Prospective Mathematics Teachers' Views on the Role of Technology in Mathematics Education

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Abstract

It is important for future teachers of mathematics to distinguish between technology as course content to be taught and technology as a teaching tool. This exploratory study examines prospective teachers' views of the role of technology in mathematics education before, during, and after their experience in a mathematics class that focused on technology in mathematics education. In particular, the researchers explore participants' views of mathematical content technology may aid in the teaching of and their views of the teacher's role in a class were technology is utilized.

Introduction

The last two decades of the twentieth century were marked by the advancement of technological aids in mathematics education. Graphing calculators, computer algebra systems, the World Wide Web, and more recently dynamical software paved the way for radical change in the way mathematics is taught. The variety of resources available and the lack of readiness of instructors to utilize these resources prompted many national and international organizations to set standards for the use of technology as a teaching tool in mathematics classrooms. Since then, much research has been published on the effect of technology on the learning process of the recipients (i.e. the students) assessing both its benefits and its limitations (Abboud & Habre, 2006; Habre, 2000; Laborde, 2001; Quesada & Maxwell, 1994). Research on teachers' views and readiness to incorporate technology in the teaching of mathematics is not as extensive (Lagrange et al. 2003). According to Schwartz (1989), the role of the teacher as the primary user of technology in the classroom is critical, and technology "provides a setting and an occasion for conjecture and creativity for both student and teacher in the mathematics classroom" (p. 51). Heid, et. al. (1990) considered the teacher in a technology-based classroom a "facilitator" of knowledge, while other research results noted that the use of technology might present problems for teachers who are accustomed to a certain routine of instruction (Healy & Hoyles, 2001). Thus, as Monaghan (2004) says, understanding the actual situation of the few teachers using technology is a major and complex issue. Even though the new generation of teachers seems to have a positive perception of technology (Abboud-Blanchard, 2005), "teaching with digital tools does not simply mean considering the software and hardware used" (Monaghan, p. 339). Teachers' own learning experience and practice with technology must reflect on their teaching practices using technology (Crisan, 2005). In addition, teachers face two main issues if and when they decide to use technology in their classrooms: deciding on the software programs to use and, most important according to Laborde (2001), the design of student tasks. On the former issue, Hall & Martin (1999) warned that instructors often lack the training and know-how to select the software that is appropriate for their classroom instruction, and on the latter, Doerr and Zangor (2000) state that a teacher's confidence in her knowledge about the calculator's capabilities [or any technology for that matter] and its potential for student learning is crucial in the way the lesson and activities are structured. To complement past research, our study explores the way prospective mathematics teachers at

the secondary level perceive the importance of technology in their future classrooms and how they design activities intended to utilize technology in a mathematics classroom.

Methodology

The Class

The target class of our study is a junior level, 4-unit course (Technology in Mathematics Education) offered at a large university in the United States following the quarter system, so the course was approximately 10 weeks. The course is designed for prospective mathematics teachers and is intended to allow participants to explore technologies that may be utilized in their future teaching career, and to reflect on the role of these technologies in mathematics education. The two sections of the course observed for this study consisted of 29 participants; twenty of them were mathematics majors and all but three planned to become teachers at some level, with 15 participants intending to teach high school mathematics. The class was organized around content rather than technology and the three content areas covered were geometry, probability and statistics, and algebra. The main computer software programs used were: The Geometer's Sketchpad, Fathom, and Excel. Other technologies employed were graphing calculators and the World Wide Web.

The instructor of the course typically introduced the technology that would be employed in a given content area and prepared class activities that often aimed at enhancing the learning of mathematical concepts. The instructor also attempted to develop the participants' skills in evaluating the educational potential of each technology employed. The participants were required to hand in homework (based on class activities), prepare three detailed lesson plans (one in each content area), and critique two articles on the teaching of mathematics using technology. Lesson plans allowed participants to demonstrate what role they envisioned technology would play in their future classrooms and they received structured critique of their work.

