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Technology Integrated Secondary Mathematics Education: Interactions between Teacher and Students in Classroom
Secondary Mathematics Education

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Students and teachers in three AP mathematics classes were interviewed and observed. This qualitative research indicated that the use of technology enabled students to learn mathematics and interact more cooperatively with each other. The results also indicated that students tended to visualize mathematical concepts when technology was integrated.

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ABSTRACT: This article reports the findings of a qualitative case study involved observing and interviewing two high school mathematics teachers and 48 high school students in three Advanced Placement (AP) mathematics classes using graphing calculators and other audio visual (AV) technology tools. Results indicate that the participants strongly believed the use of graphing calculators in secondary mathematics classrooms would help them to visualize the abstract concepts of mathematics so the learning would be more effective and meaningfully. The results also indicated that the use of technology enabled students to learn mathematics and interact more cooperatively with each other. The teachers also believed that technology integration positively influenced the way they teach secondary mathematics in a constructive manner. Technology integration in secondary mathematics facilitates learners' ability to build cognitive links among multiple mathematical representations by providing quick access to multiple representations. In this study gender difference was not detected.

KEYWORDS: Technology Integration, Mathematics Education, Teachers, Students, Secondary AP Mathematics, Interaction Between Teacher and Students

INTRODUCTION

There has been a deep concern regarding U. S. secondary students' low achievement in mathematics (The Program for International Student Assessment [PISA], 2000; Trends in International Mathematics and Science Study [TIMSS], 1995; The National Assessment of Educational Progress [NAEP], 1969). Although the evidence is ambiguous because the results of the tests can be interpreted in more than one way depending how the evaluator interprets the results (Berliner & Biddle, 1995, 2002; Berliner, 2009; Bracey, 2000, 2004, 2009), overall, the results indicate that students are not doing well. This situation has persisted for many years, at least since the *Nation at Risk* (U.S. Department of Education, 1983) report was released.

Because the public and government evaluate the education system by measurement of the achievement of students on state, national, and international mathematics assessments, improved student scores became the key indicator of the effectiveness of the mathematics curriculum. The public and government look to teachers to be responsible for improving student achievement, and that is why the *No Child Left Behind Act* (NCLB) was signed into law in an attempt to legislate better teaching. Note, though, that there are other factors that influence student mathematics achievement. Some of these factors are the physical environment, the emotional and psychological state of the learner, and parental and social involvement.

After the results of U.S. student performance on international assessments were disclosed, there were mixed reactions from many different groups of people. The U.S. government published a series of reports on the achievement levels of U.S. students. However, according to *Pursuing Excellence* (1997), a U.S. Department of Education report, the result of the 1995 TIMSS has no significant meaning until subsequent research is conducted to follow up on the findings.

> There are no educational characteristics that are present in every high-performing TIMSS country… Instead, we need to use these findings as an objective assessment of the strengths and weaknesses characteristic of each specific national education system. All countries, including the U.S., have something to learn from other nations, and have something from which other countries can learn. (p. 57)

Even though it is difficult to make direct connections between the quality of instruction and student learning of mathematics, there will always be room for teachers to improve their instruction. Because improved instruction has a positive effect on achievement, this article will link the effective use of technology with improved instruction. A government report (Wells & Lewis, 2006) shows technology capacity has grown tremendously in U.S. public schools and classrooms over the last 11 years. According to Wells and Lewis (2006), public schools have made consistent progress in expanding Internet access in instructional rooms: “In 2005, 94 percent of public school instructional rooms in the United States had access to the Internet, compared with 3 percent in 1994” (p. 4).

Even though more technology has become available in schools and classrooms, the results of national and international assessments of mathematics indicate the achievement of U.S. students has not improved. Thus, it is difficult to conclude that technology availability itself has made any impact on student achievement in mathematics. It is therefore important to investigate the role of technology in mathematics education to understand whether and how technology is actually used to learn mathematics. If we want to use technology to improve mathematical achievement, students should be able to access technology for study. Do students have access to technology? Do teachers use technology effectively? According to the literature review, the effort is not students’ alone: teachers must also know how to integrate technology to improve their teaching and effectively promote student learning. Is there any clear instruction for effective technology integration in the classroom for teachers?

International and National Studies of Mathematical Achievement

U.S. government officials, educators, and parents collectively want their students educationally prepared so they can perform competitively with students in other parts of the world. How do U.S. students perform on international and national tests?

The Program for International Student Assessment (PISA)

The Program for International Student Assessment (PISA) is a system of international assessments that, every 3 years, measures 15-year-olds' capabilities in reading literacy, mathematics literacy, and science literacy. PISA—first implemented in 2000—is carried out by the Organization for Economic Cooperation and Development (OECD), an intergovernmental organization of 30 industrialized countries (together with candidate countries who engage in OECD activities). According to the OECD/United Nations Educational Scientific and Cultural Organization (UNESCO) (2003), PISA focuses on how well students apply knowledge and skills to tasks that are relevant to their future life, rather than on the memorization of subject matter knowledge (p. 3). In other words, students' high achievement on PISA would indicate that they know how to apply their knowledge to real-life situations. Rather than seeking to indicate how well students can simply memorize a number of facts, PISA is testing conceptual knowledge.

