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Changing the Mathematics Teaching and Learning Environment Through the Use of Networked Technology

Introduction

It's 7:40 Monday morning, and as students enter a seventh-grade mathematics class in a Honolulu middle school, they prepare for the lesson of the day. They carry book bags containing all the usual array of school supplies, but there is something different about their preparations. Instead of organizing pencils, books and papers for the day's lesson, these students open laptops and connect graphing calculators to hubs fastened to their desks. They 'log in,' and immediately an icon representing their calculator is projected on a screen at the front of the class, an indication to the teacher and the student that their calculator is connected to the classroom network.

Two miles away, in another seventh-grade mathematics class located in a public charter school, the scene is similar. Upon entering class, designated students come to the board and write their group's name beside a problem assigned for homework. They will work in small groups of four or five to share experiences from the given tasks. These discussions are used to create presentations that will serve as the means for learning the mathematics targeted in the day's lesson. Other students collect calculators and cables for their group members; all connect their calculators to the hubs and log in. In neither class has the teacher yet given any directions.

This paper details changes in the teaching and learning environments of two seventh-grade teachers involved in the professional development program, *Formative Assessment in a Networked Classroom*[1] (Project FANC), a research program at the Curriculum Research & Development Group (CRDG) at the University of Hawaiʻi, funded by the National Science Foundation to study the effects of different professional development plans designed to help teachers utilize formative assessment strategies in their mathematics classes. The FANC project has provided each participant teacher with

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a TI-Navigator System[2] and a classroom set of TI-73 calculators. They also received a document camera and projector. Both teachers highlighted in this paper have made extensive use of the integrated nature of the networked technology that was provided by the project.

FANC is a research project on the use of formative assessment in a networked classroom as it affects middle grades student learning of algebra concepts. The research is focused on student growth in achievement, the effective implementation of formative assessment practices and teacher and student attitudes toward the use of these practices. The project is exploring the challenges of implementing formative assessments and researching efficient and effective ways for teachers to implement formative assessment strategies.

The project builds on evolving research on formative assessment, the emerging technology of networked classrooms and best practices of reflective teaching that address the most difficult aspects of formative assessment identified in the research literature related to effective implementation. To maximize students' achievement, both assessment *of* learning and assessment *for* learning are essential. The former is widely used in the United States, but the latter is not (Stiggins, 2002). As a type of assessment for learning, Black and Wiliam (1998a) defined "formative assessment" as "all those activities undertaken by teachers, and/or by their students, which provide information to be used as feedback to modify the teaching and learning activities in which they are engaged" (p. 7). In other words, in addition to traditional paper-pencil assessments, formative assessment for learning includes instructional activities such as questioning, discussion, seatwork, and student self-assessment. Evidence has shown that formative assessments, if appropriately implemented in teaching, can produce substantial learning gains for students at different ages, across different subjects, and over different countries (Black, Harrison, Lee, Marshall, & Wiliam, 2004; Black & Wiliam, 1998a; 1998b; Wiliam, Lee, Harrison, & Black, 2004).

As straightforward as it may sound, formative assessment, however, has proved to be difficult to use in reality (Ruiz-Primo & Furtak, 2006; Shavelson, R. J., Yin, Y.,

[2] TI-Navigator is a networking system developed by Texas Instruments that wirelessly connects each student's graphing calculator to a classroom computer.

Furtak, E. M., Ruiz-Primo, M. A., Ayala, C. C., Young, D. B., et al., 2006; Yin, 2005). One of the challenges is that many formative assessment strategies take too much time (Black & Wiliam, 1998b). Another is the dilemma many teachers face concerning what to do about the insight into student understanding formative assessment provides. Here, technology can be a solution. The technology provided to teachers in the FANC project was chosen because it enables teachers and students to communicate throughout the lesson via hand-held devices using a variety of tools. These tools allow teachers to tailor problems to meet the immediate needs of students and students are able to share responses to problems in ways that promote class discussion. In this way, both teachers and students receive immediate feedback on the level of student understanding, and the information can be used to address students' needs.

Project FANC is currently in the second year of implementation. Teachers have taken two professional development summer institutes, attended follow-up sessions during the school year, and have had coaching visits from project staff (Olson J., Olson, M., Slovin, Gilbert, M., & Gilbert, B., 2010). The teachers highlighted in this paper have been using the Navigator system for a little over a year. Prior to joining the FANC project both teachers had been part of professional development endeavors geared to developing teachers' skills in using problem solving and meaningful communication in their mathematics teaching.

