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The Design and Delivery of a Professional Development Program to Implement Formative Assessment in a Networked Classroom

Introduction

Project FANC (Formative Assessment in a Networked Classroom) is a three-year research project funded by the National Science Foundation[1] that explores a feasible way of implementing formative assessment. Formative assessment is well accepted as an effective way to improve students' achievement, but it has been challenging for teachers to use in reality. By combining formative assessment and technology, the Project FANC is exploring a new perspective to educational technology theoretically and practically. The effects of two professional development models for using formative assessment in a connected classroom are being studied in the classrooms of 32 seventh-grade teachers in 15 different schools. The 32 teachers were assigned to two groups, which for the purpose of this paper will be referred to as Groups A and B, in which they remained for the duration of the three-year project.

During the first summer of the project, teachers assigned to Group B participated in five days of professional development on the use of formative assessment in the classroom. At the same time, teachers assigned to Group A participated in professional development on the use of formative assessment using the TI-Navigator™, a classroom networked system.[2] In the second summer of the project, the three days of professional development for Group B focused on using the features of TI-Navigator for formative assessment. The professional development for Group A during the same three days provided additional work on using formative assessment and TI-Navigator with more emphasis placed on questioning strategies. In addition to the intensive training in the summer, five follow-up half-day professional development sessions were provided for teachers in both groups during each of the two years of implementation. Throughout the academic years, the project staff visited teachers' classrooms to provide coaching and assist with any technology issues. The details of the design and development of these two professional development models along with the theoretical framework on which they are built are described and discussed in this paper.

Theoretical Framework

Formative Assessment

Formative student assessment is used during learning to provide feedback for students and teachers to improve learning and teaching (Black & Wiliam, 1998a). Black & Wiliam 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 assessments, formative assessment for learning includes

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

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 and across different subjects (Black, Harrison, Lee, Marshall, & Wiliam, 2004; Black & Wiliam, 1998a; 1998b; Wiliam, Lee, Harrison, & Black, 2004).

Shavelson, Yin, Furtak, Ruiz-Primo, Ayala, & Young (2006) classified formative assessment techniques into three categories on a continuum based on the amount of planning involved and the formality of technique used: 1) on-the-fly formative assessment, which occurs when teachable moments unexpectedly arise in the classroom; 2) planned-for-interaction formative assessment, which is used during instruction but prepared deliberately before class to align closely with instructional goals; and 3) formal-and-embedded-in-curriculum formative assessment, which is designed to be implemented after a curriculum unit to ensure that students have reached important goals before moving to the next unit.

Despite their variety, when formative student assessments are used, common steps are explicitly or implicitly involved: 1) determining achievement goals that students are expected to reach—the expected level; 2) collecting information about what students know and can do—the actual level; 3) identifying the gap between the actual level and expected level; and 4) taking action to close the gap. Steps similar to 1), 2), and 4) have been addressed by Sadler (1989). Teachers and/or students can take all of the steps.

When using formative assessment, the teacher provides specific feedback rather than only grades to students. The feedback can be oral or written comments addressing what students have done well and have not done well and suggestions how to improve. Moreover, self and peer assessments are highly recommended formative assessment strategies because they can help students to develop the habit of reflection and to become more aware of the learning goal, learning gap, and how to close the gap (Black et al., 2004).

Formative Assessment and Technology

As straightforward as it may sound, in reality, formative student assessment has proven difficult to implement (Ruiz-Primo & Furtak, 2006; Shavelson, R. J., Yin, Y., 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 to be used practically (Black & Wiliam, 1998b). For example, it is time-consuming for teachers to count students' votes, and it is almost impossible for teachers to provide specific feedback on each student's work, especially with a typical teaching load of four to six classes daily, with 20 to 30 students in each class.

Black and Wiliam suggested that teachers have to believe that the time investment for formative assessment will yield reward in the future. Even so, they admitted that teachers' work loads are often overwhelmed by agendas and dominated by district specifications on what curriculum must be covered to prepare students for yearly No Child Left Behind (NCLB) high-stake tests (Black & Wiliam, 1998b). "With such rigid pacing," Black and Wiliam (2005a) pointed out, "there are few opportunities to use information on student performance to address learning needs" (p. 258).

