MATHEMATICS TEACHER ROLES WHEN USING TECHNOLOGY:

UNDERSTANDING THE ROLES OF FACILITATOR AND MEDIATOR

by

STEPHEN BISMARCK

(Under the Direction of James W. Wilson)

ABSTRACT

Investigating the effect technology has on the secondary mathematics classroom instruction has been a growing topic in mathematics education since calculators and computers became readily available to students and teachers. Most of the focus has been on students' use of technology to enhance their mathematical knowledge, while teacher use of technology during instruction has had limited research attention. The purpose of this study was to further understand the emergence of the roles of facilitator and mediator when secondary mathematics teachers used technology during instruction. The teacher role while using technology framework was a blend of Monaghan's (2004) teacher roles and Zbiek, Heid, Blume, & Dick (2007) mathematical activities framework.

Observations of three high school mathematics teachers, Bill, Joanne, and Mary, guided the discussions during individual interviews. Participants were selected because they were enrolled in or recently graduated from a technology rich mathematics education program. This selection was done to maximize the possibility that the participants knew how to use technology with the mathematics curriculum being taught. Individual pre- and post-interviews, video recordings of observations, and field notes were among the data sources. Participants were observed teaching four lessons, with varying schedules to accommodate each participant. Predetermined and emergent coding schemes contributed to comparative data analysis.

The findings of this study show that not all participants took on the same role while teaching secondary mathematical activities. Conceptual and procedural mathematical activities affected the participants' role while teaching with technology. An emergent theme of the source of mathematical activities, internal or external, helped illuminate the development of teacher roles while using technology. Procedural mathematical activities were found to only contain external sources of mathematical activities while conceptual mathematical activities contained both internal and external sources. A connection was established while comparing the source of mathematical activities with the teachers' roles while using technology. The analysis indicated that the facilitator role was only observed when teachers' had conceptual mathematical activities that involved internal sources. When an external source was observed, the teachers' role was found to be that of a mediator.

INDEX WORDS: in-service mathematics teachers, technology, teacher roles, mathematical activities, sources of mathematical activities

MATHEMATICS TEACHER ROLES WHEN USING TECHNOLOGY:

UNDERSTANDING THE ROLES OF FACILITATOR AND MEDIATOR

by

STEPHEN BISMARCK

B.S., Coastal Carolina University, 2002

M.A.T., Coastal Carolina University, 2003

A Dissertation Submitted to the Graduate Faculty of the University of Georgia in Partial Fulfillment of the Requirements for the Degree

DOCTOR OF PHILOSOPHY

ATHENS, GEORGIA

2009

MATHEMATICS TEACHER ROLES WHEN USING TECHNOLOGY:

UNDERSTANDING THE ROLES OF FACILITATOR AND MEDIATOR

by

STEPHEN BISMARCK

Major Professor: James W. Wilson

Committee: Jeremy Kilpatrick
Dorothy Y. White

Electronic Version Approved:

Maureen Grasso
Dean of the Graduate School
The University of Georgia
May 2009

DEDICATION

To my family

To my mother and father who taught me the importance of hard work and perseverance and especially to my wife for her love and support while I finished my doctorate.

ACKNOWLEDGEMENTS

I would like to thank Dr. James Wilson, Dr. Jeremy Kilpatrick, and Dr. Dorothy White for serving on my doctorial committee. Your insights have opened my eyes to many interesting topics in mathematics education, especially the use of technology in the secondary classroom. I am grateful for being given the opportunity to work critically with both pre-service and in-service teachers through assisting mathematics education classes and working with the center for proficiency in teaching mathematics. Special thanks to Dr. Wilson for his time, patience, and guidance in improving my dissertation.

TABLE OF CONTENTS

LIST OF FIGURES

Page

CHAPTER 1

INTRODUCTION

Mathematics teaching practices have been changing for the last few decades. Research shows that teachers are stepping away from the chalkboard or whiteboard and stepping into the realm of calculators, computers, and interactive whiteboards (Cyrus & Flora, 2000; Dion, 1990; Goos, Galbraith, Renshaw, Geiger, 2003; Guin & Trouche, 1999; Hollar, & Norwood, 1999; Hoyles, Noss, & Kent, 2004; Lavy & Lebron, 2004; Masalski, 2005). Even with all of the changes in the instructional practices that mathematics teachers make with technology, little attention has been given to the role teachers take on when using the technology and the curriculum they teach.

The National Council of Teachers of Mathematics (NCTM, 1989, 2000) has made recommendations to refine the present mathematics curriculum to include more depth of understanding mathematics. Reform mathematics also known as standards-based mathematics curriculum came to be based on these recommendations. Different secondary mathematics standards based curriculums (Core-Plus, Interactive Mathematics Program, Mathematics Connections, SIMMS Integrated Mathematics, and University of Chicago School Mathematics Project) do not use many of the technological resources mathematics to which teachers have access (Eron & Rachin, 2005; Senk & Thompson, 2003).

A standards based curriculum can be found in some schools, but the traditional computational based curriculum still dominates. The task of implementing the technological resources and the roles while using technology in a procedural curriculum is left up to the teacher. Teachers' judgment for the implementation of technology into their teaching practice then rests on their knowledge of technology, knowledge of mathematics, and knowledge of teaching (Niess, 2005).

The NCTM *Principles and Standards* (2000) begin to address the placement of technology in the mathematics classroom through the technology principle. In this principle the ideas of effective use of technology, appropriate use of technology, and teacher knowledge, are addressed. The NCTM emphasizes that for teachers to be effective in their use of technology they must possess a deep knowledge and understanding of the mathematics they are teaching and be able to draw on that knowledge continuously. The emphases are on how technology is used and teacher knowledge of curriculum. How the use of technology can differ from topic to topic at the secondary level and the roles teachers take on while teaching with technology were not explicitly addressed.

Purpose of the Study

The motivation for this study was brought about by reading a comment by Monaghan (2004) in his paper dealing with teacher's activities in technology-based lessons. He disagreed with the claim that using technology in teaching is straightforward and that teachers using technology relinquish didactic roles and move to become facilitators. There are several books devoted to helping teachers use technology in their classroom that reference the ability technology has to change teachers' traditional roles to become facilitators (Bitter & Pierson, 2002; Heinich, Molenda, Russell, & Smaldino, 2002; Shelly, Cashman, Gunter, & Gunter, 2002). Unfortunately, these books are focused on showing teachers how to operate the technology and do not get into detail on how to become facilitators with the mathematics. Through my own experiences as a graduate assistant involved with teacher preparation and as a secondary mathematics teacher, I was unsure about my stance on the claim. I have seen mathematics teachers embrace technology in their practice but could not make a confident claim that they were facilitators. Unlike Monaghan, I wanted to look at secondary mathematics teachers who had experience with technology through their teacher preparation and in the classroom. I was also interested in investigating any connection that mathematics has with the roles teachers take on while using technology. I wanted to perform a study that did not focus on students' learning and understanding, but instead deeply examined the role secondary mathematics teachers take when teaching with technology.