Although knowledge of software programs is vital for preparing lesson plans and student tasks, a limited amount of class time was spent on learning these programs; however, participants were expected to independently attain a certain level of mastery of the programs used. This strategy was in line with the course learning outcomes that emphasize the effective use of technological aids for the learning of specific content areas and the critical role of the teacher as the principal user of technology in the classroom. Class explorations often required that prospective teachers analyze what activities would be like if the software was not available, or think about various means to present mathematical ideas. In algebra for instance, the sine wave was constructed using GSP through an animation process that relates the unit circle to the graph of the sine function. Activities were generally followed by whole class discussions on the pros and cons of the software, on mathematical properties not covered by the class activities that can be explored using the software, and on whether the use of technology in a specific activity aims at teaching the mathematics or the technology.

The Research

The main questions addressed in this exploratory study of prospective teachers' views are: What role do these participants view for technology in a mathematics classroom, and how do these participants view the role of the teacher in a class where students are utilizing technology? Data collected to investigate these questions included classroom observations, the results of a survey administered at the beginning of the semester, and copies of participants' homework assignments, lesson plans, and article critiques. The survey gathered information about the participants' initial views on the importance of technology in the teaching of mathematics, in particular, the teaching of algebra and geometry. In addition, two well-structured interviews were conducted with four participants who volunteered to

participate in the study. The goal of the interviews was to develop a deeper understanding of participants' views related to the exploratory research questions. The interviews also gave the participants a chance to discuss the lesson plans they had developed for class and their beliefs related to class discussions that had taken place. In this paper we chose to focus on two of the interviewees: Tessa and Jay. The two participants are mathematics majors who intend to teach at the high school level. Results related to these two participants were typical of the four interviewees. The combination of whole class data and interview data allowed the researchers to develop a rich description of the class views related to the two research questions.

Results

The Survey

As Criscan (2005) suggests, prior experiences with technology may influence (positively or negatively) students' views. Prior experiences of these participants ranged from having used graphing calculators (10 participants in all) to being exposed to a variety of software programs for various courses (e.g. Excel, Minitab, and even Mathematica). Participants' evaluations of using technology were mixed, "I had a teacher show us things on the screen using Mathematica and I actually found it frustrating a bit. I didn't understand the program which almost distracted me from learning the actual math", and "For a geometry class, we used a program on the web that helped us to visually understand hyperbolic geometry. Before then, I had no idea what hyperbolic geometry was." The survey results also suggested that all participants believed technology could be helpful in the teaching of geometry, mainly as a tool for visualization and exploration. However, fourteen participants did not believe technology could aid in the teaching of algebra, mainly because they considered algebra as "a lot of arithmetic that must be learned by doing it by hand."

Seven participants objected to the statement, *Mathematics teachers should teach students how to use related technology in mathematics classrooms*. In their opinion, mathematics should be the emphasis in a classroom as expressed in the following quotes: "This is dangerous because the technology could easily become the focus and not the mathematics concepts behind it", "Students rely too much on calculators rather than their own brain", and "They got by on slide-rulers for years, and the abacus before that. The technology is not as important as the math. If you've got time, there is no harm in doing it." The majority of participants who agreed with this statement did so for reasons that are not related to the learning process. For example, they suggested that technology "can help students pursue subjects further than the way presented by the teacher" and technology is a supplemental tool "necessary to continue into higher mathematics."

All but four participants agreed with the statement, *Mathematics teachers should use technology to help teach students mathematics in mathematics classrooms*. Those who agreed gave various justifications. Six participants said that technology should be viewed as a tool, not the subject itself, and made statements similar to "This is a better idea because the mathematical concepts remain the focus." Other justifications included that lectures can be boring and technology helps add some flare to the classroom. Three participants agreed with both statements and one response stood out: "I agree with both statements because students have different learning styles; as a result, it is important to incorporate all the tools available to help students have a deeper understanding of mathematical concepts."

These results reveal a major concern among participants, namely that mathematics and not technology should remain the focus of instruction in mathematics classrooms. Most participants showed concern that technology should not be the core but rather a tool; and although the majority agreed with the statement that technology should be used in a

mathematics classroom, only one participant gave a valid pedagogical argument, namely that students have different learning styles.