In *How People Learn* (NRC, 1999), classroom networks are considered one of the most promising technology-based education innovations for transforming the classroom

environment. Some early findings demonstrate its potential to overcome one of the greatest hurdles to improving classroom assessment: the collection, management and analysis of data (Roschelle, Penuel, & Abrahamson, 2004). While feedback loops in the regular classroom are very slow, classroom networked technology has the capabilities to provide rapid cycles of feedback to improve ongoing activity in real time.

Using a networked classroom, what students know and can do can be easily assessed and anonymously displayed. Students can enter and send their responses to the teacher computer. Similarly, teachers can easily send questions, and receive, organize, and display students' answers, so that the interaction between the teacher and students and among students is greatly facilitated.

A pilot study conducted at the Curriculum Research & Development Group (Mackay, Olson, & Slovin, 2006) showed that the TI-Navigator system developed by Texas Instruments enabled the teacher to use formative assessment results more effectively because assessments in the classroom were done in real-time. Assessment of students was eased for the teacher through the use of TI-Navigator in a number of ways: checking on the level of student engagement, clarifying the source of student problems at an early stage, creating the possibility of responding instantly to student problems, and providing the availability of a variety of feedback methods.

Earlier research conducted at the Curriculum Research & Development Group (Dougherty, Akana, Cho, Fernandez, & Song, 2005) found that using TI-Navigator for teaching algebra provided a means for in-depth discussion points, leading to improved student interaction and collaboration. Dougherty, et al reported that "the use of TI-Navigator technology supports the development of a collaborative classroom environment by enhancing student interactions, focusing students' attention on multiple responses, and providing opportunities for students to peer- and self- assess student work. The ability to display a full class set of data or task responses supports a problem-solving approach to developing skills and concepts" (p. 28). Students showed improvement in the areas of: conceptual understanding, classroom interactions, quantity and quality of responses, time on task and time to start tasks.

Design of Professional Development

Formative Assessment

Input from the eight Advisory Board members along with numerous articles on professional development, formative assessment, technology and related topics (Ayala & Brandon, 2008; Black & Wiliam, 1998a; Black & Wiliam, 1998b; Black & Wiliam, 2005a; Black & Wiliam, 2005b; Gearhart, & Saxe, 2004; Guskey, 2007/2008; Stiggins, 2002; Stiggins, Arter, Cahappuis and Chappuis, 2004; Wiliam, Lee, Harrison, & Black. 2004; Wiliam. 1999) were all taken into consideration as the Project Team designed the two models of professional development (PD). The Project Team chose to design the formative assessment PD using the Seven Strategies of Assessment for Learning developed by Stiggins, Arter, Chappuis and Chappuis (2004, p.42) (Figure 1). The Hawaii Department of Education (HIDOE) is one of the partners involved in Project FANC and previously conducted sessions on formative assessment for teachers focusing on these strategies. Therefore, by building upon participants' previous general knowledge of formative assessment, understanding could be extended to the content and pedagogy of teaching and learning mathematics.

Seven Strategies of Assessment for Learning

Where am I going?

1. Provide a clear and understandable vision of the learning target.
2. Use examples and models of strong and weak work.

Where am I now?

3. Offer regular descriptive feedback.
4. Teach students to self-assess and set goals.

How can I close the gap?

5. Design lessons to focus on one aspect of quality at a time.
6. Teach students focused revision.
7. Engage students in self-reflection, and let them keep track of and share their learning.

Stiggins, Arter, Chappuis, & Chappuis, (2004, p.42)

Figure 1
Seven Strategies of Assessment for Learning

The work of Stiggins, et al was adapted to create a more complete model of formative assessment that includes elements such as the cognitive demand of tasks and questioning strategies to clarify, probe, and extend student learning (see Table 1). The Professional Teaching Standards from the National Council of Teachers of Mathematics (NCTM, 1991) note the importance of identifying the characteristics of "worthwhile mathematical tasks" and the knowledge that mathematical tasks differ with respect to their levels of cognitive demand. It is important to analyze and discuss tasks in order to determine the level of thinking required to solve them. Tasks that require students to perform a memorized procedure in a routine manner lead to few opportunities for learning mathematics. Tasks that demand engagement with concepts and that stimulate students to make purposeful connections to meaning or relevant mathematical ideas lead to a richer, more substantive set of opportunities for student's thinking. A task analysis guide (Figure 2) was adapted from the work of Stein, Smith, Henningson & Silver (2000) for promoting the development and use of mathematical tasks with higher levels of cognitive demand. This guide informed teachers' focus on the strategies associated with the question, Where am I going?