According to several research reports (Lemke, M. & Gonzales, P., 2006; Lemke et al., 2004; Fleischman, H.L. et al., 2010; Organization for Economic Cooperation and Development / United Nations Educational Scientific and Cultural Organization, 2003; OECD, 2012; U.S. Department of Education, 2001b), U.S. students did not score well on PISA in comparison with students from Korea, Australia, the United Kingdom, Japan, and Canada.

Table 1

Average mathematics literacy score comparison of 15-year-old students

	PISA 2000	PISA 2003
United States	493	482.9
Korea	547	542.2

Australia	533	524.3
United Kingdom	529	508.3
Canada	533	532.5
Japan	557	534.1
OECD Average	500	500

Considering what PISA measures, what multiple reports point out is that U.S. results are not positive and reconceptualization of mathematics education in the U.S. needs to be seriously considered (Smith, 2004).

Trends in International Mathematics and Science Study (TIMSS)

TIMSS was developed to continue the series of international comparative school achievement studies conducted by the International Association for the Evaluation of Educational Achievement (IEA) and which began in 1959. The First International Mathematics Studies (FIMS) were implemented in 1964. The Second International Mathematics Studies (SIMS) were implemented between 1980 and 1982.

However, TIMSS is the first attempt to investigate mathematics and science achievement simultaneously. It measures trends in students' mathematics and science achievement. Offered in 1995, 1999, and 2003, TIMSS provides participating countries with an unprecedented opportunity to measure students' progress in mathematics and science achievement on a regular 4-year cycle. Various resources (U.S. Department of Education, 1998b, 2001a, 2001c; Gonzales,

P. et al, 2008) indicate that the achievement of U.S. students is not high compared to other participating nations.

Table 2

Comparison of comprehensive mathematics achievement by nation and grade level: TIMSS 1995, 1999, and 2003

	TIMSS 1995			TIMSS 1999			TIMSS 2003		
Grade Level / Country	4th	8th	12th	4th	8th	12th	4th	8th	12th
United States	545	492	461	---	502	---	518	504	---
Korea	611	581	---	---	587	---	---	589	---
Australia	546	519	522	---	525	---	499	505	---
United Kingdom	513	498	---	---	496	---	531	---	---
Canada	532	521	519	---	531	---	---	---	---
Japan	597	581	---	---	579	---	565	570	---
International Average	529	519	500	---	521	---	495	466	---

*Note! TIMSS scores for 4th and 12th graders in 1999 are not available because they were not measured. For the same reason, the TIMSS scores for 12th graders in 2003 are not available. Some scores are missing in 1995 and 2003 from Korea, The U. K., Canada, and Japan because they did not participate with the assessment for various graders.

The National Assessment of Educational Progress (NAEP)

NAEP, or "the Nation's Report Card," is the only nationally representative and current assessment of what America's students know and can do in various subject areas. Since 1969, assessments have been conducted periodically in reading, mathematics, science, writing, history, geography, and other fields.

Now, let us take a look at how our students performed on the NAEP assessment. Because this is one of the major assessments that the U.S. government administers, there are numerous government reports (National Center for Education Statistics, 2006, 2011; U.S. Department of Education, 1998a, 1998b, 2004) that are available for accountability purposes.

When the mathematics achievements of eighth graders in Hawai`i were compared to the nation average of eighth graders in the United States, there was a clear and very consistent gap between the two scores (See figure 1). Based on the seven NAEP scores resulting from assessment in seven different years, the eighth graders in Hawai`i consistently achieved below the national average.

