Collaborative Mathematics with Classroom Networks

PI: Tobin White
Submitted May 1, 2009

UC Davis Collaborator(s) and K-12 Collaborator(s)

Five participants collaborated in this research project. Tobin White, faculty member in the School of Education at UC Davis, organized the team, led the development of technology and lessons, and coordinated the research. Teresa Lazdowski of Monterey Trail High School and Debbie Jefferys of Dixon High School collaborated in the development of activities and implemented all lessons in their respective Algebra I classes. Kevin Lai and Matthew Wallace, graduate students in the school of education, assisted in all phases of technology and lesson development and the collection and analysis of classroom implementation data. In addition, though he was not funded through this grant, Matthew Wallace implemented all lessons in his own Algebra I class at Laguna Creek High School.

School Participation

The study involved the three teachers named above, representing two districts and three high schools, and focused on one class of Algebra I students taught by each of the three teachers.

Research Questions

This study explored the potential for supporting mathematics teaching and learning with a novel classroom technology. In particular, we drew on classroom networks of graphing calculators as resources for supporting collaborative student learning. The UCD researchers and the teachers worked together to develop innovative lessons and activities that integrated this new technology into effective instructional practice. As Ms. Lazdowski and Mrs. Jefferys implemented a series of these activities in their classrooms over the course of the school year, they and Dr. White worked together to investigate the following research questions:

1. In what ways does the classroom network provide a resource for teachers to design and implement collaborative learning activities?

2. How and to what extent do these network-supported collaborative activities support student learning?

3. What kinds of activity designs are most effective for engaging students in productive and mathematically meaningful collaboration?

Research Design

The investigative approach in this study reflects the emerging paradigm of design-based research (Brown, 1992; Cobb, et al., 2003; Design-Based Research Collective, 2003). Rather than cleanly separating the process of designing novel instructional environments and approaches from their implementation and evaluation, design research uses iterative cycles of design, implementation and revision to investigate conjectures about teaching and learning. Similarly, design research blurs the boundaries between technology developers, teachers, and researchers; in that spirit, this research was a collaboration between the classroom teachers and the university researcher at each stage and through successive cycles of development, instruction, and redesign.

The classroom networks used in this study equipped each student with a graphing calculator, and wirelessly linked those calculators to a laptop computer managed by the teacher (Figure 1). Dr. White's research team has developed software programs for the calculators and the computer that use this network to engage students in small-group and whole-class problem-solving activities and open-ended mathematical investigations. These activities are novel in that the network allows students to interact with one another both through face-to-face, spoken discourse, and through the links between their devices. Consequently, they present distinctive possibilities for new forms of collaboration and new forms of student participation (White, 2006).

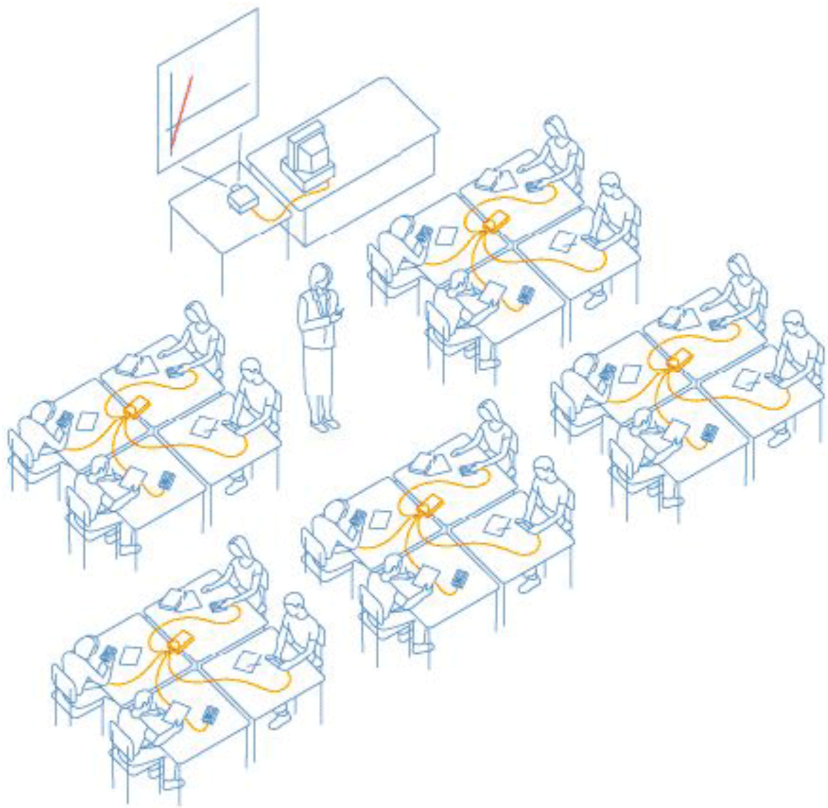

Figure 1: A classroom graphing calculator network (image courtesy of Texas Instruments)