An essential component of the formative assessment PD was an emphasis on asking good questions that provide information about students' understanding. A good question possesses three features: 1) It requires more than recall of a fact or reproduction of a skill, 2) It has an educative component; that is, the pupil will learn from attempting it and the teacher will learn about the pupil from the attempt, and 3) It is, to some extent, open; that is, there may be several acceptable answers or several methods to finding a solution (Clark, 1996). Rich questioning provides teachers not just with evidence

about what their students can do, but also what the teacher needs to do next, in order to broaden or deepen understanding. Questions should be posed that can promote an extended exchange with a single student, involving a second, third, fourth or even fifth follow-up question to the student's initial answer. With such questions, the level of classroom dialogue can be built up to quite a sophisticated level, with consequent positive effects on learning (Wiliam, 1999).

Formative Assessment Using TI-Navigator

Four functions of TI-Navigator system are particularly helpful for formative assessment implementation: 1) Quick Poll—allowing teachers to immediately collect and display all the students' votes to a question; 2) Screen Capture—allowing teachers to monitor individual students' work progress at anytime; 3) Learn Check—allowing teachers to administer quick and frequent formative assessments and provide timely feedback; and 4) Activity Center—allowing students to work collaboratively to contribute individual data to a class activity. The four functions are closely aligned with the general principles or specific strategies of formative assessment, such as voting for options, sharing ideas, self-assessment, and peer assessment. Table 2 presents a description of each TI-Navigator function, the alignment between each function and formative assessment needs, and the advantages of the function when it is used to implement formative assessment.

The professional development on formative assessment using TI-Navigator was based on the potential that TI-Navigator possesses when it is used as a formative assessment tool. It is efficient; information can be transferred between the teacher's computer and students' calculators instantly, and students' work can be assessed and displayed quickly and used for classroom discussion. Students' work or answers can be shared with the whole class anonymously, so that the students who made mistakes will not be embarrassed. The system is convenient; teachers can pre-store formative assessment questions before hand and send them to students instantly at the appropriate moment. Teachers can easily share good assessment items with each other, and formative assessment records can be saved and retrieved at any time. In addition, researchers at the Stanford Research Institute suggested that TI-Navigator may facilitate collaborative learning by establishing "positive interdependence" that promotes interaction and commitment to group learning goals and enable the teacher to maintain both individual and group accountability (Stanford Research Institute, 2004). The teachers in a study by Owens, Demana, Abrahamson, Meagher & Herman (2004) found that students in TI-Navigator classes were perceived to be more responsive to individual learners' needs, more focused on knowledge building and assessment, and more community centered. However, while the teachers obtained information about student's knowledge, but they may not have changed their instructional procedure based on the information obtained. They found stronger evidence for technology implementation than for change in instruction and that teachers did not make full use of the potential of the connected classroom for formative assessment. (Owens, Pape, Irving, Sanalan, Boscardin, & Abrahamson, 2008). Therefore, Project FANC PD model was designed around a framework for formative assessment on which to focus the implementation of TI-Navigator.

Table 1

Formative Assessment Model[1]