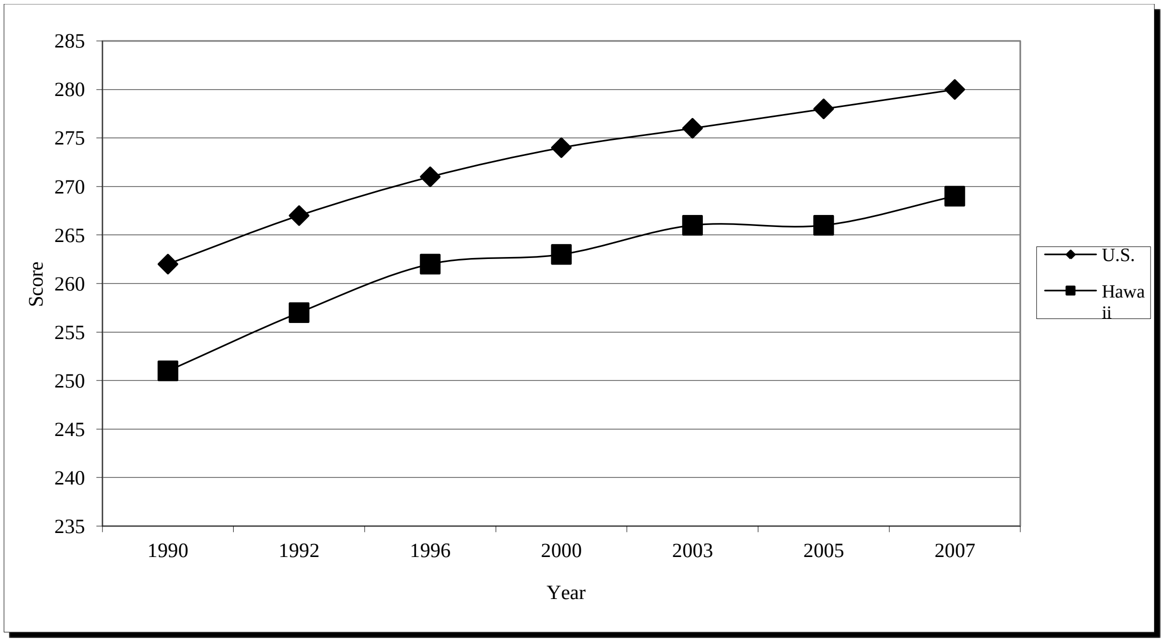

Figure 1. Trends in average mathematics scale scores for 8th-graders: Various years, 1990 – 2007* (Hawai`i vs. U.S.)

*The maximum score is 500 points.

Because the mathematical achievements of average U.S. secondary students on the international assessments were already discouraging, the NAEP scores of Hawai`i secondary students strongly demanded a need for meticulous evaluation of mathematics education in the state. The mathematical achievements of Hawai`i and U.S. secondary students, as indicated in the results of the NAEP test shown in Figure 1, were basically very discouraging

Hawai`i State Assessment (HSA)

The Hawai`i State Assessment (HSA) is an assessment initiated by the State of Hawai`i Department of Education (HIDOE) to meet the U.S. government requirement for compliance with NCLB. The assessment is carefully aligned with what is tested on the NAEP since the assessment is mandated by the U.S. government as is described on the HIDOE Webpage (Hawaii Department of Education, 2006)

> The Hawai`i State Assessment results shown below contain the scores of *all* children tested in the state. Although the data are used as part of the process for determining Adequate Yearly Progress (AYP) for a school, there is a key distinction between the results reported on this page and those reported on the NCLB page. For NCLB reports, results are provided for test participation, percent proficient for subgroups, and graduation/retention. For AYP participation rates, all children tested at a school are included in the calculations. For AYP proficiency, the data are "filtered" for students who have been at their school for a full academic year. This means that only the scores for tested students who have been at their school for a full academic year are used in the AYP proficiency analyses for a school. Thus, please remember that the results reported via the links below are for *all* children tested in the state. (p. 1)

The achievement of Hawai`i public school 10th graders on HSA for the last six years was tracked and compared with the achievement of West High School (WHS) 10th graders in Table 3.

Table 3

WHS Hawai`i State Assessment Mathematics Proficiency Levels for 10th grader: Years, 2002 – 2007

	Mathematics Proficiency Level (Meets + Exceeds)	
Year	State (Grade 10)	WHS (Grade 10)
2002	19%	13%
2003	18%	9%
2004	21%	18%
2005	20%	21%
2006	18%	14%
2007	29%	26%

The achievement of the research school (WHS) students was generally below state average scores except in the year 2005. In 2003, the school achievement was only half of the state average.

Given the fact that the achievement of Hawai`i state students on the NAEP test was not very hopeful, mathematics education at WHS appeared to be dreadful when consider how WHS students achieved on the HSA. As one of the school's mathematics teachers, the school's mathematics education needed serious structured to help improve the situation.

Conclusion

After considering the achievement of U.S. students on the national and international assessments, one can clearly understand Smith's (2004) belief that mathematics education needed to be changed and possibly reconceptualized.

> Mathematics education needs reconceptualizing because students know very little mathematics by the time they graduate from high school. Mathematics has become a subject to be feared and dreaded for centuries. […] Regardless of who is to blame, most students entering high school are not prepared to problem solve nor are they interested in mathematics except as the dreaded requirement needed to graduate. (p. viii)

If the achievements of U.S. students on these assessments are not comparable with their counterparts in other parts of the world, it is important to reevaluate and improve our education system.

Purpose of Research

Therefore, the purpose of this research is to disseminate the important of integrating technology into the secondary education mathematics classroom. This discourse, in distinction to previous research, sheds light on the practical implications of integrating technology into the classroom by highlighting the practices, insights, and lesson learned. The goal of this research is to encourage and assist teachers, educators, instructional developers, and educational researchers on future initiatives that involve integrating technology into secondary education mathematics classrooms. Specially, our research questions are:

1. Do teachers and students understand the role of educational technology in learning mathematics?
2. How do teachers and students use technology in mathematics classes?

> Naturally, technology has influenced mathematics education tremendously in the last decade. Unfortunately, many mathematics educators use technology as a crutch instead of using it to enhance mathematics education. (p. ix)

Many teachers usually think that they understand how to integrate technology into their instruction. However, research has showed that when some teachers used technology, it was obvious that they did not know how to use it effectively. Some of them were struggling with the idea of integrating technology for instructional purposes. Many teachers used technology mainly for presentation and communication purposes. That is different from using technology for instructional purposes.