Secondary mathematics teacher education programs across the nation have been offering preservice and inservice teachers the opportunity to learn more about technology and its uses in the classroom. Some of these programs offer a limited number of technology courses, whereas others have more extensive opportunities. Programs that offer multiple courses in the use of technology in the classroom as well as specific technology courses to mathematics education are what I consider technologically rich mathematics education programs. In these programs are professors with many years experience using technology in teaching who making themselves available to answer students' questions. These programs provide students with unlimited access to a computer laboratory, with each computer containing several dynamic mathematics computer programs, such as Geometer's Sketchpad, Fathom, Graphing Calculator, and Maple. Students are encouraged to use these programs while in their methods class and student teaching. The availability of technology, expertise of professors, and infusion of technology into courses are the components that define a technologically rich mathematics education program. Such programs infuse topics from the secondary mathematics curriculum with the use of technology.

Secondary Mathematics Curriculum and Technology

"The right questions about technology are not broad ones, about which hardware or software to use, but about how each works in a certain curriculum" (Goldenberg, 2000, p. 1). There have been many studies of the effect that technological tools have on student learning when placed in the hands of students (Adams, 1997; Goos, Galbraith, Renshaw, & Geiger, 2003; Hativa, 1988; Hollar & Norwood, 1999; O'Callaghan, 1998; Palmitter, 1991; Porzio, 1999). Adams, O'Callaghan, Palmitter, and Porzio found that the implementation of instructional technology (graphing calculators, computer algebra systems, and computer based curriculum) had a positive effect on students' conceptual knowledge. On the other hand, Groos et al. and Hativa found that similar instructional technologies had no effect. In Hativa's study, a computer based curriculum confused the student more than it helped. Broad conclusions about students' learning of mathematics with technology cannot be made.

Few studies have examined the roles of teachers when using technology in the classroom. It is now time look at how secondary mathematics teachers are using the technology in coordination with their mathematical activities, how mathematics teacher education is preparing them to use technology, and how the secondary mathematics curriculum influence technology use. Kaput and Thompson (1994) used an ocean wave analogy for mathematics education research done on technology. Waves were equated to surface level studies dealing with computers or calculators as a primary aid to computation. Swells are deeply involved studies that look closer at the role of the technology in learning and cognition. I conducted a "swell-like" study involving the role of teachers when using technology during mathematical activities.

Zbiek et al. (2007) reviewed the research literature on technology in mathematics education and gave a perspective on teachers' use of technology. They recommended focused research on the constructs involving the interactions between students, teachers, curriculum content, mathematical activity, and tools to assist researchers in explaining the effects of technology on many aspects, including curriculum content and roles of teachers. Using and building onto these constructs for technology in mathematics education is a way to integrate previous and future studies "into a solid body of research that both spurs continued scholarship and informs practice" (p. 1169).

Mathematical Activities

In many instances, it can be said that a single mathematical lesson can be composed of one or more mathematical activities. The tools and mathematical activity construct proposed by Zbiek et al. (2007) relates to technology uses in different types of mathematical activities. This construct relates ways cognitive tools can provide special opportunities or impediments to learning in the context of a mathematical activity. A technical mathematical activity is described as performing procedures. Using technology is many times referred to as technical regardless of how it is used. To avoid any confusion for the reader, I will refer to technical activities as procedural activities. A conceptual mathematical activity involves depth of knowledge and understanding. This dimension can be observed though the use of reasoning and mathematical connections. The definition of a mathematical activity used in the present study differs from that of Hand, Williams, and DeAnda (2007), who describe a mathematical activity through the discourse of mathematics as students interact with it. This description may be an interesting way to view a mathematical activity, but my focus is on mathematics teachers' interaction with mathematics. The definition of a mathematical activity by Zbiek et al. (2007) puts the main focus on the interaction the teacher rather than the student has with the mathematical activities.

While investigating mathematical activities, I developed the source of the mathematical activities that the participants implemented while they used technology. I offer the following terms:

1. *External source of mathematical activities* is when a teacher relies primarily on the textbook or other outside resources to teach the material for the course.
2. *Internal source of mathematics activities* is when a teacher relies primarily on his or her own knowledge of mathematics and self-made mathematical activities to teach the material for the course.

Overview of the Study

Interactionism theories (Crotty, 1998) guided my analysis of three in-service teachers' inclusion of technology into their classroom instruction. In particular, symbolic interactionism guided this study. Teacher roles while using technology were defined through the use of interactionism. I used the procedural and conceptual mathematical activities construct (Zbiek et al., 2007) as the framework for my analysis. The video analysis tool (VAT) was used in collaboration with the procedural and conceptual mathematical activities framework as a means to analyze the data (Recesso, Hannafin, & Khosha, 2003). Chapter 2 provides a description of the theoretical framework.

This study grew out of an incident that happened during the 2006- 2007 school year. Four mathematics teachers, myself included, were hired at the same time to teach at the same high school, which we will call University High School. All of the participants had recently attended a technologically rich mathematics education program. My efforts were focused on the other three of these teachers. They came from different backgrounds and had a range of teaching experiences; one with no experience teaching high school and others with several years. These teachers also held different degrees, bachelor's, master's, and doctoral degrees. All three teachers had taken at least one course on instructional technology in the secondary mathematics classroom and had been exposed to the use of technology in the act of teaching during several other classes in their program. The mathematics classrooms in University high school were equipped with a laptop computer, overhead video projector, smartboard, and classroom sets of scientific and graphing calculators.

Over the duration of four classes, I observed, took field notes, videotaped, and interviewed each participant for the same class period or block. The four observations were conducted on two successive days for each participant. Pre- and post-interviews accompanied the observations. A list of data sources and further description of the study are included in chapter 3.

The analysis of the data used a framework for classifying mathematical activities that involve the use of technology (Zbiek et al., 2007). The mathematical activities in each video observation were coded according to category. Descriptions and characteristics of each category were used when determining the code for an activity. Each mathematical activity was then coded according to the role the teacher took with the technology. This coding corresponded to the descriptions of mediator and facilitator given by Monaghan (2004). A more detailed explanation of the coding and analysis can be found in chapter 4.

Research Questions

A teacher's knowledge of technology and how to use it is essential to using it both appropriately and effectively in a secondary school mathematics classroom. I believe that more emphasis is needed on the mathematical activities as it promotes the use of technology. Mathematics education researchers need to look at how teachers from technologically rich mathematics education programs are addressing the curriculum they teach through the roles they take on when using modern technological tools. The following research questions guided the study:

- How are mathematical activities developed by secondary mathematics teachers from a technologically rich mathematics education program categorized when they use technology?
- What roles, mediator or facilitator, do teachers from a technology rich mathematics education program take when the use of technology is observed?
- How do these roles fit into different mathematical activities?

These research questions reflect three specific purposes of the study. The first purpose was to identify how teachers from different backgrounds, all with knowledge of technology, integrate the mathematics curriculum and the technology. The second purpose was to identify the roles that teachers from a technology rich mathematics education program take on through different mathematical activities. The roles of mediator and facilitator were derived from a study by Monaghan (2004) on mathematics teachers' activities in technology-based mathematics lessons. The third purpose was to identify how mathematics teachers' roles when they use technology fit into the categories of mathematical activities. In this study, mathematical activities are defined by two categories: procedural and conceptual (Zbiek, Heid, Blume, & Dick, 2007). Teacher roles when technology was used fit into two categories: mediator and facilitator. (It was not the intention of this study to evaluate different teachers' performances in a school with readily available technology. I have used pseudonyms to protect the identity of all the participants. A pseudonym was also used for the high school where the participants taught.)