The case of Mr. S

Mr. S. has been teaching mathematics for 11 years. He has always been interested in new materials, teaching strategies and computer software that would lead to student gains in achievement. He was satisfied with the gradual improvement his students made. But it was not until he joined the FANC project that he experienced a significant shift in the classroom environment. From a class in which lessons, conducted and assessed by the teacher, progressed according to the prescribed plan, Mr. S's mathematics class environment has become one in which the responsibility for learning is shared by students and the teacher, lessons have become more responsive to students' needs, and assessment informs all.

Mr. S. builds his curriculum from a variety of materials and resources. Before joining the FANC project, Mr. S. planned every aspect of the lesson prior to teaching it.

He still plans carefully before class begins but the Navigator capabilities allow him to poll students on additional questions that may arise in the course of a lesson. Moreover, the teacher and students can immediately see the results of this poll, which leads to a discussion of the answers, both correct and incorrect. Mr. S. feels that talking about answers that are incorrect is just as valuable as talking about the correct answers and such a discussion often brings a different perspective to understanding how a problem is solved. Thus, the formative assessment for the teacher as well as for the students happens continually throughout the lesson.

Students work on problems that have been given to them during class or for homework. They work together in small groups to discuss their results. The small group setting is a safe environment for students to share ideas and discuss their answers. They can make corrections or add things to their own paper that someone from their group might have done differently. This is the first step to formative assessment for the students. They are already talking, getting feedback from their peers, having to make sense of the differences and making changes. The Navigator system can now be used to collect answers from everyone. The class as a whole can look at the results and discuss the different answers. This is the next step in formative assessment. Students are able to see their answer compared to the answers from everyone else in the class. They can immediately gather information based on the answers and the teacher can also assess what the students know and how many students are getting the correct answer. While assessment usually comes at the end of learning, in this environment it is actually just the beginning.

As students are randomly called on, they come to the document camera to share their method of obtaining their answer with the rest of the class. Since they have already discussed the problem in their groups, they are more likely to share their results without feeling anxious about whether their answer is right or wrong. Even students that did not do the problem or did not understand the problem have discussed it in some detail and therefore have something to share. Students ask each other questions; different answers and solutions are discussed; and at the end of the process there is a deeper understanding of the problem.

The TI-Navigator system and how it is used in class has helped inspire the use of more technology. Mr. S. has obtained laptops for each student, and the school subscribes to an Internet education application that allows students and teacher to co-create documents online and share them with others in real time to view or edit. Mr. S. has created a series of what he terms as case studies, stories that prompt inquiry and guide students in thinking of their problem questions to promote learning. One such story,

> *Stevenson Middle School just had its first ever hot dog eating contest. Ivy, Christie and Ethan were the three contestants and all of them did a great job. Each person was given 50 hot dogs and 10 minutes to eat as many hot dogs as he/she could. At the end of the competition each student had to report their total to the judge, Mr. S. Ivy said she ate 70% of her hot dogs. Christie said she ate 18/25 of her hot dogs. Ethan said he ate 0.68 of his hot dogs*.

involved fractions, decimals and percents. After reading through the story, students collaborated to gather as much information as they could. From there, students determined what questions could be asked about the story situation. They shared their ideas and added them to the story document, thus turning the story into multiple word problems. Students again studied the story to find the information they need to answer the questions they generated. A partially completed example of student work is included in Table 1, where each entry was generated by students and uploaded to a common document.

Table 1. Sample of student entries for the hot dog eating contest case study

Facts	Hypotheses	Need to Know	Learning Issues
Each person gets 50 hot dogs Stevenson had their first hot dog eating contest Need to report their total to the judge Ivy, Christie, and Ethan were competing in the contest Each person was given ten minutes to eat as much of their hot dogs Ivy ate 70% of here hot dogs Mr. S's the judge	Who ate the most hot dogs? How many hot dogs did they eat in all? Why didn't each person get more than 10 minutes? Who ate the lease amount of hot dogs? Compare the amount of hot dogs that each of them had. Put the people in order from mot hot dogs eaten to least hot dogs eaten.	How many hot dogs did each person eat? What percent of the hot dogs did each person eat? What person ate the most hot dogs?	How can we change fractions to decimals to percents? Change all of the amounts to percents. How do we change a decimal to a percent? What is the percent each person ate? What is a proportion?