The second research question addresses what types of experiences students and teachers have when they study mathematics with technology. Even though many researchers (Hughes, Packard, & Pearson, 1999; Tiene & Luft, 2002; Wilson, 2005; Hollebrands et al, 2010) have shown what type of technology tools have been used and what type of instruction has been implemented in what content area, it often is not clear what the participating students and teachers thought about (and what their experiences were) using technology tools in their learning and teaching.

METHOD

Participants

The participants in this study were enrolled in one of three mathematics classes – one Advanced Placement (AP) calculus class and two Advanced Placement (AP) statistics classes. There were 16 students In the AP calculus, 14 students in the AP statistics period 2, and 18 students in the AP statistics period 6. These classes were selected because the teachers were both interested in technology-integrated instruction. The two teachers and their students graciously agreed to participate in the study voluntarily.

In order to compare sample group with the general population of students who took AP mathematics courses statewide and nationally, a set of data collected by the College Board (2004). In the school year (SY) 2004-2005, 67.33% of the national test-taking student population was White and 16.74% was Asian. However, the mix of ethnicities in the state of Hawai`i was different from the national population: 74.51% of the Hawai`i population of test takers was Asian and 13.94% was White. Over 80% of both the national and state populations were White and Asian even though White prevailed in the national population and Asian prevailed in the Hawai`i population. (See Table 4.)

At first glance, the mix of ethnicities in the WHS AP mathematics classes was different from that of the national population, but resembles that of the Hawai`i AP classes (see Table 4): 70.83% of the WHS AP mathematics student population was Asian and 10.42% was White. The number of the Filipino students in WHS AP mathematics classes was very large and, for statistical purposes, the Filipino population was included in the Asian population.

Table 4

Comparison of the mix of ethnicities in WHS AP Classes to that of National and Hawai`i State AP Classes, SY 2004-2005

Ethnicity	U.S.	Hawai`i	WHS
Not Stated	6249 (2.19%)	44 (3.91%)	___
American Indian/Alaskan	1052 (0.37%)	4 (0.36%)	___
Asian/Asian American	47654 (16.74%)	839 (74.51%)	34 (70.83%)
Black/Afro-American	10595 (3.72%)	9 (0.80%)	2 (4.17%)
Latino: Chicano, Mexican American	9365 (3.29%)	6 (0.53%)	___
Latino: Puerto Rican	1294 (0.45%)	5 (0.44%)	___
Latino: Other	8050 (2.83%)	3 (0.27%)	1 (2.08%)
Other	8747 (3.07%)	59 (5.24%)	6 (12.50%)
White	191719 (67.33%)	157 (13.94%)	5 (10.42%)
Total	284725 (100%)	1126 (100%)	48 (100%)

One participating class was one section of AP calculus taught by a teacher (Mr. A), who had been teaching the same course for two years when this research was conducted. The teacher also had a certain level of interest in integrating educational technologies as part of his instruction. Due to the level of work the students were required to produce, they constantly used graphing calculators (Texas Instruments TI-83) on a daily basis.

In addition to the graphing calculator, the teacher also used Microsoft PowerPoint to present to the class the concepts of the lesson along with practice questions via television monitors connected to a computer provided by the school to every teacher. He also used television monitors as a presentation and communication tool by attaching a video camera to them through RCA cables. When he or his students were presenting their ideas and work to the entire class, that work was displayed by simply placing it under the video camera.

The other two participating classes were two sections of AP statistics classes taught by another teacher (Ms. B) who had been teaching the same courses for two years when this research was conducted. Ms. B was also interested in technology integration as an instructional aid for the classes she taught. However, her background and knowledge of the implementation of educational technology was rather limited when compared to Mr. A's. In her classes, she set up a TV monitor and video camera system, which she used as a presentation tool for the students. She also used a TI-83 graphing calculator to explain the concepts in class, and most of her students had TI-83 graphing calculators for their own personal use. She also utilized the overhead projector for her lectures and student presentations.

DATA ANALYSIS

The interview and observation data were analyzed using a triangulation method with five different sources of data. Grounded Theory (GT) (Christiansen, 2011; Glaser, 2002, 2004, 2011; Glaser & Holton, 2004) was also applied as a major data analyzing tool because of the type of collected data. The GT method was used to provide a learning experience for readers, as Boaler and Humphreys (2005) mentioned: “Teachers and researchers are finding that analyses grounded in actual practice allow a kind of awareness and learning that has not previously been possible" (p. 4).

According to Glaser (2002; 2004; 2011), GT involves comparing one segment of data with another to determine similarities and differences (e.g., comparing one statement from an interview about using calculators in mathematics education with another statement from another interview or observation).

RESULTS

Participating students believed that, overall, they had good experiences when using educational technology in their classes. When they were asked to respond to various statements that describe opinions regarding educational technology usage in school, they also strongly agreed with the statement that educational technology was beneficial to those who study mathematics and science. However, they disagreed with the claims that educational technology would benefit only those in vocational education or only college-bound students. Students strongly believed that educational technology would benefit all students as long as they used it to study mathematics or science.