Where am I going? (Beginning with the End in Mind)	Knowledge	Dispositions
• Identify the worthwhile mathematics students need to know • Identify how teachers and students will use information from formative assessment • Communicate to students clear expectations of quality mathematics	• Mathematics content knowledge for teaching • Mathematics content and processes standards/benchmarks • Purpose of formative assessment • Recognize indicators of quality mathematical reasoning and work	• Holds high expectations for all students • Views students as collaborators in the process • Focuses on students and how they can learn • Views formative assessment central to classroom practice • Views formative assessment as sensitive and constructive • Views teaching as a reflective practice
Where am I now? (Gathering Data)	Knowledge	Skills
• Focus on the learner's prior mathematical knowledge • Use multiple sources of evidence to guide goal setting • Provide specific and timely descriptive feedback • Provide opportunities for peer and self assessment	• Learning progression in mathematics • Pedagogical content knowledge • Student's previous learning • Variety of formative assessment tools and strategies and their appropriate use	• Embed formative assessment in instruction • Create conditions that allow for productive formative assessment • Give students descriptive feedback • Teach students to self-assess and assess peers
How can I get there? (Taking Action)	Knowledge	Skills
• Use questions to clarify, probe and extend thinking • Design lessons that scaffold and build on current knowledge and experiences • Provide opportunities for students to analyze their work and make improvements • Engage students in tracking, reflecting on and communicating about their progress	• Mathematics knowledge • Pedagogical content knowledge • Linking content to student's prior knowledge • Vygotskian ZPD • Formative assessment tools for documenting & communicating student progress	• Interpret the evidence • Use a variety of strategies to match instruction to the gap • Use effective questioning and act on "teachable moments" • Create conditions that allow for productive formative assessment

[1] Adapted from Stiggins, R. J., Arter, J. A., Chappuis, J. & Chappuis, S. (2004). Classroom assessment for student learning, Portland, Oregon: Assessment Training Institute, Inc.

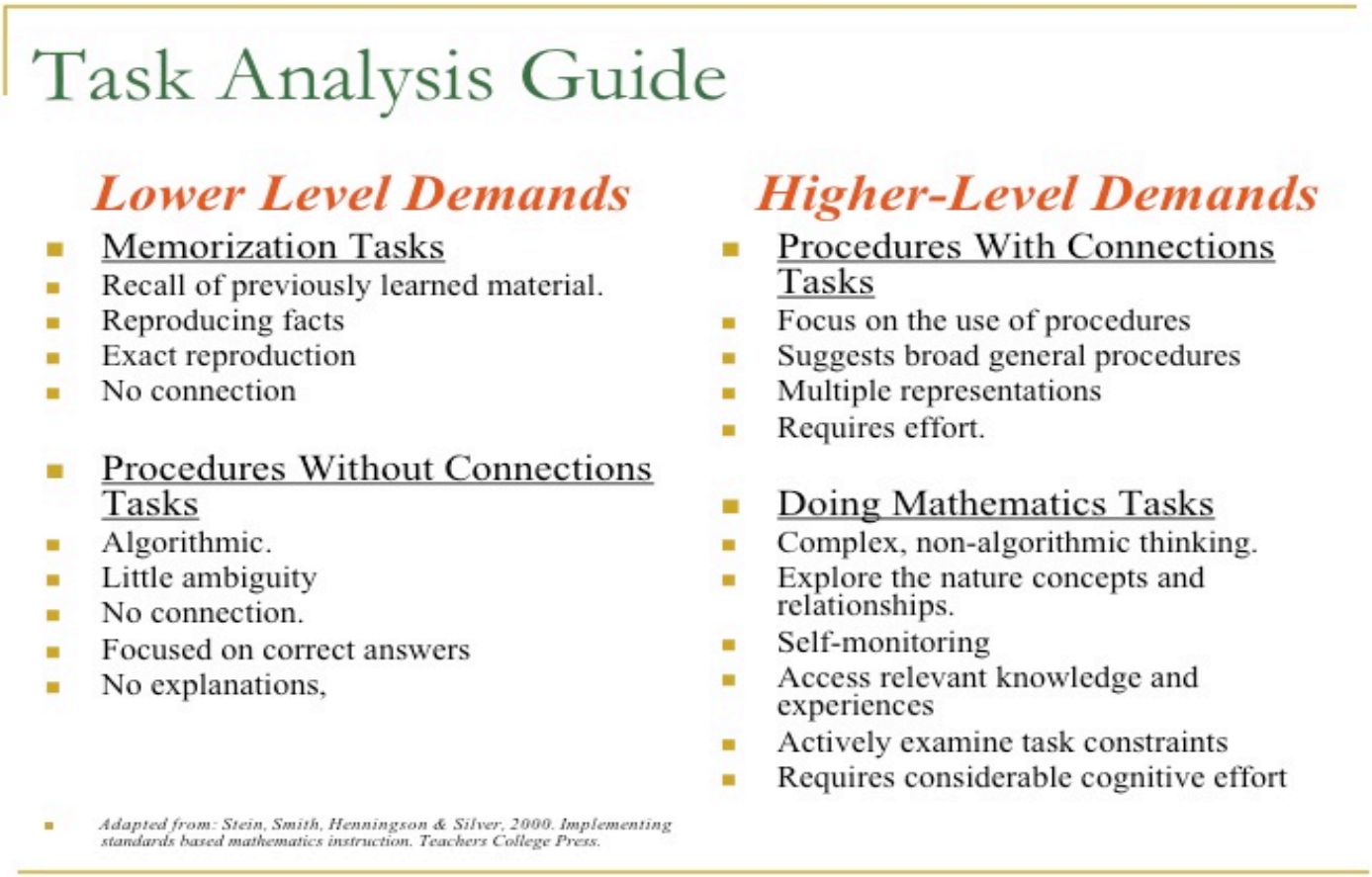
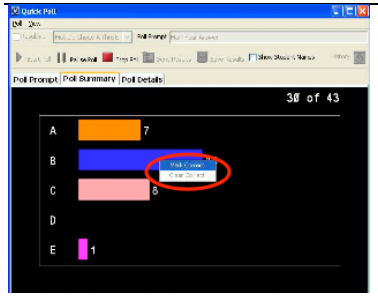
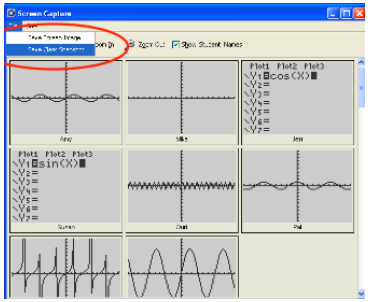
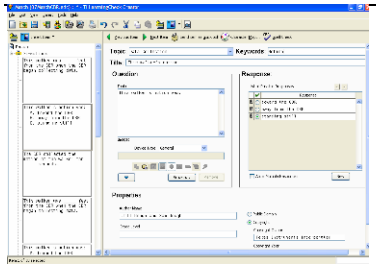
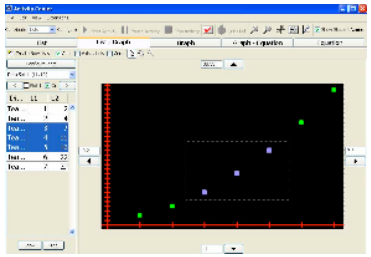


