe one of the students didn't change their slope to be negative. Alyssa (off camera) recognizes that the actors with the incorrect motions are Jessica and herself but remains quiet thereafter. Alyssa thinks that she did not make the slope negative, but on running the motion again the(ir) two actors are moving in the correct direction.

Nick (N) then begins to argue, rather forcefully, that the domains are wrong. Kirsten believes that the domains do not matter, and that you can always end at three. Nick, frustrated, says that “you’ll keep going if the domain isn’t changed”. The teacher asks him to listen to Kirsten, who explains that if you go for a longer amount of time, you will not pass three, you will (just have to) go slower. Nick believes this will only work if you have the right slope. Luke goes to the board and draws the action of two actors as if they are being “traced.” He shows two actors traveling at the same rate, and the one that travels for a longer amount of time goes farther. Kirsten then goes to the board to show that an actor can travel the same distance in more time if they go slower. Nick is emphatic, and says then you would have to change the slope.

In this example the students who created the two wrong motions (the **Principle**) are not voicing their beliefs on the motions they created, yet two other students (and later more) are **Animators** of their constructions, during an analysis of the work of the whole class. One might think of the students with the wrong answer as a Principal, yet the representation of their work has been projected from their own local workspace on the calculator to a parallel, yet different, object in the aggregated environment. And the Computer (which projects their work) can be thought of as an **author** of their work through creating/or re-creating or publicizing their work. We have often seen that students do not always identify with “their” object after it has been collected and displayed publicly. So whilst the mathematical function has been originally authored by, and represents the beliefs of, the student, it might be perceived differently by the student when in public display. The public display of all students’ contributions has fuelled a group analysis of the overall system of motions. Note the teacher has not chosen to show the graphs of their motions yet and says very little (just asks Nick to listen to Kirsten). MathWorlds on the computer can be thought of as a ratified participant in this communicative event, and although, non-verbal, is a voice box for the class analysis. The computer software is also an **animator** for the set of beliefs for the whole class. This has only been made possible through the integral role of classroom connectivity. Having a representation of their linear expressions they submitted that can be executed (i.e., press play to run a simulation of all their motions at once), the teacher has created a further role for the computer environment that tests the conjectures of the students in debate. In fact neither Nick, nor Kristen are wrong but they are approaching it from different perspectives. If you fix the domain (which is up to the individual members of the group) then you would have to change the slope of the graphs; if you fix the slope then you would need to change the domain. We also believe that although Jessica and Alyssa are ratified participants in the classroom, their work has led to a more general focus for analysis by their classmates, and they choose not to participate. We believe the ratification process has occurred not just through some students choosing to begin a communicative event, but primarily with the computer (following aggregation and execution of the representation) to highlight (and potentially ratify) whose object is to be discussed. The computer does not point (physically) to two members of a class. In fact the discussion is around the two objects and other contributions and NOT at the contributors. This has been done non-verbally, which we believe is a new result of classroom connectivity that can help students reason and generalize mathematical variation as well as analyze strategies and misconceptions.

ANALYSIS 2. PARTICIPATION IN TIME AND SPACE

Studies of language use do not always refer to the material world or the built environment through which meaning is mediated and made sense of. A major exception is the study of *Deixis*, which examines the properties of linguistic expressions (indexes) that cannot be interpreted without reference to a nonlinguistic context of their use (Duranti, 1997). Deixis extends to the use of gestures, movements, posture and gaze as well as pointing acts used in collaboration with speech. We continue to analyze our classroom episode focusing on how participation is effected by the role of deixis and physical action, and how the public workspace has become a motivator for debate and analysis of other students' thinking (Radford Demers, Guzman & Cerulli, 2004). We begin with the teacher asking A to speak:

T Go ahead Amanda.

A  If you do it again *{A is standing at her desk pointing to board}* and you watch the bottom two people on that, the bottom two dots. *{She is referencing two actors that have a correct motion, but go much slower than the remainder of the class.}*

T Do you want me to go back to the beginning?

A Yeah.

N Yeah, but the longer you go…

R It doesn't matter.

The teacher (T) has ratified Amanda (A) as the primary speaker. Amanda has decided to focus on two other motions that are correct but explain how you can have a longer duration but, depending on where you start, the speed will be different. She needs to stand up and point (note the two fingers which actually move up in down in reality) to focus the attention of her analysis.

N  

{N is standing at front of class, facing class, next to teacher, T}

If you go longer then you gotta make your slope …

{holds two hands apart at waist level, brings them together} shorter

A It doesn't…

R No, no, 'cause if…

Nick (N) is frustrated and although what he says is correct he is not interpreting what Amanda (A) and others have said previously. He decides to not only stand up but also face the class. The motion of his arms through space describes what he is saying and he uses his posture to try to convince the class. He has interrupted Amanda, the primary speaker. He has sat on his desk perpendicular to the class up till this point, showing some resilience towards his classmates making sense of the aggregation.

N How're you gonna tell me? *{open arms, is still facing class, trying to lead the discussion}*

R … that part of your graph has the same slope, so that means they both have the same slope, you can't change it. *{R points both index fingers towards each other, then moves both hands together to cross fingers}*

{A gets out of seat, heads to front of class, then returns back to seat but remains standing}

A Plus, the bottom two have this…

T Robert, what you're saying is, they both have the same slope?

R 

Well you, those two, kept going they were partners. *{A is standing, but partially turned around to face R. R repeats action from hands described above}* They both had to have the same slope, and they have to keep that slope so they can meet at three.

A Well they didn't because…

R In their amount of time, then they put too much time, and they went past it. *{again repeats motion with hands, A sits down in seat and turns towards K}*

Robert (R) has begun to support Amanda in making sense of the situation. His use of gesture is an important indicator of this process. The motions of index fingers mimics the motions of the objects in the aggregated display that is under discussion. Amanda who was the primary speaker, looks behind and appreciates Robert's analysis (prompted first by his verbal description but followed by his gestural actions—see when she partially turns her head) and sits down. This interaction leads to resolving the two motions by changing the domains of the functions helping K understand.

REFLECTIONS

This paper has focused on the impact on classroom participation of networked classrooms, which allow the aggregation and public display of students' mathematical work on hand-held devices in a parallel software environment on a teacher's computer. We have used the theoretical perspective of linguistic anthropology to deconstruct the categories of speaker and hearer to analyze the complexity of participation that occurs when students generalize their own and their classmates' contributions to this public workspace, recognizing speech acts as an activity of socio-historical depth. In addition, emphasis on participation reframes speech not only in terms of oral but spatial expressions. This analysis can give us tools to understanding particular points in a classroom discussion when the dominant discourse is challenged in subtle but effective ways. The networked classroom appears to propitiate a rich set of communication events where analysis of mathematical variation is brought to a social plane where students can understand the core mathematical ideas in focus from a collaborative perspective. Our future work will look at significant shifts in content knowledge of particular students from our quantitative datasets with respect to the various forms of their participation highlighted in our present analysis with the aim of understanding whether such *participatory learning* can impact engagement, and realization and understanding of abstract mathematical concepts.

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