Participants' concern for focusing on the mathematics instead of the technologies used in the classroom surfaced constantly in the discussions that took place in class. For instance in one assignment, participants were asked to tessellate the plane using both GSP and a web-based Java applet. For many participants, the mathematics behind tessellation was lost while using the Java applets because the applet did not require them to utilize their mathematical knowledge. On the contrary, using GSP one has to perform translations and/or rotations. Consequently, as one participant put it "the math behind the seeds" is learned. Still, many participants thought that "there would have to be great care going into the way the activity is presented" and that the activity "needs to be a guided one as opposed to sending them off with a list of instructions." The remaining data will show, however, that participants needed the entire course to describe classroom situations where technology was being used primarily as a tool to teach mathematics.

The First Lesson Plan

Three weeks into the quarter participants handed in their first lesson plan. The focus of the lesson plans was geometry and participants were asked to incorporate appropriate technology in the teaching process. Participants chose their own grade level and their own topic. In all, there were 11 lesson plans (participants were allowed to work jointly) collected as data for this study.

For the majority of participants, the technological aspect of the lesson plan was restricted to the *measuring* and *construction* capabilities of Geometer's Sketchpad as *discovery* tools for mathematical concepts. Table 1 below summarizes the objectives and tasks of the first lesson plan. For example, in Tessa's plan the number π was to be *discovered* by *measuring* the ratio of the circumference of an arbitrary circle to its diameter. The learning outcomes of her plan were "to take an extremely abstract concept and be able to put a visual application and understanding on the meaning of π." Jay's lesson plan used the *animation* feature of GSP to animate one endpoint of a chord along a circle while keeping track of the *measurements* of the chords, to notice among other things that the diameter is the chord with the largest measure. One may conclude, therefore, that none of the lesson plans aimed at teaching the technology, but rather all used GSP to teach mathematics. All plans included discovery questions, but technology was employed mainly for the sake of visualization and computation while only one lesson plan utilized the dynamic nature of the software.

Table 1: Use of GSP in the first set of lesson plans

Topic (# of plans)	**Use of GSP**
Alternate Interior – Exterior Angles (1)	Basic Construction / Measuring
Interior angles of Triangle/quadrilaterals (2)	Basic Construction / Measuring
Estimating Pi (4-Tessa)	Basic Construction / Measuring
Estimating area of a circle (1)	Basic Construction / Measuring
Area vs. perimeter of a rectangle (1)	Basic Construction / Measuring
Diameter vs. chord (1-Jay)	Basic Construction / Measuring Dynamic use of software
Understanding the circle (1)	Basic Construction

The Second Lesson Plan

The subject of the second lesson plan was the incorporation of technology in the teaching of probability and statistics and was collected around the middle of the quarter. Nine such plans were collected. Technology was again employed as a tool, but unlike the first set of

lesson plans, the software programs (Excel, Fathom, and Java applets) were generally used to *analyze* concepts and data. Table 2 below illustrates the topics, the use of technology, and the questions prospective teachers posed in the second lesson plans.

In Tessa's plan, students were to collect data from thermometer readings in two different settings and discuss the equations that fit the data. Activity questions required the investigation of possible linear, quadratic, exponential, or logarithmic fits, and students were then asked to find the best fit, and to *analyze and explain* any outliers in the data. The learning objectives of Jay's second lesson plan were to *calculate*, *identify*, and *interpret* the mean and median for given data sets. Jay suggested recording the hits of a baseball player and then measuring the batting average (mean) of the player, to conclude among other things the best/worst player in a baseball game. To find the median, Jay suggested working with various lists of numbers, then proposed changing one number in the given set of data by a large factor and re-calculating the median.

Table 2: Characteristics of the second set of lesson plans

Topic	**Use of Technology**	**Analysis Question**
Real life data (Tessa)	Scatter plot/Linear fit	Is a linear fit best for validity of media information?
Coin flipping/random variables	Histograms	Relative frequency of events
Data collection	Histograms	Relative frequency of events
Batting Averages (Jay)	Mean/Median/Mode	Best/ worst player
M&M's	Bar Graph (Excel)	Ratio of colors to line graphs of M&M bag
M&M's	Pie charts (Java Applets)	Probabilities and percentage errors
Sample set	Mean/Median/Mode	Meanings
Random babies	Probability (Java Applet)	Long term frequency of an event
Survey	Pie chart; bar graph	Predicting probabilities and best graph type

The Third Lesson Plan

The subject of the third lesson plan was the incorporation of technology in the teaching of algebra. Seven lesson plans were collected during the ninth week of the quarter. Technology in this set of lesson plans was again used as a tool to aid in *computation* and *visualization* and the type of questions posed varied between *investigative* and *explorative*. Table 3 highlights the characteristics of participants' third lesson plans including the type of questions they posed for students to explore.