Our activity designs draw on principles from Cohen (1986; 1994) for organizing student small groups into effective and equitable learning spaces. Key elements in this approach include the assignment of roles that specify distinctive ways for each member to contribute to the group, and tasks that necessitate the combined efforts and resources of students in each of those roles. The balancing of role contributions and task demands in the design and implementation of collaborative problem-solving activities represents a way to structure divisions of group labor so as to treat rather than reproduce problems of status. Similarly, our designs use the classroom network to distribute different mathematical resources to the calculator of each student in a group, and pose tasks that require students to collectively coordinate their respective resources. In particular, this study focused on graphical activities in which students' actions on their respective calculators move different coordinate point locations (Figure 2) displayed in a collective graph projected to the front of the room (Figure 3).

In the summer of 2007, Dr. White and two UCD graduate student researchers, Kevin Lai and Matthew Wallace, met with Ms. Lazdowski and Mrs. Jefferys over four full days to plan several instructional sequences to be implemented in their Algebra 1 classes over the course of the 2007-08 school year. Participants worked together to build the teachers' familiarity with the software designs for the calculator network, and to identify the units in their Algebra curricula that would be particularly well-suited to activities with the network. We then worked together to plan classroom implementation and data collection for these designs. In the project proposal, the implementation was planned for four relatively brief rounds lasting several consecutive days each. Over the course of our summer meetings, we decided that it would be better to focus on a smaller number of implementation rounds spanning longer cycles of lessons. In particular, we agreed that given the particular utility of one of our network designs for supporting students' exploration of linear functions and their graphs, and the centrality of linear functions to the Algebra I curriculum, we should focus on building a longer unit that allowed us to address that topic in greater depth over a period of approximately four weeks in the fall. Then, guided by lessons learned from this linear unit, we planned and implemented a shorter second unit on quadratic functions and their graphs in the late spring.

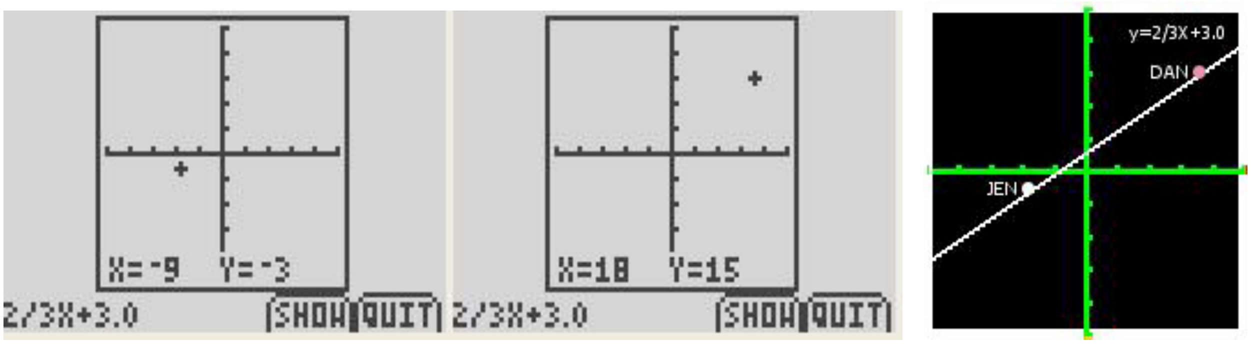

Figure 2: Two individual student calculator screens, each displaying a coordinate point, and a collective graph on the teacher's computer of the line formed by those students' respective points.