The design of this study incorporated cognitive theories in an attempt to find out how mathematics teachers used mathematical activities and the surrounding technology to build and connect topics present in mathematics education research. Brown and Borko (1992) mention the need for multiple-perspective studies in terms of intervention research. Although this study was not an intervention study, the perspective presented here could be used to enhance the ways instructors of mathematics integrate technology.

CHAPTER 2

APPROACHES TO TECHNOLOGY USE IN MATHEMATICS EDUCATION RESEARCH

“Appropriate uses of technology tools can enhance mathematics learning and teaching, support conceptual development of mathematics, enable mathematics investigations by students and teachers, and influence what mathematics is taught and learned” (Wilson, 2000, p.1).

This literature review is made up of three sections: secondary mathematics students’ interactions with technology, technology use as it pertains to mathematics teachers, and teacher roles when using technology in a mathematical activity framework. The first section examines previous studies that focused on the students’ interaction with technology in a secondary mathematics classroom. The second section focuses on studies that primarily dealt with mathematics teachers’ use of technology. The third section describes the framework that was used to conduct the research and analysis in this study.

Secondary Mathematics Students’ Interactions with Technology

Many of the studies mentioned in this section focus on the effects that technology had on student learning and understanding. Even though the present study was not completely concerned with student learning, it is helpful to reflect on the results of such studies to project the need to further investigate mathematics teachers’ roles when using technology.

O'Callaghan (1998) investigated how students conceptual understanding of functions differed by the method they were taught. The framework of O'Callaghan's (1998) study derived from the function model, which consists of four component competencies: modeling, interpreting, translating, and reifying. O'Callaghan sampled three classes of algebra students. One class used a computer-intensive algebra program (CIA) and the other two were traditional teacher instructed classes (TA). The researcher was the instructor for the CIA class and one of the TA classes. The other TA class had a different instructor. O'Callaghan did not mention if the other instructor had taken part in the design or analysis of the study.

O'Callaghan (1998) collected both quantitative and qualitative data. The quantitative analysis showed that the CIA students demonstrated a significantly better overall knowledge of functions, components of modeling, and interpretation. The departmental final examination showed no significant differences between the three classes. Through the analysis of the interviews, O'Callaghan found that students from the CIA class reacted more positively to their curriculum than the TA students did. The CIA students found the topics in their curriculum more practical and relevant to their lives. O'Callaghan made reference to one CIA student's post- interview where the student was able to come up with her own realistic example of the composition of functions. "The findings from both the quantitative and qualitative aspects of this study indicated that the CIA students had a better knowledge of the individual components of modeling, interpreting, and translating as well as better overall understanding of the function concept" (p. 36).

O'Callaghan's (1998) study posed an interesting question regarding students' development of rich understanding of the function concept through different curricular methods. The way in which the qualitative portion of this study was conducted and analyzed did not help portray students' understanding of function. The number of students interviewed and how they were selected from the class were not reported. O'Callaghan provided narrow chunks of CIA students' interviews and made no reference to TA student interviews regarding function understanding. Attention to how the instructors presented the different curriculums would have been helpful. When O'Callaghan described previous studies involving CIA classes, he raises the topic of teacher roles. He mentioned that teachers and students take new roles in CIA classrooms. "Teachers must serve as guides and facilitators for discussions, provide stimulation and feedback to student activities" (p. 22). An investigation of teacher roles could have given O'Callaghan data for further understanding of students' algebraic knowledge.

Hollar and Norwood's (1999) study was an extension of O'Callaghan's (1998) study. Hollar and Norwood examined the effects of a graphing-approach intermediate algebra curriculum on students' understanding of the function concept. The purpose of their study was to determine whether a curriculum using hand-held graphing calculators facilitated reflection of knowledge concerning the function concept. O'Callaghan's function test was used assess students' understanding of functions.

Three tests were used to collect the data: a pretest, a posttest, and a departmental final examination. O'Callaghan's function test was the basis for the questions on the pretest and posttest. Hollar and Norwood (1999) found that there was no significant difference between the classes at the beginning of the semester. An analysis of variance on the pretest results showed no significant difference in the CIA and TA classes. Students' understanding of the function concept was analyzed using a MANOVA on the four component scores and the total score on the function test. The MANOVA revealed significant differences in each of the components as well as the total scores for the CIA and TA classes. Analysis of the departmental final exam showed no significant difference for the scores of the treatment and the control groups. Hollar and Norwood concluded that the students who had access to graphing calculators had a significantly better understanding of the function concept.

Hollar and Norwood's study cleared up some of the design issues in O'Callaghan's (1998) study. This report gave more detail as to how the instructor was using the technology than O'Callaghan's report. Each instructor in the intermediate algebra graphing-approach class had integrated the use of a graphing calculator into the curriculum and presumably into his or her practice. Unfortunately, there is not much detail concerning how these teachers were teaching with the technology. All that was reported was that a calculator was used to explore, estimate and, discover algebra. Even though there is limited information about how the teacher interacted with the technology, the use of technology did increase these students' understanding of mathematics. In their recommendation for further research, Hollar and Norwood hint on investigating the teacher's role in a technology rich environment. "A continued research focus is needed to help find ways to facilitate the transition from operation to structural conception in students. Studies are needed to advance knowledge of how structural and procedural concepts interact when students are doing algebra within a technological environment" (p. 225).

Porzio's (1999) study looked at the effect of differing emphases in the use of multiple representations and technology on students' understanding of calculus concepts. This study was conducted by examining three types of calculus classes: traditional calculus course, calculus course that included the graphics calculator, and an electronic course using computers. Porzio found that students from the course that was completely taught by a computer demonstrated the best understanding of various calculus concepts. These students were also found to make more connections across the topics than the other two classes sampled.

Hativa's (1988) study concentrated on a young girl's (Sigal) understanding of mathematical concepts and ability to solve mathematical problems when she received both the curriculum and instruction from a computer-based program. Sigal's teacher performed some instruction, but did not use the computer-based program during the lessons. Hativa found that Sigal was not advancing in the computer program even though she had relatively no problem solving identical problems by pencil and paper. This issue was attributed to many software related problems, which were: no remedial tutorials, mixed practice, recycling through lower levels, timed solutions, evaluation of each digit as typed, and mental performance of intermediate steps. Hativa noted an interesting finding concerning Sigal's attitude toward the computer-based curriculum. Sigal surprisingly enjoyed the computer program more then classroom instruction, even though she was not performing as well. This many have been a consequence of self-paced individual instruction. The author found that Sigel separated computer arithmetic from classroom arithmetic. Sigal believed that these were two different methods of arithmetic.