There were 87 items on the questionnaire in total, but not all of them were related to the study focus questions. Therefore, responses that were not related to the focus questions were excluded in this evaluation and discussion.

To see the bigger picture drawn by the questionnaire responses, its items were clustered under three main topics and one special interest topic to evaluate alignment with other main ideas, which gave a clear baseline for the data analysis. For each cluster used, the actual question and the profile of it that shows how students responded to each item of that particular cluster. A summarized each cluster by explaining any outstanding finding from the cluster are as follows:

Focus 1: What roles do students and teachers report for technology integration? Why do they think those are the roles?

Table 6 shows all the questionnaire items that I expected to be related to the first topic of my study. The table was organized to include the item number, the question as asked in the questionnaire, and its profile. To help in understanding how students responded to each item, the actual percentage of students' responses in each category of the Likert-Scale (SA=Strongly Agree, A=Agree, D=Disagree, SD=Strongly Disagree, and NR=No Response).

Table 5

Profiles of the student responses to focus 1

Item #	SA	A	D	SD	NR
9	Educational technology should be available to all students who enroll in math and science.				
	76%	21%	3%	0%	0%
25	People who like computers like mathematics.				
	9%	24%	62%	6%	0%
64	Mathematics and computers go together well.				
	18%	74%	9%	0%	0%
67	People who like mathematics like computers.				
	12%	26%	50%	9%	3%

Students considered technology an important mathematics-learning tool (see items 9 and 64). Students considered technology integration to be an essential part of effective mathematics learning. I was surprised to find that more than 50% of students (items 25 and 67) did not think that people who liked computers liked mathematics and did not think that people who did not like mathematics liked computers.

However, few items asked students to indicate how they thought technology should be implemented into mathematics learning. Therefore, it was not able to find any specific way of integrating technology that students considered ideal for implementing technology into their mathematics learning.

Focus 2: *Do teachers and students use technology in mathematics classes?*

All the questionnaire items that were related to the second topic were organized in Table 7 according to the item numbers, with the actual question as given on the questionnaire.

Table 6

Profiles of the student responses to focus 2

Item #	SA	A	D	SD	NR
8	I have had experience with educational technology in a different class before.				
	62%	35%	3%	0%	0%
18	My experience with educational technology was positive.				
	41%	53%	3%	3%	0%
46	I have used calculators in my previous math classes.				

		62%	38%	0%	0%	0%
47	I prefer calculators to computers in mathematics class.	38%	53%	9%	0%	0%
58	It is easier for me to learn from the computer.	3%	26%	62%	9%	0%

Students mainly preferred to use calculators rather than computers in class: 91% preferred calculators (item 47). Students (94%) had positive experiences with educational technology (item 18). However, 71% of students said they disagreed with the statement that it is easier to learn using a computer (item 58).

Based on their experiences in multiple classes, students had positive experiences with using educational technology. They also have used technology to do their work outside of class. In other words, they do not have any problem with using technology and are willing to use it whenever they need to complete their work. In a separate item, they reported satisfaction with the way their teachers used technology in mathematics instruction. In most cases, teachers used calculators in mathematics classes. That is why every student in the classes had experience using a calculator. In addition to that experience, they felt comfortable using calculators in class.

In fact, when the researchers observed the class, the students used the calculator (the TI-83) extensively. They also used different types of technology tools for presentations. However, students used their calculators for study purposes throughout the class time. Teachers taught students how to use the calculator by demonstrating it. Once students knew how to use it, they used it constantly for their own learning and when they discussed work with their friends in class. The calculator was part of their daily learning activity.

Teacher Interviews

When interviewed the two participating teachers to discuss how they perceived technology integration into their instruction. To focus on those topics relevant to the study, a series of questions were given in advance as a guideline for the interviews. To analyze this set of data, Pre-selected questions helped the researchers to focus on key ideas that they wanted to find out during the interviews, and they also helped them compare the two teachers' responses effectively.

Question 1: What are your earliest recollections of educational technology as part of instruction in your entire teaching career?

1. Mr. A

The teacher had taught at three different schools. In the first school, he did not have much opportunity to use technology in his teaching. When he moved to the second school, however, he worked with other teachers in a team setting and used more technology in the classroom. He was a part of the team that did a project that was able to incorporate technology a little better. He used a commercially made computer software called *Algebra Animator* to teach mathematics and had many good memories about this particular software. He remembered using the software was kind of unique because students could physically see what was happening and what their number meant in the equations.

The teacher pointed out that visualization of the concept was strength of the software they incorporated to teach algebraic concepts. He learned how to visualize the concept by using this particular software. He added, "And kids got something out of it. I mean, they got to see how the equations worked or not. And it was a visual thing, which I liked."

2. Ms. B

Ms. B's earliest recollection of using technology was when she was in college. She primarily used a graphing calculator to teach mathematics. She used different models of calculator each year. She attended some workshops to learn how to use graphing calculators to teach mathematics.

Question 2: What are your professional experiences using educational technology as part of your research and teaching?