Mr. S. believes that the use of such stories gives context to many mathematical problems. It has resulted in students being much more engaged in what happens in class and in taking ownership of their own learning. The collaborative approach has allowed students from all ability levels to work together and help each other succeed. The collaborative approach used by Mr. S. illustrates components of formative assessment, especially in that students receive feedback on their thinking and reasoning.

The case of Mr. B.

Mr. B.'s teaching situation shares many similarities with Mr. S.'s but there are some significant differences. While both schools are public, Mr. S.'s school serves the geographical vicinity while Mr. B. teaches at the University Laboratory School (ULS), a public charter school, which serves as a laboratory venue for the CRDG. The ULS student population is selected to be representative of the state in terms of ethnicity, socio-economic status and previous academic success. All classes are heterogeneous and all students take the same courses. Mr. B. uses a given curriculum, the *Reshaping Mathematics for Understanding* (RMU) program developed at the CRDG with ULS sixth- and seventh-grade students. The curriculum takes a problem-solving approach to present all concepts and emphasizes the use of visual contexts and spatial thinking in presenting key topics and in giving students the opportunity to make connections among concepts. Students explore concepts collaboratively supported by a moderate level of technology. Students initially use a small group setting (4 to 5 students) to share experiences from the given tasks. These ‘micro’ discussions are used to create presentations using multiple representations (diagram, written method, equation, among others) to demonstrate understanding. Students then use a document presenter to share their findings with the entire class. This ‘opening’ of the discussion to the class allows for students to refute, pose questions, share alternative methods for solving the problems, reinforce understanding and to assess themselves as they relate to the collective development of the group.

Mr. B. takes the role of a facilitator, guiding students towards understanding using a combination of classroom management techniques, formative assessment tools and heuristic questioning strategies. He encourages student accountability for self as well as group and is always looking for opportunities to improve the quantity and quality of student interaction.

Because the classroom environment was naturally ripe for collaborative technologies like the TI Navigator, Mr. B. was excited about its application, and he felt that the impact on the environment was immediate. The collaborative learning dynamics as well as the role of the teacher began to take on new characteristics as well as changing existing ones.

To get a good understanding of what kind of impact the technology was having on the learning Mr. B. used one of the tasks from the existing curriculum with the TI-Navigator system and the TI-73 calculators. This strategy would give him a ‘baseline’ experience without the technology to compare with this new technologically enhanced venture.

Prior to this task the students had a approximately two months' experience using the TI-Navigator with the calculators. Students had used some of the list functions as well as the scatter plots but had little to no experience with the *y* = function of the calculators. On this day, they were given a task from the RMU program called "Chelsie & Kelsey". The problem comes from the unit on patterns and functions and its original intent was for students to organize the given data and derive a rule or describe a pattern based on their analysis of the set. Because it is the first problem in the unit, expectations for conceptual understanding are not as high as they are later in the unit. These initial problems are mostly used as a stepping off point for students to explore freely and develop ideas about the relationships. Although they are rich enough to prompt a discussion of many related topics, the developmental pacing is usually determined by student readiness and time.

Chelsie & Kelsey

Chelsie asked Kelsey if he wanted to play a number game called, "Mystery Rule."

"Sure, " said Kelsey, how does it work?"

"You tell me a number and I'll tell you one back." said Chelsie, "If you can guess what I'm going to say before I say it, then it's your turn."

Kelsey said, "Okay. My first number is 5."

Chelsie said: 11

Kelsey: 0

Chelsie said: 1

Kelsey: 6

Chelsie answered: 13

Kelsey: 10

Chelsie said: 21

Kelsey: 1

Chelsie said: 3

Kelsey said: 7

But before Chelsie could answer, he said, "Wait, I know. You were going to say 15."

What rule does Kelsey think Chelsie is using? What are some other number pairs that would fit that rule?