These studies found that technology had mixed results in the area of student understanding. Reports by other researchers (Christou, Mousoulides, & Pitta-Pantazi, 2004; Edwards, 1997; Goos et al., 2003; Owston, 1997; Ruthven, 1990) show that different avenues need to be explored and developed in order to draw conclusions about students understanding when technology is used. Rather than examine technology use versus no technology use, there is a need to examine mathematics teachers' use of technology.

Technology Use as it Pertains to Mathematics Teachers

Kaput (1992) wrote of many challenges mathematics teachers would face as an immediate consequence of technology. These challenges included: difficulty for the average teacher to implement computers into a typical classroom on a regular basis, pressure through the curriculum toward easy measurable skills, limited experience and training in the use of technology in a classroom setting, and little if any technological support for their daily work. All of these challenges exist today and will continue.

Kaput (1992) advocates a strategy for analysis that describes roles of new technologies in the mathematics classrooms and how they affect each content area. Even though this was a good recommendation for investigating the effect of technology, it would be an enormous task and almost impossible to keep updated with new technologies. One idea that resonated in Kaput's paper was the classes of mathematical activities. He described four classes of mathematical activities that related to school mathematics:

1. Syntactically constrained transformations into a particular notation system, with or with out reference to any external meaning.
2. Translations between notation systems, including the coordination of actions across notation systems.
3. Construction and testing of mathematical models, which amount to translation between aspects of situations and sets of notations.
4. The consolidation or crystallization of relationships and/or processes into conceptual objects or cognitive entities that can then be used in relationships or processes at a higher level of organization. (pp. 524-525)

These four principles of a mathematical activity were later synthesized by Zbiek et al. (2007) into the two categories of procedural and conceptual.

Teacher Roles When Using Technology in a Mathematical Activity Framework

"The marginalization of technology by educational institutions has also turned our attention to the need for a more precise analysis of the role of the teacher in these new and changing didactical contexts" (Hoyles, Noss, & Kent, 2004, p. 313).

Mathematical Activities

Drawing from empirical and theoretical literature on technology in the mathematics classroom, Zbiek et al. (2007) present several constructs to help unify and make sense of how technology might fit into the mathematics classroom. These constructs are centered about five areas of interest: the student, the teacher, curriculum content, the mathematical activity, and the tool. The constructs are defined by the interaction one area has with another. The construct that was of interest to this study was the interaction of the tool and a mathematical activity through externalization of representation. Zbiek et al. (2007) make a careful distinction between two different types of mathematical activities: procedural and conceptual. A procedural mathematical activity is seen as something mechanical (Zbiek et al., 2007). Constructing mathematical knowledge or portraying mathematical concepts through procedures and skills would fit into the domain of a procedural mathematical activity. A conceptual mathematical activity involves understanding, communicating, and using mathematical connections (Zbiek et al., 2007). Activities that involve finding and describing patterns, conjecturing, generalizing, abstracting, and connecting representations fit the construct of a conceptual activity.

Artigue's (2002) paper reflected on several French research projects that focused on how computer algebra systems (CAS) were used in secondary mathematics classes. The studies were chosen because their anthropological and sociocultural approaches took into account procedural and conceptual mathematical activities. Artigue's (2002) paper covers selected "framing schemes" or mathematical activities where students used a calculator with CAS capabilities to investigate and solve problems. One problem involved nine students determining the best view or window for a rational function. It was found that this task involved conceptual activities such as making conjectures, testing and proving conjectures, and refuting false claims. Only two students successfully changed the view of the window to see a good representation of the graph. The paper also gives details on the techniques French students use when using a CAS calculator. Artigue (2002) commented that students are trained to use their techniques in different contexts, some routine and others conjecture oriented. Routine techniques were associated with procedural mathematical activities and conjecture oriented techniques were associated with conceptual mathematical activities.

Lagrange's (1999) paper attempted to analyze the integration of graphing calculators (TI-92) in 4 high school pre-calculus classes. The purpose of Lagrange's research was not to prove that teaching was better with graphing calculators, but to reflect on the changes that graphing calculators may bring to the teaching and learning of mathematics. There were classroom observations and interviews of 25 teachers. The interviews also involved questioning nearly 500 students. The analysis was done on a compilation of mathematical activities and provided interesting insights on how technology may support the learning of mathematics. The findings from Lagrange's research suggested that understanding mathematics with the help of a computer algebra system was not a view students generally considered. Students enjoyed the new classroom situations, but did not recognize that the situations could bring better comprehension of mathematical content. The findings also included teachers considering using the calculators as a break from teaching algorithmic skills and set techniques.

In Lagrange's (1999) study, constructivist approaches were fundamental for the investigation of a relationship between the conceptual and the procedural part of a mathematical activity. The theory helped him conceptualize changes in the mathematical activity in the classroom when students use complex calculators. Through his conceptualization, Lagrange determined that the conceptual and the procedural part of a mathematical activity are related more than previously thought. It can be proposed that conceptual mathematical activities evolve through multiple procedural mathematical activities.

Artigue's (2002), Lagrange's (1999), and Zbiek et al. (2007) papers view mathematical activities as being procedural or conceptual and describe how each was observed. Much of the focus in these studies was on how students' mathematical activities as they used technology. Lagrange (1999) included teachers in his study but did not report on how teachers developed their mathematical activities. Teachers' mathematical activities absence from mathematical activity literature is surprising since teachers' mathematical activities could influence students' mathematical activities.

Teacher Roles

Monaghan (2004) investigated what high school mathematics teachers do when they use digital technology in their lesson. Thirteen English mathematics teachers from seven English High Schools participated in Monaghan's study. Participants with limited experience and interdicted that they wanted to try to incorporate technology into their lessons were chosen for the study. The teachers and researchers met for 1 full day and 3 half days before the start of the school year. The days were designed for the researchers to demonstrate different mathematical software systems and for teachers to use the software, discuss how technology could be integrated into their classrooms, and discuss different types of activities made possible. The technological tools that were demonstrated were spreadsheets, graphical software, calculators, and algebra and geometry systems. Data was by teachers and university-based researchers and included observations, weekly journal entries, and teacher and student interviews. Saxe's four parameter model was used to analyze the data. Saxe's model looks at the interactions of activity structures, conventions artifacts, prior understanding, and social interactions have with each other and emergent teacher goals.

Monaghan's (2004) findings suggest there were interactions between all 4 components of Saxe's model and emergent teacher goals. Monaghan describes two roles the teachers took through their interaction with the students. Monaghan believed that teachers take on the role of mediator rather than facilitator in a technology-based lesson. A mediator, according to Monaghan, is a teacher who plays an active role in students' learning through social interactions between teacher and students. Mediators are seen to fit in a social constructivist paradigm. The role of a teacher in a radical constructivist paradigm is that of a facilitator. Teachers who lead discussions between themselves and students with a computer display as the focus are described as facilitators.

Farrell (1996) did not place emphasis teachers' on knowledge when investigating teachers' use of technology in a mathematics classroom. She was able to compare teachers' roles with and without technology (graphing calculators) and student's roles with and without technology. She used a taxonomy of roles provided by Fraser et al. (1987). The roles were defined as follows:

Manager: Tactical manager, director, authoritarian.