1. Mr. A

Mr. A learned by accessing information on the National Council of Teachers of Mathematics (NCTM) website and by subscribing to a magazine called *High School Mathematics*, an NCTM publication. He also searched the Internet for mathematical information in general. He had been reading both online and offline to understand effective ways of teaching mathematics because he believed that reading what other people do for better teaching through the Internet was helpful.

Then he talked about his communication through email with other calculus teachers across the nation, as he needed some tips to be a more efficient calculus teacher. He joined a listserv and constantly received emails from other Calculus teachers throughout the nation. He believed communicating through email helped him greatly. He was even able to communicate directly with the author of the textbook he used to teach his class.

When he taught the laptop program, his students did homework assignments on their computers. He incorporated Microsoft PowerPoint and Excel into his instruction. Students used PowerPoint to present their works and Excel to do their assignments. Students were required to prepare PowerPoint presentations for selected assignments. Students' solutions were shared, in class, when they had time. However, if they did not have enough time, their work was posted on a class Website.

Mr. A thought passing out and collecting assignments became more manageable with technology integration. When the teacher wanted to give lengthy information to students, he simply put the information on a disk and passed it around the class. When students received the information on a disk, they copied and pasted right into their hard drives. From the rubrics to descriptions and more, they received information. Students just needed to type it out. Mr. A thought technology integration was a neat experience.

Mr. A used Web pages to instruct and to communicate with the students and their parents. Another way to use Web pages was to inform and initiate meaningful communication between parents and teacher. He used a Palm Pilot to send out multiple emails with a very simple process. He explained, "With Palm, all you need to do is one or two buttons. It creates 180 emails in a few minutes and I connect to the computer and send it out. And I can do it in a short time."

2. Ms. B

Ms. B was somewhat experienced with graphing calculators, the Web, and an overhead projector in the past. When she started to teach the AP statistics classes, she began to incorporate the Web and the overhead projector. Therefore, her use of technology up to that point was very limited, to the graphing calculator.

She was using educational videos and a video camera to show examples. She also used her laptop computer with a TV monitor. One day, she wanted to use her computer and video camera alternatively by connecting to a TV monitor. She did not know how to use them. I explained to her how she could connect them by using a simple tool. I gave her a switch box and an extra RCA cable and showed her how to set it up.

Question 3*: What is your personal vision for the future of educational technology at High School/District/State DOE level?*

1. Mr. A

Teacher A emphasized the importance of preparing students for their future with technology skills because most professionals nowadays use computers to some extent. Therefore, he believed that the more we had it in the hands of the students, the better prepared they would be for their future. The teacher thought that using the Web would be an excellent way to give students more opportunities to access technology.

Teacher training would be one of the key factors for successful technology integration into curriculum. He believed that if teachers first get used to using technology tools for teaching, helping students to use technology tools for their learning would be much easier. Mr. A believed that it was important to train all the pre-service teachers at the college level. He was very skeptical about the situation because he had not seen many new incoming teachers who were ready for technology integration. He noticed that if teachers were not ready by the time they get to their classroom, it was not going to happen any time soon.

He thought that even though teachers might collaborate with each other in teaching, if they were not comfortable using technology, they would not integrate technology. He believed that many teachers were still not comfortable with using technology.

2. Ms. B

The teacher started with the idea of having her own mini computer lab in her classroom. She wanted to her students to be able to go online and “research” whenever they needed to. In addition to that, she envisioned all of her students having their own TI-83 graphing calculators.

She mentioned what teachers had in their teaching area. There were about four to six computers in each instruction area. The teacher thought that most students and teachers were using those computers to type up documents. To use the computers more meaningfully, she said she would use them as a search tool. She wanted students to look online for the concepts they were studying for better understanding while they were in class.

She believed that providing more training for teachers would be necessary for effective technology integration. However, she also thought that motivating teachers to participate in training was another very important key for effective technology integration. Ms. B wanted to learn how to use technology for teaching, but she hesitated because she did not know how to start. She was discouraged by the amount of time and efforts she thought she had to put in for effective technology integration.

To use technology more meaningfully, ample training and support were crucial. However, there were two technology coordinators at the school at that time. Therefore, all teachers and students could not receive proper assistance from them when they had questions or simply needed help. She believed that with some help from a technology expert, technology integration would be much more manageable.

Question 4*: How does your technology background influence your perception of using educational technology while you teach mathematics?*

1. Mr. A

This topic was covered in the previous discussion. Therefore, we skipped this portion. After he learned how to use technology tools, he had been using any available technology for his teaching. He used various software, Palm Pilots, and Web pages to teach students mathematics. However, he pointed out that teacher training was vital for meaningful and effective technology integration in class.

2. Ms. B

Ms. B was feeling comfortable with using the calculator as an aide as part of her lesson. She was using a video camera to show students what she did and what was on her calculator. She liked to use a video camera in class because she could show the calculator buttons while she explained how to use calculators.

She pointed out some of our math teachers don't know how to use the calculator. She believed that stay away from it because they don't have to use it. She thought that being able to see how calculators and other technology tools can help their lessons would encourage other teachers to integrate technology into their instruction.

She thought that teachers had to invest much time in learning how to integrate technology, and the amount of time they had to spend would influence teachers' perception of technology integration. She believed that spending too much time was one of the critical factors of and a major obstacle for technology integration in class.