Figure 2
Task Analysis Guide

Table 2
Four Functions of TI-Navigator System and Their Connections With Formative Assessment

Navigator Function	Function Description	Formative Assessment Needs [a]	Advantage of Using TI-Navigator
 **Quick Poll**	The teacher asks a question (can be on-the-fly or planned-for-interaction); all the students respond via calculators; the teacher views and displays all student responses immediately. Various answers are presented as a bar graph, so that common misconceptions can be identified and addressed immediately.	• Gives students a choice among different possible answers by asking them to vote on the options. • Increases waiting time after questioning to encourage thoughtful reflection. • Engages all the students.	• **Increased Waiting Time:** Slow thinkers will not be interrupted by the "spoken out" answers of fast thinkers. • **Engaging all:** the vocal ones will not dominate Classroom. Shy students will have the same opportunities to share their opinions. • **Efficient**: It takes a second to count and display the votes. Teachers do not need to take time to count hands or tally. • **Anonymous**: Students will not feel embarrassed if their answers are wrong. • **Confidential:** Students will not and cannot follow those high achievers in order to be "safe."
Screen Capture 	The teacher can capture what is on each student's calculator screen through the teachers' computer at anytime, so that the teacher can monitor students' progress by identifying (a) who is not on the task, (b) who is having difficulties with calculator usage or concepts, (c) who is making careless mistakes, and (d) who is on the right track.	• Asks all students to write down an answer and then reads out a selected few.	• **Efficient:** Without circulating around the classroom, the teacher can view every student's work progress in real time and identify who needs help. • **Easy for Sharing:** The teacher can share an individual student's answer with the whole class when necessary. The answer can be a common mistake or exemplary work. • **Anonymous:** When an individual student's work is shared through screen capture, the owner of the work will not be embarrassed.