Table 3: Characteristics of the third set of lesson plans

Topic	**Use of Technology**	**Type of Questions**
Vertices and intercepts of quadratic functions (Jay)	Locate points using the point tool in GSP	Investigative
Changing coefficients of a quadratic function	Animation using created sliders in GSP	Investigative
The opposite vs. the reciprocal function	Reflecting a graph across the x-axis using GSP tools	Investigative
Real world problems with linear equations (Tessa)	Linear fit, intersections, and slopes of lines in Fathom	Exploration
Slope and intercept of a line	Drawing lines with the line tools in GSP	Exploration
Ordered pairs in the plane	Graphing ordered pairs in GSP	Exploration
Vectors and matrices	Construct parallelograms using vectors in GSP	Investigative

Connecting real-world problems with linear equations was the focus of Tessa's plan. To accomplish this task, either Excel or Fathom may be used to graph data tables, draw a linear fit, and *explore* the implications of different slopes and intersections of lines. The learning goals of the lesson plan are achieved through very detailed and well-designed student activities. In Jay's plan, GSP was used to *explore* the shape of a quadratic function, and introduce the concepts of vertex and x-intercept by locating the points on its graph. Class activities developed by Jay included an *investigative* activity where students explore whether quadratic functions that have no x-intercepts exist.

In summary, the data from the three sets of lesson plans suggest a development in participants' use of technology. Participants initially employed the software primarily for measurement and construction purposes, but later began to incorporate more creativity in their use of technology and began to recognize more mathematical content areas that could be taught effectively using technology. On the survey, participants did not articulate a role for technology in the teaching of algebra because "it is mostly working with numbers and should be treated as such", and that "there is no need to bring extra aid for algebra...even calculators will hurt the student trying to learn algebra." Participants' creativity in their algebra lesson plans contradicts this attitude about the importance of technology in the teaching of algebra.

Results from Interviewed Participants

Being able to write lesson plans is important, but it is vitally important that participants are able to reflect on how these lesson plans will be incorporated in the classroom and that they understand their role in a classroom situation where technology is being used. Interviewees presented their opinions of the role of technology in the teaching of mathematics, discussed their own experiences as students in a math class where technology was employed, and shared their views of the teacher's role in a classroom where technology is utilized. The results from Tessa and Jay are typical of the beliefs of the whole class and are discussed in detail below. The interviews took place during the fourth and eighth or ninth week of the quarter.

Tessa

Tessa began the first interview by saying that technology is "very useful" and "key" in a mathematics classroom. She elaborated on this statement by referring to her own experience as a high school student using the TI-83 graphing calculator in class. Tessa thought her instructor was able to enhance the lesson plan with the TI-83, but she added that "some of the things were lost", probably because punching "things into the calculator and getting the answer out" is a kind of cheating. Tessa's experience with technology has helped her formulate an opinion about the subject, and therefore during the first interview when she was asked how she would incorporate technology in an algebra class, she emphasized that learners should understand concepts and work using pencil-and-paper before adding the technological component, which "makes it easier to visualize." Tessa was less adamant, however, about the manual explorations in the teaching of geometry. The learning objective for using GSP to teach mathematics was restricted in Tessa's mind to visualizing figures and operations, such as translations and rotations.

While discussing her role as a teacher using technology, Tessa revealed a "bad" experience she had in a classroom:

> "I have had teachers where, because of technology, they have backed out. They would kind of just set us up in a computer lab with a list of instructions and half of us knew what was going on, half of us did not."