I asked Ms. B why she was willing to use calculators and other technology tools even though she had to spend a significant amount of time with them. She told me some of her good experiences with using technology in her class as her answer. Technology integration would be more challenging for teachers who did not have a positive experience like she had. Ms. B expressed her subtle frustration and disappointment for the negative experiences that many teachers had had and how that prevented student learning in mathematics classes.

She thought that providing more professional development (PD) opportunities would help teachers learn how to use technology. Ms. B mentioned that she had more PD opportunities in her previous school. She wanted to attend more workshops to learn how to use a graphing calculator and other types of technology.

Ms. B believed that there were too many meetings for teachers and many of them did not serve their purposes. She talked about the meetings, "...you know make a department meeting instead of millions of meetings, none of them work or productive." She envisioned having a department meeting with a technology person in which teachers would learn how to use different technology tools. She believed each meeting should not be longer than an hour per session. Even though I believed it would be more appropriate to discuss this issue in another research, I wanted to mention it in this study because this issue would directly affect a teacher's attitude toward technology integration.

At this time, I felt that Ms. B firmly believed that teachers at this school were burned out because they had too many meetings to attend and very limited time to improve their instruction. She thought that if she knew how to use technology, she would use it more often and that would change the way she would instruct her students.

Question 5*: How does your technology background influence on students' learning mathematics?*

1. Mr. A

The teacher strongly believed that making technology available for each student was very crucial and that would be the beginning point of effective technology integration. He believed that students would have stronger ownership for their own work when they use technology tools. He picked the laptop program as a good example of using technology for learning mathematics.

He also had positive experiences with PowerPoint presentations. If he required students to use PowerPoint when they presented a problem, they thought about their problems differently and gave more thought before they presented their problem to the class. Even students who normally did not want to study mathematics began to think about mathematics problems more seriously and focused on problem solving when they used PowerPoint presentations.

He believed that the PowerPoint integration motivated students to complete the work thoroughly and they had a positive learning experience. He recognized the influence of technology when the quality of student work went up. He said, "You know, so, it was really unique to see that they are thinking at a different level."

I noticed that students spent more time preparing their work when they presented their work with technology tools. In addition to that, it would be challenging for students because they had to learn how to use new technology tools as well as the mathematical concepts they were working on. Students would learn mathematics better if they focused and persevered with solving given mathematics problems. If the learning process could be fun, students would learn more effectively since they focused on the problem longer. When students used technology tools for learning mathematics, they enjoyed learning more since they were doing work in unconventional ways.

2. Ms. B

When I asked if students would learn more because they knew how to use technology, she started to explain that students would learn better when students have technology in their hands. First, she said mathematics learning would be enhanced by the speed and accuracy when students use technology tools. She explained,

> Yes, because like discovery functions, how do you discover different functions unless you have some kind of graphing tool? To type in different functions, there is no other way to do it. I mean, yeah, you can do it by hand. We have worksheets we use but it takes forever and it's not instantaneous and as quickly as if they can see how the function is moving. It was opening and closing up and down, and of course they are going to graph that quicker than when they took them, and you know, an hour to just graph four different functions. And then they say, 'Oh, now I can see it.' So, I definitely think it enhances it, and it would help improve their retaining of the information.

Ms. B strongly believed that technology would enhance the communication between a teacher and students. She said students would ask as they work on problems. Some questions they frequently asked were "What did you put in?" "What's that?" "Is the function shifted?" She added that students would discuss with each other about the different functions, the way they are moving if they work with their graphing calculators. She strongly believed that technology would definitely increase the communication between them because it is instantaneous.

Question 6*: What do you believe motivates or would motivate mathematics teachers to use more educational technology for their instructional purpose?*

1. Mr. A

Mr. A believed having teachers visit and learn from each other was an important part of technology integration because it would motivate teachers to integrate technology into their instruction. He believed that, by watching good examples, teachers would use more educational technology for instructional purpose. When a teacher could visit and see how other teachers integrate technology, he or she would have a better idea of technology integration.

2. Ms. B

Ms. B's idea for motivating teachers to integrate technology into their instruction was to provide them with clear and simple instructions with many good examples. She emphasized the flexibility and the practicality of the application to accommodate the differences of teachers. She believed teachers would be more interested in incorporating more technology if they could learn how to use the tools without spending too much time.

Ms. B thought that not many teachers would change the way they taught even after an expert explained to them how they could incorporate technology in their curriculum and what kind of technology was available for them because they were simply too busy to integrate their own. Therefore, giving practical training with applicable examples would motivate them. She said that she had some of the technology tools in her classroom because not many teachers were interested in using them. She thought that having not enough time was a possible reason why not many teachers were interested in technology integration.

When I asked Ms. B how teachers could motivate students to use technology in their learning, she replied immediately,

> Well, having it available in classroom. These kids seem really interest in technology anyway. They all have a MP3 player; they all know how to do all these crazy things on computer already. They already got motivated by TV, you know, wanting to be upon current technology but I just think that having it available. A lot of them will get on there and figure things out without having needing an instruction and without it they can do it, you know.