Task Setter: Questioner, example-setter, strategy-setter, decision maker

Explainer: Demonstrator, context setter, rule giver, image builder, focuser

Counselor: Consultant familiar with the problem and able to advise and help when called upon to do so, devil's advocate, encourager, stimulator, and diagnostician

Fellow investigator: True participant in the problem solving process because also unfamiliar with problem and its solution.

Resource: System to explore, giver of information.

The sample was composed of six high school pre-calculus teachers who were asked to videotape 10 consecutive lessons. The data was collected at the end of the first year the teachers' implemented a curriculum designed to use calculators and computers in pre-calculus. The instrument used to perform the analysis was the systematic classroom analysis notion (SCAN) matrix. The instrument listed the roles that teachers, students, or technology could assume in the classroom. There were two observers and the investigator coded the video tapes. The videotapes were coded according to these roles and if technology was or was not used.

The results provided evidence that the roles that teacher exhibited when technology was in use differed from the roles the teachers exhibited when technology was not in use. The data were analyzed by finding the percentage of 5 minute segments containing teachers in a given role. The percentages were displayed when a teacher was using technology verses not using technology. The role of manager was observed during virtually all of the observation segments, with and without technology. The teachers assumed the role of consultant, fellow investigator, and resource more often when using technology. Farrell concluded that teachers were holding on to their roles as manager and task setter while taking on new roles of consultant and fellow investigator when technology was used.

When students were using technology, they worked together more often than when technology was not used. The students assumed the roles of task setter and consultant more often when technology was in use. The roles of manager and fellow investigator were not observed during lessons without the use of technology, but were observed a small percent of the time when technology was in use.

Farrell's (1996) study on teacher roles with and without technology provides a starting point and portrays the need for further development of teacher's roles when using technology. Teachers' roles need to be examined in more depth rather than calculating the percentages of segments in a certain category. A weak methodology and the lack of description of the instrument of analysis give the results little validity. Incorporating multiple methods for data collection could have strengthened the results. The SCAN instrument then could have been used along with descriptions of the each type of role observed.

Farrell's (1996) categorizations of the different types of roles were confusing. Farrell interpreted the roles as a hierarchy of teacher dependence to form her categorizations. An example of this confusion comes from defining the role of a resource as a giver of information. This role seems to fit into a lower category of teachers' role. Instead, the role of a resource is presented at the top of the hierarchy. Farrell's study showed the need for a descriptive qualitative study to further examine teachers' roles when they are using technology in their practice.

Mathematical activities and Teacher Roles Framework

The overall framework for this study can be seen as a compilation of frameworks presented above. This framework used Monaghan's approach but did not focus on the interaction the teacher had with the student to define the roles of mediator and facilitator. Instead, this framework defined the roles of mediator and facilitator in terms of the way the teacher interacted with the technology. The backdrop of the framework was the mathematical activities. Figure 1 gives an illustration of this framework on the left and an illustration of the framework as it relates to the research questions on the right. What follows is a discussion of each of the components that framed the present study. Each component is discussed regarding the way cognitive theory guided the view.

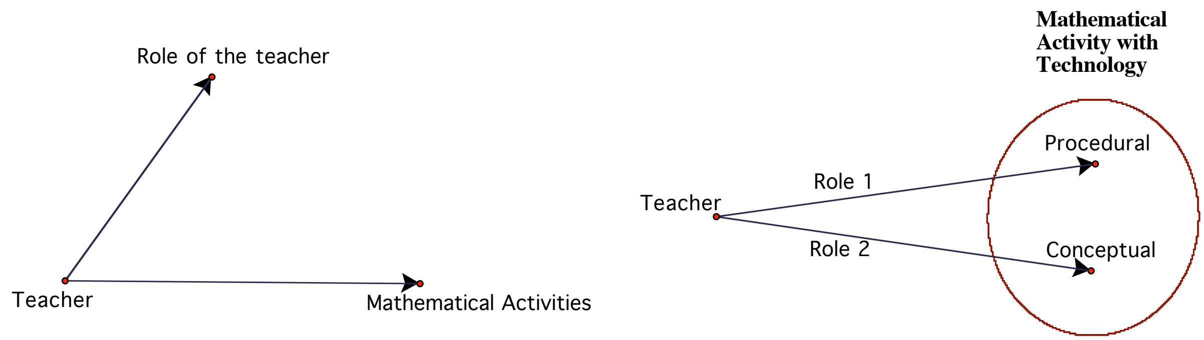

Figure 1. Theoretical framework in terms of interactions.

Symbolic Interactionism Theoretical Component

Symbolic interactionism is a theory grounded in constructivist epistemology. The key concept of symbolic interactionism is to explore the understandings in a culture and the roles people take on as they act. In many senses, a classroom is a culture of many roles and actions. In this theory, human beings act on things based on the meanings that the person made for that thing (Crotty, 1998).

The observation of people who work with things in their environment is the primary methodology used with symbolic interactionism. The general role of the researcher is to observe processes, assess how situations are interpreted by the participant, and explain how these interpretations lead to the participants' actions (Meltzer, Petras, & Reynolds, 1975). Symbolic interactionism sees society as being conscious and self-conscious. People are conscious and self-reflexive beings who actively shape their own behavior (Sandstorm, Martin, & Fine, 2001). People need to be conscious and consciously thinking of what they are doing in order to interact with things around them. The theory also allows a researcher to look at a participant as if he or she is an actor. Actors make meanings for objects and act on these objects by the meaning that they have defined for them. Observing participants' actions will tell the researcher how the participants view the object that they are acting on, which enables the researcher to get something of an insider's view of how the participant is thinking about the object. In symbolic interactionism this idea is known as the emic perspective. Monaghan's (2004) description of the roles teachers take on when interacting with technology during their practice fits into the theory of symbolic interactionism.

Employing the teacher roles when using technology in a mathematical activity framework enabled the present study to deeply examine the teacher's role and also the effects the mathematical activities had on the teacher's role. A teacher's role in the classroom has the possibility of affecting how students will use technology and learn through the use of such technology.

CHAPTER 3

METHODOLOGY

Working with three mathematics teachers at the same high school, I was able to conduct research to better understand the roles mathematics teachers take on when technology is readily available to them. Since I wanted to understand how the teachers were using the technology, how they interacted with the mathematics curriculum, and what role they took with the technology as they presented the curriculum, I used qualitative data collection techniques. These techniques are appropriate in explaining the categorization of teacher roles and mathematical activities. The methods also provided me with the means to fully describe the connections secondary mathematics curriculum had on teacher roles when using technology. Using a triangulation of methods that involved interviews, observations, and field notes, I was able to interpret and justify categorizations.