Therefore, in her opinion her role as a teacher should not change, and "technology is just another tool to use in your interaction and instruction of the subject." Tessa hopes to use technology in her classes, but she sounded uncertain about the approach to follow. She liked the way GSP and other tools were incorporated in the course assignments, yet she felt that because she has the mathematical background, she was concentrating on the technological aspect of the course. In accordance with the findings of Doerr and Zangor (2000), it appears that Tessa is in some ways also concerned about her knowledge of the technology employed and what it can offer in order to enhance her lesson planning.

Tessa's responses during the second interview implied that she had reflected on the role and importance of technology in mathematics education. In her opening statements she said, "I would definitely integrate it [technology] more readily than I would have beforehand." She added that, while she hasn't formed specific ideas, the class has given her the tools to incorporate technology in the classroom:

> "I think, even just having the opportunity to learn some of these technologies like GSP, I probably wouldn't have sat down and figured it out by myself, you know? I may have, but I doubt it. I probably would have just stuck with the calculator, but now I feel like I have been given tools."

While discussing her lesson plans, Tessa stated that she was able to "add more depth" to the statistics lesson plan. But she admitted that incorporating technology in an algebra lesson plan was more difficult: "How could I use this to help them visualize graphs? What exactly do I want to teach? Is the technology point worth adding it?"

Unlike the first interview, Tessa had formulated a clearer vision of the role of the teacher in a mathematics classroom where technology is utilized and suggested that the teacher's role is more critical and challenging when utilizing technology:

> "Actually it takes almost more to be able to engage them on the computer… I think it takes almost more planning, in a way, being aware of who is getting lost, and who is not; so I think you almost have to step it up a notch in a different way, as a teacher using technology."

During the quarter Tessa had continued to develop her views of the role of technology in mathematics education. The second interview suggests that she is more committed to using technology in the classroom and that unlike the first interview she sees the teacher's role as being different than in a traditional mathematics classroom. The interview results also suggest that Tessa was considering important questions as she was writing lesson plans, questions that will help her develop quality plans for her future students. Consequently, Tessa succeeded in writing quality lesson plans that focused on using technology to teach mathematics. As a result of the course, Tessa has developed a view of the necessity of technology in mathematics instruction and has begun to articulate specific situations where technology will be beneficial, and specific uses of technology that will enhance student learning.

Jay

During the first interview Jay articulated a deep appreciation for and some potential roles of technology in a mathematics classroom, and shared his own school experience to justify his inclinations. For example, Jay stated that a lot of students have "a really tough time with math", but being able "to see a physical representation of something" is very helpful. Jay suggested that technology can not only benefit the learning of geometry, but also the learning calculus: "putting different values for a, b, and c in a quadratic formula and seeing the effect", or instantly getting the derivative of an equation and being able "to see them all [function, derivative, second derivative] plotted on a graph simultaneously at your command, I think it will make it easier for people to grasp."

Jay's views for utilizing technology in a classroom are similar to Tessa's. He stated that he will use just enough technology in the classroom "to help them [students] understand it [the math]", and he cautioned that at the high school level students might depend on technology to perform better. In Jay's high school, graphing calculators were used in math classes, but mainly for computational purposes; in his words, "I wished to look at graphs and answer some of the questions without having to do any of the computations." At the end of the interview, Jay hoped that using technology will change peoples' perception of mathematics.

The second interview discussion focused on the lesson plans Jay wrote for the class, on the role of technology in the classroom and the role of the teacher who is utilizing technology in a classroom. In his second lesson plan, Jay used technology to help students understand mean and median. While describing the plan Jay stated, "...we kind of posed questions that they would do on computers, like what happens if you add a 100 to the set of data? What happens to the average and the median?" Jay suggested that answering such a question "... furthers the comprehension of what average is and what it looks like." His third lesson plan utilized GSP to graph functions in the coordinate plane and Jay stated, "It is not really using technology to teach these subjects; it is just making the graphing a lot easier for them." Thus, Jay was viewing technology as a tool to make computation and visualization easier.