She strongly believed that student were ready for technology integration in their mathematics learning. If tools were ready and available, students would use it for their study and if teachers were ready to use technology, students would be willing to as well. When technology was incorporated, the quality of teaching and learning mathematics improved.

DISCUSSIONS

When students used their graphing calculators, according to Tall (2002), they were moving from the iconic stage to formal-axiomatic mode in which,

> *Formal* proof comes into play, first in terms of local deductions of the form 'if I know this, then I know that.' What distinguishes the formal mode is the use of formal definitions for concepts from which deductions are made. (p. 7)

In order to present their thoughts and ideas to other students, those presenting needed their knowledge to be at the symbolic-proceptual stage.

When Tall (2002) and McGowen & Tall (2010) explained how students could build an embodied understanding of calculus through the use of local straightness and visual ideas of area, he mentioned two concepts--*a generic organizer* and *a cognitive root*--which were useful in building an embodied approach to mathematics (p. 12). According to Tall (2002) and McGowen & Tall (2010), when students used graphing calculators they experienced the two concepts. If students experienced a generic organizer, it enabled students to manipulate *examples* and *nonexamples* of a specific mathematical concept. In this study, students said that they could visualize problems and manipulate their problems and saw different outcomes when they used graphing calculators for problem-solving.

Tall (2002) and McGowen & Tall (2010) said a cognitive root was a concept which was potentially meaningful to the student at the time, but which contained the seeds of cognitive expansion to formal definitions and later theoretical development. In this study, for example, when students used their graphing calculators to zoom in and then zoom in further, they were examining local straightness. Students were able to both confirm their ideas and verify their solutions. As they solved given problems, each and every confirmation they had helped them understand the theorems and axioms they were learning as they completed their assignment.

I believe the similar experiences and understandings would be possible without technology, but technology integration made the process more understandable and clearer to students for several reasons, including, in particular, making it easier to visualize and facilitating cooperation.

In Tall's research, he pointed out four main stages of learning mathematics: graphic, numeric, symbolic, and verbal. I studied the collected data and sorted the connections between what I observed and what Tall (2002) and McGowen & Tall (2010) explained in his research. As he pointed out, students started formal learning by beginning with the initial deductive stage. In the three classes, I observed that students used their graphing calculators to begin the process by looking at the correct and accurate graph of the function or relation that is related to their problems. When they understood the problem by using graphical representations, they were able to process the problems symbolically or numerically. When the numeric and symbolic process was completed, they were able to verbalize what they understood. At this point, students were able to communicate with each other and share their thoughts and ideas in their presentations or through an informal cooperative learning process.

From the educational technology point of view, I looked for the "three primary curricular goals" discussed by researchers (Cradler et al., 2002; Cradler & Bridgeforth, 2005): achievement in content-area learning, higher-order thinking and problem-solving skill development, and workforce preparation.

The comparison between the research findings and the results of the collected data analyses indicated that the way teachers implemented graphing calculators and other educational technology tools helped students achieve the first goal; their graphing calculators helped students achieve better test scores in mathematics. Unfortunately, I found little evidence that technology integration in the three classes promoted higher-order thinking and problem-solving skill development. Technology integration did not appear to give students workforce preparation opportunity either. This was not unexpected because these students are mostly college bound.

COCONCLUSIONS AND RECOMMENDATIONS FOR TEACHER EDUCATION

Training teachers on how to use specific technology for their own teaching content would be more effective instead of teaching how to use technology in general. Students strongly indicated that when teachers used technology in their instruction, teachers' demonstrations of specific steps in graphic calculator functions and uses helped students learn better and reduced instructional time. Providing teachers with numerous opportunities to observe how other teachers actually use technology in classroom settings would be one of the most effective ways to prepare teachers to use specific technology tools for teaching particular concepts. Offering mini hands-on workshops would be another way to prepare teachers. However, developing and offering different workshops according to what each teacher might need more specifically would be very challenging. To accommodate what teachers need without putting in too much time, effort, and resources, on the part of both teachers and their trainers I would like to recommend that a collection of various video sessions be developed for training in each technology as an ideal and practical solution (Lu & Rose, 2003). One of the participating teachers suggested that teachers visit each other on a regular basis for a similar purpose. However, requiring teachers to visit each other could increase expenses and cause other unforeseen challenges.

Good teacher education programs for secondary mathematics teachers should include several areas of training: technology tools, learning labs, and opportunities for observation and reflection. First, technology tools are necessary; while they study in colleges of education, all pre-service teachers should own or have access to software they would need to use when they teach in their own classrooms. Second, pre-service teachers in colleges of education would benefit from learning labs. In such labs, they should have opportunities to practice, and discuss what they found about or what they did not understand regarding, the use of certain technology tools, which they can practice using in class, at home. All pre-service teachers should have many examples of how to use technology and time to observe and reflect on using that technology. When they want to see how technology integration can be done effectively, they should be able to access the examples and compare them with what they are actually doing in practice. As they reflect upon what they can improve for their own technology integration, pre-service teachers would prepare themselves more effectively.

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