Navigator Function	Function Description	Formative Assessment Needs [a]	Advantage of Using TI-Navigator
 **Learn Check**	Teachers can send information or questions to all students at one time. Students respond through their calculators. Students' answers can be relayed instantly and displayed anonymously.	• Students complete a few problems or questions at the end of instruction and check answers. • Allows teachers to work with others and outside sources to collect good test items. • Uses portfolio or collections of student work formatively.	• **Convenient:** Questions and assessments can be pre-stored in the teacher's computer and sent to students at the appropriate time. There is no need to copy, distribute, and collect papers. • **Efficient:** Due to automatic grading, teachers do not need to spend time grading students' quizzes. Meanwhile, students can get feedback immediately and learning gaps can be closed soon after they are identified. • **Easy to Share High Quality Assessment:** Assessment items are in digital format. High quality assessment items can be created collectively by teachers and assessment experts and shared by teachers easily. • **Easy to Keep Record**: Each student's responses and correct answers to the assessments can be saved and retrieved easily. Hard copies can be printed for students as possible portfolio entry.
Activity Centre 	Students can contribute to a shared workspace that is projected to the class in real time, e.g., contributing a data point (x, y), an equation, or a data list for an algebra topic. Students can work collaboratively in pairs or groups, discussing, self-assessing, and peer assessing their own work.	• Encourages students to use self-assessment and peer-assessment. • Promotes more dynamic class discourse.	• **Flexible:** Students can work individually, in pairs, or in groups when they contribute their ideas to the class activity. • **Anonymous but identifiable**: Student contributions to the class data are anonymous. However, each student/pair/group can choose their own color to show on the projected screen of the class' responses, so that students can be more engaged when discussing conflicting data.

Note: a. The formative assessment needs are cited from the articles written by Black, Wiliam, and their colleagues (Black et al., 2004; 1998a; 1998b)

Delivery of Professional Development

Project FANC involved the delivery of PD using two different models during a two-year period. Both models were based on formative assessment and TI-Navigator, however there was a difference in the manner in which these models were delivered. The PD in the model delivered to the participants in Group A focused on implementing the formative assessment using the features of TI-Navigator for both years. The PD in the model delivered to Group B participants focused on implementing formative assessment strategies the first year and then applying those strategies when using the features of TI-Navigator the second year.

The following five-day PD was delivered in Year 1:

> Group A: Teachers participated in five days of professional development on formative assessment and strategies for using TI-Navigator in their classrooms. In addition five follow-up days and coaching were conducted throughout the academic year.
>
> Group B: Teachers participated in five days of professional development on formative assessment and strategies for using formative assessment in their classrooms (not using TI-Navigator). In addition five follow-up days and coaching were conducted throughout the academic year.

The following three-day PD was delivered in Year 2:

> Group A: Teachers had an opportunity to reflect on their first year of using TI-Navigator for formative assessment and ways to further implement it in their classroom. In doing so, teachers were asked to focus on questioning strategies when using TI-Navigator and choosing mathematical tasks that would provide the opportunity for rich tasks and questions. The project is in the midst of the second academic year of implementation, during which time there will be an additional five days of follow-up and coaching.
>
> Group B: Teachers had the opportunity to reflect on their first year of using formative assessment and learn how TI-Navigator can be used for formative assessment in their classrooms. In doing so, teachers were asked to apply the work they did with questioning strategies and choosing mathematical tasks that provide opportunities for rich questions for which the TI-Navigator would enhance instruction. The project is in the midst of the second academic year of implementation, during which time there will be an additional five days of follow-up and coaching.

At the beginning of the project all participants were given MacBook laptops, LCD projectors, Elmo visualizers (document cameras), and a classroom set of TI-73 graphing calculators. Participants in Group A were also provided with TI-Navigator Systems for their classrooms during Year 1 while participants in Group B were given TI-Navigator Systems in Year 2. While Professional Development was delivered to Group

A and Group B during the same five days during the first summer, the groups met in different locations and did not interact with each other. In fact, since there were participants from each group at two of the schools, participants were asked not to discuss the nature of the professional development in which they participated with the other group. During the second summer when participants in both groups worked with TI-Navigator, they met in the same building, but different rooms for the same three days.