Participants

The participant selection process used three criteria. All participants must have recently attended or graduated from a university considered to have a technologically rich mathematics education program, the participants must teach mathematics at a high school where technology is readily available, and mathematics teacher that were in their first year of teaching at University High School. There were two other mathematics teachers teaching at University High School that had graduated from a technology rich mathematics education program, but they had been teaching their for several years and taught mathematics to English language learners (ELL). This study was focused on teachers teaching through mathematical activities and the strategies used to teacher ELL students may affect the mathematical activities. The other nine teachers at University High School had not attended a technology rich mathematics education program. Selecting participants using this criteria helped to insure that the teachers would not be discouraged from using technology either because of their ignorance about the use of such technology for mathematics instruction or because such technology was not accessible. It is also important to understand that the participants were not selected to specifically look at the technology they were using during instruction. This study was focused on these teachers as they taught mathematics in part to see what type of role they took on when they used technology. The technology itself was not the main focus of this study. In designing this study, I wanted to look at mathematics teachers in different phases of their educational and teaching careers. I believed that this would help to broaden the study and influence a wide variety of teachers and teacher educators. Many times teacher educators and teachers involved with professional development encounter mathematics teachers with varying education and teaching experience. Using three participants with those qualities makes this study applicable to both teacher educators and in-service teacher professional developers.

Bill, a white male in his early thirties, was a recent graduate of a technologically rich mathematics education program. He was a very energetic person and wanted to get into teaching mathematics because he was good in mathematics in high school. Bill received a bachelor of science in mathematics education. He began his college education at a different university and transferred into the mathematics education program. Bill was a nontraditional student. He had a career as a musician before he attended college. This was his first full-time teaching position.

Bill did his student teaching in a high school comparable in size to the one where he is now working. The only professional development in technology that Bill had received was through his studies for his bachelor's degree. Through these classes, Bill learned how to use Texas Instruments graphing calculators, Microsoft Excel, Geometer's Sketchpad, Java Bars, Maple, and Fathom.

Joanne, a white female in her fifties, is a recent graduate of the mathematics education doctoral program. Joanne, like Bill, did not begin her career in education. She received a bachelor's of science in accounting and worked as an accountant for over 20 years. As Joanne raised three children, she became bored with her accounting business and sold her practice. "For a lack of anything else to do," She decided to substitute teach at her daughter's high school. "I just loved it" she said. Wanting to pursue a career in education, Joanne went back to school for a master's in education and received her teaching certificate at the same time. To receive the teaching certificate, Joanne had to complete student teaching, which she did in a rural high school with the student population evenly split between White, Hispanic, and African American students. Joanne greatly enjoyed her student teaching experience and wanted to work there the next year, but no positions were available.

Joanne's first full time teaching position was at a large school (approximately 2400 students) in the suburbs of a metropolitan city. The student population was mostly White, but there were also Hispanic and African American students. The economic status of the students ranged from low to high, with most of the students in the middle. Joanne did not like working at the school because of a 2-hour commute each way and a hostile teaching environment. A mathematics position opened at a school closer to her home for the next school year, so she decided to leave and take the new job.

Joanne started her second school year in a much different high school than she had taught before. This school was located in the mountains of Georgia, enrolling around 700 students. The high school had very little technology available. There was no Internet access and very few computers. The only technology available to students was that of graphing calculators. Joanne describes the school as if you were “walking into a time warp.” Even though it was lacking resources, Joanne enjoyed teaching at the school because of its “very high standards.” While teaching, she received a specialist in education degree in mathematics education. After teaching at this high school for 3 years, she became dissatisfied with the classes she was being assigned and decided to move to another high school.

For Joanne’s fifth and sixth years of full-time teaching, she decided to move out of public school and teach at a private boarding school. The private school was diverse; one-fourth of the student population came from 17 counties. Joanne was very happy with her new job, calling it the best professional learning community that she had ever been a part of. The teachers were provided with many technological resources, including Texas Instrument graphing calculators, Geometer’s Sketchpad, and smartboards. Joanne explained that through her interactions at the private school, she really learned how to teach. During her second year, she became overwhelmed with the extracurricular activities that she was involved in and decided to take a temporary teaching position at a nearby college. She taught mathematics at the college level for 1 year and soon after began her doctoral program.

Mary, a white American female in her late twenties, was a graduate student in the mathematics education program. She received a bachelor’s of science in applied mathematics from a medium sized university in a different state. While she was completing her bachelor’s degree, she received a secondary mathematics-teaching certificate. After graduating, Mary taught for 6 years at a private boarding school in Texas, not far from her previous university. The private school was for secondary students in Grades 7 through 12. Like many private schools, it was small, enrolling around 110 students. The school was for economically disadvantaged students and was predominantly Hispanic, although there were Black, White, and Asian students as well. Mary taught Algebra (regular), Geometry (regular), Algebra 2 (advanced and regular), Pre-Calculus (advanced and regular) and AP Calculus AB at the private school. Her class size varied from 2 - 12 students.

The only professional development, involving technology that Mary could remember taking while teaching in Texas was a weeklong seminar on Geometer's Sketchpad. She said that it was helpful and taught her the basic features of the computer program. Mary had learned how to use the graphing calculator while taking classes for her bachelor's degree. While talking about graphing calculators, she explained that she had only used them in the 11 and 12grade classes.

In 2005, Mary decided to go back to school to pursue her master's degree in mathematics education and possibly a doctoral degree. At the technologically rich mathematics education program, Mary learned more uses of the Geometer's Sketchpad in the classroom and learned how to use Java Bars. By the end of this study, Mary received a master's degree in mathematics education.

All three participants were in their first year of teaching at University High School after recently attending a technology rich mathematics education program. Each participant had different experiences with technology prior to this study. Both Mary and Joanne had taken professional development courses on the use of technology in the mathematics classroom. Bill had not been exposed to the use of technology during instruction in the same manner. Bill and

Mary had taken courses in the technology rich mathematics education program that were focused on the use of technology to investigate secondary level mathematics problems. Joanne did not take such a course while she attended the technology rich mathematics education program.

Setting

The high school, which will be called University High School, is located a short distance from the university that all the participants attended. The full-time student enrollment at University High School was around 1,500 students. The students were African American (53%), White (27%), Hispanic (15%), and other (5%). There were almost 100 full time teachers; 15 were in the mathematics department.

University High School began to implement career academies into the structure of the school during the observation period. The four career academies included: the arts, media, and communication academy, the business, finance, and marketing academy, the engineering, industry, and technology academy, and the human and public service academy. The implementation of the career academies was intended to give students the opportunity to focus on an area of study that interested them. The programs were also designed to promote interdisciplinary connections. Teachers were encouraged to work in and outside of their departments when planning lessons. Because of the academy design, subject area departments were not housed in the same areas, as in previous years. This arrangement meant that mathematics teachers were spread throughout the school and had different planning periods. Participant observations and interviews were conducted within each participant's classroom.

Data Sources

The central focus for this study's data collection was on teachers' mathematics instruction when technology was made readily available to them. The data were collected in the form of field notes, interviews, and videotapes of the four lessons observed from each participant. Every night after data was collected; I digitized and uploaded the video observations into the Video Analysis Tool (VAT).

The VAT is a Web-based program in which data can be uploaded and analyzed using lenses. A lens contains areas where the video can be coded according to a specific framework and commented on. The video then can be refined to smaller portions according to its coding. This process produces individual video clips that can be viewed according to a specific code. Refined clips that have already been coded can then be recoded using a different lens' or the clip can be further refined. The VAT saves these refined clips and can be accessed from any Windows computer with Internet access. The original unrefined view clip is also saved either for viewing or further analysis using different lenses. The lenses used for this study can be found in Appendix A and Appendix B. The check box indicates that the element could have been checked during the analysis to show that it was observed. The text box was used to type comments about the clip.