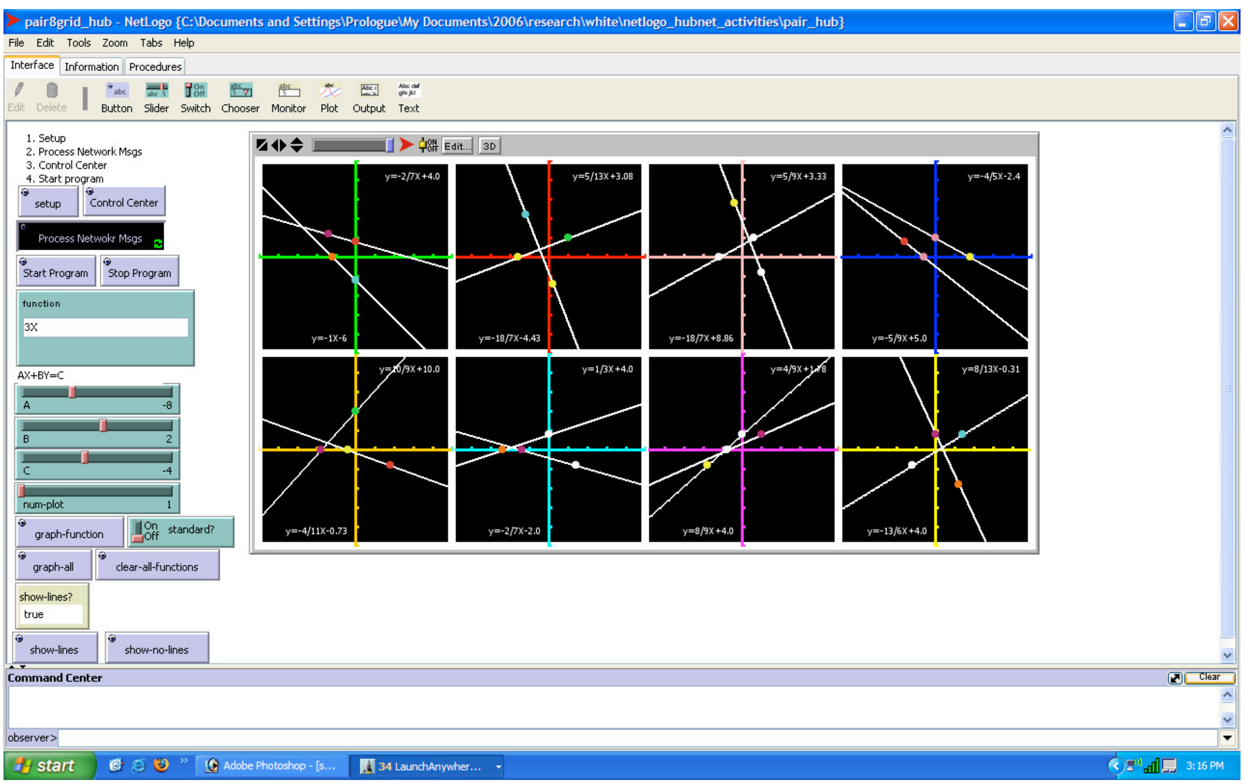

Figure 3: The teacher's computer screen, projected at the front of the room and displaying the points of all students and the graphs of all groups.

During the 2007-08 school year, Dr. White, Mr. Lai and Mr. Wallace met regularly with Ms. Lazdowski and Mrs. Jefferys to plan and conduct implementation of the structured lesson sequences, and then to review results, reflect on successes and failures, and make appropriate revisions to the subsequent lesson sequences. In some cases, we substituted a single Saturday workshop for two scheduled mid-week meetings, as we found the combined demands of lesson planning and reviewing video and assessment data were far better met by fewer longer rather than many shorter blocks of time.

Data Collection

During the linear and quadratic units, Dr. White, Mr. Wallace and/or Mr. Lai were present to observe and videotape the class session. Our data collection included stationary cameras and tabletop microphones trained on two to three (depending on the number of students in each class providing parental consent) selected student small groups, and another camera that focused on combination of teacher and server display at the front of the room. Where possible, the group cameras focused on the same student groups for the duration of each lesson sequence. To date, we have collected approximately 100 hours of video data from these sessions. For each of the linear and quadratic units, the teachers administered pre- and post-assessments designed in collaboration with the UCD researchers and targeted to key relevant concepts. In addition, for all collaborative problem-solving tasks, we generated computer log files documenting students' activity n their calculators as they worked to complete collaborative tasks.

Data Analysis and Results

Videotape of the teachers as they taught with support of the classroom network provided a critical resource for each to reflect on her own strategies for orchestrating collaborative activities and discussions and guiding students' engagement with the mathematical objects on their respective devices and in the whole-class display. The UCD researchers are also analyzing these videos with regard to the particular ways the network supports each teacher's efforts to conduct these activities. Similarly, the UCD research team has analyzed the videotape of student groups to investigate students' developing expertise in solving problems with the network tools, and to examine the extent of student participation and the nature of collaborative interactions during group activities. These latter analyses, in particular, serve as a resource for comparing among different activity designs to see which approaches may be most effective in supporting student collaboration. Finally, we have scored and analyzed all pre- and post-assessments, and developed metrics for comparing and evaluating groups' problem solving processes, and individual students' respective contributions to those processes, using data from the log files. In combination with the analysis of small group interactions in collaborative tasks, these analyses are allowing us to build accounts of relationships between group-level collaborative processes and individual student learning. Below, we briefly describe emerging results from these analyses in relation to each of the three research questions.

1.In what ways does the classroom network provide a resource for teachers to design and implement collaborative learning activities?