While discussing the role of technology in the classroom, Jay suggested using it more during lecture than in activities, "or maybe small in-class activities." His hesitation to use technology beyond lecture is because any class activities that utilize technology need to be "well organized, well thought out so that the learning [of mathematics] doesn't get lost." The second interview also revealed that Jay does not see a different role for the teacher in a classroom where technology is utilized. Jay believes that with technology, students could do more explorations, "…but will that exploration change the student-teacher role; probably not – maybe. I don't know if I can make that tie yet in my own mind, from what I know about it." He then added: "If students and teachers were both to take on a leading role, the teacher wasn't the authority figure in the classroom, then that would probably be a good thing. Is technology going to do that? I mean…I wouldn't think so."

During the quarter, Jay developed a view that technology could aid in computation and visualization, and broadened his understanding of situations where technology could aid in the teaching of mathematics. While Jay seems poised to utilize technology in these situations, he is still uncertain of what role technology will play in the classroom. Whether he will use technology to aid in lecture, as the focus of class activities, or as a tool to broaden the students' comprehension of mathematical concepts is still unclear. This conflict for Jay became obvious when he said in the second interview that technology is only used to make "computations easier" and "graphing a lot easier." This contradicted Jay's first interview where he elaborated on the usefulness of technology to explore quadratic functions and the effect of the parameters on the shapes of these functions, and on the importance of technology in viewing the graphical relationship between a function and its derivative. His comments are also not reflected in the development of his lesson plans. Finally, Jay has had difficulty determining his role in the classroom if he utilizes technology and hasn't been able to view technology as a tool to create a student-centered classroom.

Discussion

The results from the two individuals interviewed present a development of views of the role of technology in mathematics education similar to the rest of the class. In accordance with the survey results, these participants began with a view that technology should be used to teach mathematics and should not be the focus of instruction in a high school classroom. Their initial views regarding the use of technology in the classroom are based on their past

learning rather than their teaching experience. Therefore, not only do they lack the practical assessment for using a technological component as a complement to traditional teaching, but also in many ways their own learning experiences have provided them with a pre-disposed set of ideas and beliefs regarding the use of technology in the teaching of mathematics. For instance, many of the participants did not initially view a large role for technology in the teaching of algebra; as one participant said: "these are mostly equations classes… at least this is how they were taught to me." Class discussions early in the quarter also revealed that the focus while doing the class activities was "to get the technology down", while one participant commented "it is hard to learn the technology and the math." These observations are in line with other research results. The instructors' practices researched by Monaghan (2004) revealed a concern that "tasks in technology-based lessons led their students to focus on the technology…at the expense of the mathematics."

As mentioned earlier, the design of student tasks is more important than the new way of teaching mathematics (Laborde, 2001). How successful was the instructor in designing the activities? For many participants the activities and the class discussions constituted a median to think about the various technologies and where, how and when each can be used. Other participants suggested that the learning goals of the activities should have been discussed in advance. However, the class provided participants the opportunity to develop their views of mathematical content areas where technology could play a positive role in student learning, and to be creative in developing exploratory lessons that incorporated technology to teach mathematics. While the first lesson plans mainly focused on using technology as a computational tool (and only one lesson plan focused on the dynamical nature of the software as a learning tool for students), the second and third sets of lesson plans employed software programs to visualize, investigate and analyze mathematical ideas. Although the subjects of this study articulated ways to incorporate technology, they generally struggled to clearly define the role of the teacher when utilizing technology to teach mathematics.

Participants' lack of experience teaching mathematics or even observing mathematics classrooms may have hindered the development of their views about the role of technology in a mathematics classroom. The majority of participants in the class had strong mathematical backgrounds and hence were able to articulate creative ways to explore mathematics using technology. Their lack of experience teaching mathematics may have caused participants not to realize the pedagogical potential of the dynamic nature of the software. This deficiency almost certainly hindered participants from being able to describe the teacher's role in a classroom where technology is utilized. Based on these results, it seems feasible that a course of this nature has the potential to begin the prospective teachers' necessary reflection on the role of technology in mathematics education. The results also suggest that such a course should be combined with authentic activities that allow prospective teachers to relate what they are learning to mathematics classrooms. These authentic activities could include watching videos of classroom situations, becoming familiar with adopted curricula in local schools, talking to local teachers, adapting school curricula to include technology, and developing and implementing potential activities that utilize technology to teach mathematics in a local school.

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