The delivery of the PD to both groups followed parallel models where possible. The same formative assessment model (see Table 1) was presented to both groups as well as the Task Analysis model (see Figure 1) for cognitive demand of mathematic tasks. While the implementation of formative assessment both with and without the use of TI-Navigator was expected to take place throughout the school year in teachers' classrooms, the focus of the research data collection on student learning was during the third quarter of the school year when most teachers taught lessons related to patterns and functions, the algebraic reasoning topics found in grade 7 in Hawai'i. Therefore, the PD in both groups included a session in which representatives from the HIDOE described the expectations for 7th grade work with patterns and functions in the Hawaii State Content and Process Standards and Benchmarks.

While the formative assessment model, questioning strategies, and rich mathematics activities were essential components in both professional development experiences, the actual delivery and focus varied. Brief descriptions of the focus of each PD during the first year are given below:

Group A

The formative assessment model, questioning strategies, and mathematics activities were connected to the use of TI-Navigator. Since participants were learning how to use the technology, significant time for hands-on experiences with the features of TI-Navigator was provided. While participants learned how to use the features of TI-Navigator, video examples of 7th grade classrooms at the University Laboratory School (ULS) at the University of Hawaii using TI-Navigator for formative assessment were shared. Discussions of the mathematics and the questioning strategies used in the video examples followed the viewing.

As participants engaged in mathematics activities that utilize handheld technology and TI-Navigator emphasis was placed on creating/choosing good tasks and asking good questions. The participants were involved in identifying how TI-Navigator can provide valuable formative assessment feedback prior to, during, and following the activities. There was a focus on the 'added value' of handheld technology in a connected classroom.

Participants were asked to use their curriculum materials to develop lessons and good formative assessment questions for use with TI-Navigator that could be used during first month of the school year. During the PD participants planned for first uses of TI-Navigator in the classroom and how to create a technology classroom environment. Classroom management issues and ways to manage the formative assessment data collected via Navigator were also addressed.

At the follow-up sessions, participants shared how they implemented formative assessment with TI-Navigator, troubleshooting tips, and ways the classroom climate was changing. They were given additional opportunities for hands-on experiences with the

features of TI-Navigator to gain more comfort and expertise with the technology. In addition, they engaged in mathematical activities and questioning strategies that could take advantage of using TI-Navigator for formative assessment.

Group B

The formative assessment model, questioning strategies, and mathematics activities were focused on designing appropriate tasks in which students could demonstrate their thinking. In-depth discussions on ways to analyze student work and interpret results in terms of what it reveals about student understanding took place. Participants in Group B were provided with opportunities to examine tasks and lessons and where the tasks fit in the learning progression students were expected to learn. Participants worked on selecting and modifying tasks using the processes of reversibility, flexibility, and generalization to deepen students' understanding of the mathematics content.

Ideas on creating a mathematics learning environment that included creating an assessment conversation with student-to-student interactions were shared with participants. Classroom video segments from ULS 7th grade classes of students discussing their solutions to mathematics problems illustrated the importance of having student communicate their thinking processes. During the PD participants planned for implementation of formative assessment with a focus on handling student work for review and revision: collecting, filing, redistributing.

At the follow-up sessions, participants shared how they implemented formative assessment, examples of student work, and ways the classrooms climate was changing. They were given additional opportunities for engaging in mathematics activities and questioning strategies they could use in their classrooms.

The PD for both Group A and B looked more similar during the second summer as both groups were now using TI-Navigator. However, since participants in Group B were new to the technology, more time was devoted to learning how to use the features of TI-Navigator while in Group A more time was devoted to increasing formative assessment questioning strategies.

Summary

As seen in the descriptions of the two PD models, one of the primary differences between the models is the order and emphasis on formative assessment and on the use of TI-Navigator for formative assessment in the delivery. This design was generated due to the difficulties identified with implementing formative assessment in classroom. To use technology to implement formative assessment adds another level of complexity. Project FANC is trying to determine if there is a difference, based on student outcomes, between these two designs. After two years of PD, to check if there is a difference in student outcomes, pre and post student data is being collected. In addition, data is continually being collected on how teachers are implementing each of the PD models and the effects of these models on student learning. For a more in-depth analysis of teacher implementation, case studies of ten teachers are being conducted to give a picture of various degrees of implementation of formative assessment strategies using the TI-Navigator. Full results on the project will become available starting in December 2010.

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