In a heterogeneous classroom, it is often a challenge for the teacher to decide on the appropriate speed at which to bring all students through the content. While many students are certainly ready to go deeper into the introductory problems, it cannot be at the expense of those that are not. These two challenges, time and student readiness, were impacted heavily by the TI-Navigator system and the TI-73 calculators. Through the streamlining of student collaborations and the arming of the teacher with new formative assessment tools the class was able to go much farther than before.

The New Collaboration in Mr. B.'s Class

The original intent of the task required the students to compile the data given, analyze it to form conclusions about the relationships between the different data sets and share their findings with the group. These requirements remained unchanged with the addition of technology, but the speed and efficiency at which the students approached these tasks changed significantly.

Compiling

With the TI-73 students were able to enter large data sets with more ease. In addition to the increased speed, they had access to larger data sets (Figure 1) from members of their group and their class. For this task students could not only create T-Charts to organize the data but then connect those charts to a scatter plot to make a graphical representation.

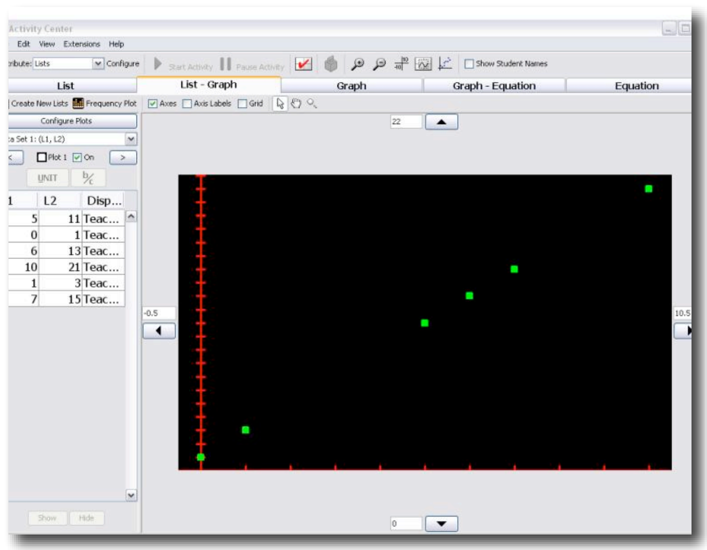

Figure 1

Analyzing

The technology allowed the students to take the large data sets and use the TI-73 tools and TI-Navigator Activity Center to analyze, compare and draw conclusions. Traditionally, they would have eventually made the connections between the multiple representations (list, graph, equation), but the nature of the TI technology encourages students to

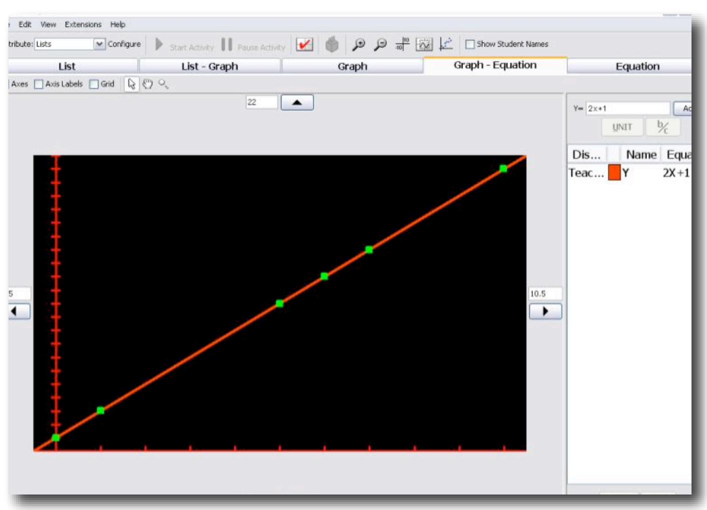

Figure 2

make the connections earlier as all the representations were available and interconnected. Students were able to check their rule against the data set by using the y = function. They soon realized that the solutions given to them from the task all fell on the line (Figure 2) and additional data accumulated from the same rule would also fall on the same line.

Sharing

The wireless technology also opened up new and speedier lines of communication between students and between student and teacher. When prompted to find additional sets of data based on the rule, students were able to 'send' their responses to the Activity Center (Figure 3) and compare their responses to other members of the class in real time. Discussions about appropriateness of the answers and how they related to the 'line' were important in developing understanding of linear qualities. Discussions about the rate of change and distance from one point to the other allowed for the first conceptual awakenings of slope.