This question provided focus throughout our ongoing workshop and meeting sessions between UCD research team and classroom teachers, from initial planning and design conversations to debrief and review following implementation cycles. In the middle of the linear unit, we gathered for a Saturday workshop to review sample video from sessions in each teacher's class, and to discuss challenges and effective strategies for teaching with the networked activities. A critical discovery from this session related to the ways the teachers were capitalizing on the network as resources for interacting with groups and organizing classroom discussion during collaborative activities. We discussed challenges each teacher encountered when trying to spend too much time at the tables of individual groups and thus losing track of activity in the rest of the classroom. And we looked at instances when one teacher had begun to use the projected computer display to mediate these interactions by staying at the front of the room and engaging different groups about their respective problem-solving efforts by focusing on their respective graphs in that shared display. Not only did this allow teachers to more effectively manage interactions with multiple groups during quickly-progressing problem-solving tasks, but it also appeared to draw groups into productive comparisons of their respective strategies.

2. How and to what extent do these network-supported collaborative activities support student learning?

In general, assessment results indicate that students had productive learning experiences as a result of working through the linear unit. By the simplest measure, the mean score of all students in the three classes on our pretest was 12.5 out of 52 possible points, while the mean score on the posttest was 28.6 out of 52. Our data analysis efforts have involved comparing individual students' posttest gains with the ways they interacted with one another and with the technology, as indicated by video records and server logs. The analyses of log and especially video data are both very time-consuming, so our insights are still evolving, but we have identified some key patterns in the ways group members interacted over time, which of those patterns were more and less supportive of individual assessment performance for each group member. We are developing typologies of different forms of student mathematical thinking and interaction in this environment that we expect to serve as key models for both designing future lessons and activities, and for teaching with these designs and classroom network tools.

3. What kinds of activity designs are most effective for engaging students in productive and mathematically meaningful collaboration?

We learned a number of important lessons from each classroom implementation about the often-subtle differences between tasks and activity structures that opened up and closed down collaborative interactions in this environment. Each teacher experimented with different modifications of the lessons and activities, sometimes generating individual student worksheets or other handouts to parallel whole-class and small group activities, other times simply identifying a key concept or idea to emphasize through a brief lesson or example prior to the start of networked activities. Some of these modifications worked better than others, and because in most cases the teacher were not teaching the same lessons on exactly the same day, there were many opportunities to share those discoveries in meetings or by email and make adjustments in the next session accordingly.

Dissemination and Continuing Work

During the 2008-09 academic year, my doctoral students and I have conducted extensive analyses of data from each implementation along the lines described above. We made presentations of preliminary results from these analyses at the 2009 AERA meeting in San Diego, and at the research presession of the 2009 National Council of Teachers of Mathematics meeting in Washington, DC, and are in the process of developing three journal manuscripts highlighting various aspects of this ongoing work.

The efforts of the 2007-08 school year supported by this CRESS Collaborative Grant have also borne considerable fruit for ongoing collaboration and research. In 2008, I received an award from the National Science Foundation to fund related research for five years; this includes both continued participation from and collaboration with the same teachers as we develop and implement new activities and lessons, and my own engagement as researcher-teacher in an Algebra class for the 2009-10 and 2011-12 school years. With support from the NSF grant, the collaborations and research begun during this CRESS Grant project have continued throughout the 2008-09 academic year. In August, 2008, Ms. Lazdowski, Mrs. Jefferys and three graduate students joined me and a professional software developer for a four-day workshop at UC Davis to revise the network and software designs and lessons for one set of classroom activities, and to sketch the development plans for three new designs based on the same principles for collaborative student learning but covering different introductory Algebra topics. In 2008-09, we implemented revised versions of the linear graphing unit in both Ms. Lazdowski's and Mrs. Jefferys' classrooms, and piloted versions of each of the three new activity designs.

References

Brown, A. (1992). "Design Experiments: Theoretical and Methodological Challenges in Creating Complex Interventions in Classroom Settings." *Journal of the Learning Sciences, 2*, 141-178.

Cobb, P., Confrey, J., diSessa, A., Lehrer, R., and Schauble, L. (2003). Design Experiments in Educational Research. *Educational Researcher, 32*(1), 5-8.

Cohen, E. (1986). *Designing Groupwork: Strategies for the Heterogeneous Classroom*. New York: Teachers College Press.

Cohen, E. (1994). Restructuring the classroom: Conditions for productive small groups. *Review of Educational Research, 64*(1): 1-35.

Design-Based Research Collective (2003). Design-based research: An emerging paradigm for educational inquiry. *Educational Researcher, 32*(1): 5-8.

White, T. (2006). Code talk: Student discourse and participation with networked handhelds. *International Journal of Computer-Supported Collaborative Learning, 1*(3), 359-382.