The data collection was divided into two time frames. The division occurred because of the preparation and administration of a state-mandated test. The preparation and administration of the test took 2 weeks in April, and data collection was put on hold during that time. The first time frame was from the beginning of March until the beginning of April. The second time frame was from the end of April until the first 2 weeks of May. Figure 2 displays the data collection timeline for each participant.

Participant: Bill

March 7	Observation One Interview One
April 4	Observation Two Interview Two
April 5	Observation Three
April 18	Observation Four
April 19	Interview Three
April 20	Interview Four

Participant: Joanne

March 8	Interview One
March 22	Observation One Interview Two
April 3	Observation Two Interview Three
May 2	Observation Three Interview Four

Participant: Mary

March 8	Observation One Interview One
April 13	Observation Two Interview Two
May 2	Observation Three
May 3	Observation Four

Figure 2. Data collection timeline.

In early February, I contacted each of the participants through e-mail to see if he or she would participate in the study. I did not begin the study until February, so the participants had at least a month to get acquainted with their new classes from the second semester. As each teacher responded, a date and time was scheduled to discuss the study, fill out paper work, and answer questions. The participants were aware that this study was examining how they taught mathematics with the use of technology.

I was able to observe, take field notes, and videotape each teacher for the same class or block throughout the study. At the beginning of the study, I observed teachers and conducted interviews for each teacher once per week. This amount of time enabled me to observe several units and topics. The last two observations were conducted on consecutive days. This was done to enable me to observe the continuation of a lesson to the next day. Many of my previous observations were coincidently conducted at the beginning or end of new topics. I had observed very few lessons where the teacher was building on mathematical principles first examined in the previous days. I conducted a brief semi-structured interview with each teacher before class to find out about the mathematical topic to be covered, see what his or her goals for the lesson were, and get information regarding the instructional strategies to be used. The semi-structured interview protocol can be found in Appendix C. Interviews ranged from 5 minutes to 30 minutes. Since I was also teaching mathematics in the same department as the participants, I was able to conduct observations during my planning period.

Data Analysis

Data analysis was a continuous task starting at the beginning of the data collection. Ongoing analysis of video observations was conducted to guide and adapt my observation schedule. The focus of this study was always on the teachers and their use of technology in their practice. Initial data analysis efforts focused on the ways in which they used the technology. During the analysis, other interesting questions arose concerning the mathematics activities and the teachers' role while teaching with technology. After I realized the importance of these two factors in mathematics education research, three main phases of retrospective analysis into effect. The first phase was to identify and describe the different mathematical activities observed during each lesson that involved technology. The second phase was to identify and describe the roles the teachers were in while using the technology to present a concept through a mathematical activity. The third phase involved linking the mathematical activities with the roles of the teachers.

The last phase involved cross-referencing each mathematical activity with the role the teacher was in while using technology. Each mathematical activity was matched with the role that overlapped with it. This matching was done to look for trends in the mathematical activity and role of the teacher while using technology for each teacher and across teachers.

Classroom observations were reviewed and cut into mathematical activities by using the VAT. Class observations were not transcribed do to their length and the ability to use the VAT. After the mathematical activities were determined and the lenses applied, interviews and field notes were used to further support finding made by using the VAT. Interviews were reviewed for their relevance to the mathematical activities and teacher roles observed. Interviews that were found to be useful were transcribed after the lenses were applied to the classroom observations. Field notes were used in the same fashion as the interviews. Field notes were reviewed after the observations went through the VAT and the relevant interviews were transcribed.

CHAPTER 4

FINDINGS

In this study, three teachers were observed and interviewed on how they taught various secondary mathematics topics when technological tools, such as smartboards, computers with Geometer's Sketchpad (GSP), scientific calculators, and graphing calculators were readily available to them. Each situation provides a glimpse of the teacher's classroom experiences, the mathematical activities presented, and the roles the teacher took on when using technology. The goal of this chapter is to create a detailed description of the types of mathematical activities that teachers trained with the use of technology used and the roles they took on while teaching with the technology. Specifically, I address the following questions for each observation of each participant:

- What was the mathematics topic of each lesson?
- How were mathematical activities used in each lesson?
- Were the mathematical activities procedural or conceptual?
- What role did the teacher take on while using the technology?

The analysis is organized by participant. It begins with a description of the class and moves on to portray each classroom observation. Each classroom observation is broken down into three sections: the mathematics topic, the mathematical activity or activities, and the role the teacher took on when using technology. I coded each mathematical activity by observing a change in the mathematical focus. I used video observations, field notes, and interviews for this analysis.

There were two lenses uploaded into the VAT for this analysis. The first lens had to do with the mathematical activity. This lens had two selections: procedural activity and conceptual activity. In order to confirm and validate the selection, the lenses provided several words describing the actions done during a mathematical activity. Check boxes were used to select the describing action or actions, and a text box was used in each category to provide comments on the lesson. The descriptive actions used for a procedural mathematical activity were definition, display information or procedures, geometric constructions, measurement, and computations. The descriptive actions used for a conceptual mathematical activity were finding patterns, defining, conjecturing, generalizing, connecting representations, predicting, testing, and refuting. I used text boxes were used to further comment on the mathematical activity and determine which category best fit the mathematical activity. The second lens concerned the role of the teacher when using technology. This lens had two selections of mediator and facilitator. These selections used descriptive words to confirm and verify the role. The words used to describe a mediator were lecturer, director, and, demonstrator. The descriptive words used for a facilitator were supporter, consultant, and questioner. Check boxes were used to select the describing word or words, and a text box was used in each category to provide comments on the lesson. Describing words were selected only when the teacher role in the classroom involved the use of technology. The observations were not transcribed.

Bill

Bill was an animated teacher; always walking around the classroom waving his arms and cracking jokes with his students. The classroom environment was welcoming, but also a feeling of urgency for the work that needs to be done. Bill felt that students need to learn to be good people as well as students of mathematics and displayed these ideas throughout the classroom with motivational posters along side mathematical posters. There was a smartboard at the front of the room, mounted to the wall. There were 30 student desks in the classroom, all occupied. The students' chairs were arranged in rows facing the Smartboard. The smartboard was connected to Bill's laptop, which sits on his desk to the left of the smartboard. The video projector, which provides the image for the smartboard, was mounted to the ceiling at the center of the classroom. There was a large dry erase board on the right wall of the classroom that shows very little wear and only has a few scattered comments and mathematical problems on it. The back wall had two bulletin boards one with announcements and the other with essential questions. Each classroom in University High School was required to have essential questions displayed somewhere in the classroom every day. The essential question was intended to have students and teachers think about what the goal of their lesson was that day.

For his second semester of teaching mathematics at a public school, Bill was assigned two Algebra two college preparatory (CP) classes and one Algebra and Trigonometry CP class. Bill was pleased with his class load and was not disappointed with the absence of being assigned any honors classes. The class observed in this study was his Algebra two class. I made four observations of this class. Bill described this class as an average class, well behaved and respectful.