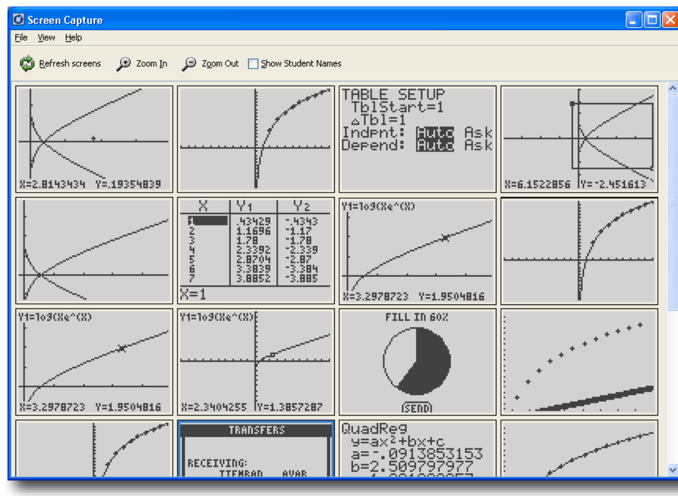

Figure 3

Mr. B. the Ringmaster

Previously, the teacher's role was to facilitate and lead the student exploration in the direction of the desired conceptual benchmark. With the introduction of the technology Mr. B. soon found himself struggling to keep up with the rate at which students were making connections and the questions they were posing in class. The challenge was to make sure the pace was appropriate for a heterogeneous classroom and that all students were being brought along into this uncharted territory while not stifling the accelerated progress being made. In this environment, formative assessment tools and techniques became paramount to the teacher's ability to manage a fast paced learning environment.

The Screen Capture tool on TI-Navigator gave Mr. B. and his students a look at classroom sets of data. Having access to classroom sets of data opened up opportunities to understand alternative methods and to explore reasons why specific responses were ‘appropriate’ or ‘incorrect.’

While it was somewhat anticipated the technology would improve student collaboration, empower student exploration and provide new tools for the teacher to more effectively guide students towards understanding, what Mr. B. was not ready for were the changes to the mathematics being learned.

The combined elements of rich tasks, appropriate technology and a collaborative learning environment resulted in not only changing how the students in these classes were learning mathematics but also the mathematics they were learning. Students in this experience delved deeper into the mathematics than similar classes of students had accomplished in prior years.

Watching the increased levels of communication, the elevated levels of engagement and shift in mathematics content has been both exciting and sobering for Mr. B. His increased use of technology and formative assessment ideas learned from Project FANC allowed him to see more opportunities for inclusion of both in his teaching. However, while he is tempted to escalate levels of technology in the classroom he remembers it is important that any technology introduced to the classroom must be consistent with the curricular goals. When introducing new technology into the curriculum he knows it is important that he strengthens the existing foundations of an effective inquiry environment. In doing so, he will focus on technological applications as they relate to three aspects of an inquiry environment: collaborative learning, student empowerment and formative assessment.

By initially focusing on these three areas Mr. B. hopes to avoid diluting the inquiry experience by keeping the focus on mathematical tasks while improving students’ abilities to explore the tasks by more efficient means. It is this ‘experience’ and its components that are so important to the development of concepts over time. His goal is to use formative assessment to bring about student understanding and conceptual change by providing immediate feedback to students and focusing his attention on reducing the gap between the student's current level of understanding and the level of understanding outlined by the curriculum standards and expectations.

Summary

The paper describes changes made by two seventh-grade teachers who are participants in project FANC. First, the use of technology prompted each teacher to reconsider his instructional approach and the manner in which he interacted with students. In general, each teacher developed a more open-questioning form of teaching and required students to actively engage in classroom discussions as well as work collaboratively and communicate ideas to other students in class. Second, access and use of technology expanded the boundaries of the learning trajectory of students' content understanding. Students were able to process the content in a more sophisticated way than the teachers had experienced in the past. Third, the expansion of the learning trajectories created dilemmas for each teacher in how to use the formative assessment information made available by the networked technology. Both teachers made use of these features of the networked technology, quick poll, learn check, screen capture, and activity center that enabled them to assess their students' thinking and to provide opportunities for classroom discussion.

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