> Well, this is an Algebra two CP class, college prep, predominantly juniors with some sophomores and I believe I have one senior taking it for the second time. I have some that are failing, some making A's, and a lot in the middle. They are [a] generally respectful class, not too many behavior problems, and they participate fairly well as far as the average high school kid goes, in my experience. (Bill, Interview, 3-7-07)

Observation One (3/7)

Mathematics Topic

This lesson focused on the properties of exponents of real numbers. The product of powers, quotient of powers, power of powers, and zero properties of exponents were all covered during the lesson. Each exponent property was presented as a separate mathematical activity.

Mathematical Activities

Introduction Activity

The lesson began with reviewing the procedures for calculating exponents. "What's seven to the fifth power?…What does it mean?…It's five sevens multiplied together" (Bill, Video, 3-7-07). The calculation of 7 to the fifth power was not performed; the expression was written as expanded multiplication on the smartboard. Bill moved on to another power, 7 to the third power. As with the previous example, he wrote 7 to the third power on the board as expanded multiplication.

This introduction activity can be viewed as a procedural activity. It fit into the procedural category because of the reliance on computations and displaying procedures. Bill did bring up the multiplication concept, which in some cases is considered a conceptual activity, but the concept was seen as computation based. The fact that students did not actually compute the powers did not change the focus on computation. Bill used the smartboard to manipulate the expression so it could be written in expanded multiplication form.

Product Property of Powers

This activity began with the smartboard displaying 7 to the fifth power multiplied by 7 to the third power. Bill explained that the answer would be 7 to the eighth power by using the smartboard to write out the expanded multiplication of both powers and counting the number of sevens. He then asked the students to conjecture how the property is defined. After several students were defined the product property as the addition of exponents, the definition in terms of variables was displayed on the smartboard. Bill presented this definition on a ready-made slide on the smartboard. The ready-made slide was prepared by Bill before the lesson.

The product property of powers activity was a procedural activity. Mathematical connections and relationships were presented during this activity, but these connections were to the definition of exponents. Students had learned the definition of exponents in middle school and the definition is computational. The smartboard was used so that the class could see the computational element of exponents. The smartboard was used to display these procedures.

<u>Quotient Property of Powers</u>

Bill used the same powers as in the previous example, 7 to the fifth and 7 to the third, to write the quotient of 7 to the fifth over seven to the third. Bill used expanded multiplication to simplify or "cancel out" (Bill, Video, 3-7-07) the quotient. He presented a ready-made slide to the students with the definition of the quotient property of exponents. He then reciprocated the original quotient and simplified the problem two ways. First, he used the expanded multiplication to get 1 divided by 7 squared. By using the quotient property, Bill subtracted the two exponents and got 7 to the negative second power. He used these two methods to show the equivalence of negative exponents and quotients containing positive exponents.

This mathematical activity fit into the category of a conceptual activity. The emphasis is on understanding the mathematical connections between division of powers and subtraction of their exponents as well as the connection between the quotient property and negative exponents. This activity used multiple representations when solving a problem involving the quotient of powers in order to show the relationship between powers with negative exponents and powers of a fraction. The smartboard was used to emphasize this connection. The smartboard's software enabled Bill to go back to previous slides that involved the division of powers to show how negative exponents and powers of a fraction can be created.

Power of a Power Property

Bill used the example of the quantity of 7 to the third raised to the fourth power. He used expanded multiplication to write out the answer. This time, Bill did not ask the students to make conjectures of the definition for the power of a power property. Instead, he just gave the students the definition verbally and switched to a ready-made slide where the definition was written out in terms of variables.

This power of a power activity was procedural. The activity was presented in similar ways as previous conceptual activities except the focus was not on making mathematical connections but on performing mathematical actions. There were no opportunities for students to make conjectures, find patterns, or generalize the concept. The property was done very quickly and emphasized the calculations needed to perform the operation.

Zero Power Property

Bill began this activity by asking the students what 3 divided by 3 was. Many students responded with the answer of 1. He acknowledged their answers and said, "Anything divided by itself is one" (Bill, Video, 3-7-07). He then asked what three to the zero power equaled. Students were not sure of the answer. Bill then wrote down the problem 7 to the fifth power divided by 7 to the fifth power. Using the quotient property, he subtracted the exponents to get 7 to the zero power. Bill went on further to show the expression in expanded multiplication form and simplifies. He then asked, what anything to the zero power was, and the students replied with one.

This mathematical activity was a conceptual activity. It was used to build understanding through the use of mathematical connections and relationships. Bill was able to connect the concept of a zero exponent to the quotient property in order to define the zero power property. This activity also used multiple representations to further the relationship between the quotient property and the zero power property. In this case, the definition was not given to the students; it was realized through mathematical connections.

Teacher's Role When Using Technology

Bill's role throughout the entire lesson was that of a mediator. He played an active role in student learning through social interactions. The smartboard was used as a medium for Bill to present the written aspects of solving a problem or giving a definition. At no point, did the students or Bill interact with the mathematics because of the use of the smartboard. Bill used this instructional tool as a way to deliver the mathematics of the lesson. He provided the information that students needed to take notes on with the smartboard. The notes were prepared before the lesson and typed on the smartboard software provided with the interactive white board. "My lecture notes are concise on one frame of my smartboard and I don't talk when I first put them up, I let them [students] write them down" (Bill, Interview, 3-7-07). All of the mathematical learning was done through social interaction with the teacher. Further justification for Bill's mediator role when using the technology is given by an interview conducted before the lesson was observed.

When asked about the type of instructional strategies he would be using during the lesson, Bill replied that the instruction would be traditional.

> Well, for what I have planned today, it's going to be more, somewhat of a traditional lecture with examples [to] provide some practice opportunities for the kids. I like to mix up calling on problems as a group, calling on individual kids to answer one at a time and I always like to, often like to provide class time for them get together in small groups to work on some things. We will definitely be doing that. I have some class work planned for them. (Bill, Interview, 3-7-07)

When asked more about how he would be using the examples during the lesson, Bill brought up the use of calculators. "Actually I start with examples. I like to, not always, but in this case I am starting with examples. I basically start by saying, 'Everybody put their calculators away'. And then I use some examples that we sort of do as a group" (Bill, Interview, 3-7-07). Bill explained that he does not have any issues with students using calculators, but he did not want this class to use them because it would take away from the learning.

> It's a distraction from the lesson. It's easy to plug seven to the third in, but you have to think a little more when you're thinking what seven to the third, you have to think about seven times seven times seven, which they would not plug that into their calculator. They would never plug in seven times seven times seven. Or they may, but they know to plug in seven carat three, you know. (Bill, Interview, 3-7-07)

Observation Two (4/4)

Mathematics Topic

This lesson was focused on *n*th root polynomials and rational exponents. The algebraic definitions for *n*th root equations and rational exponential equations were written explicitly using variables.

Mathematical Activities

Introduction Activity

The class began with Bill reviewing the concept of square roots and how to calculate the square roots of perfect squares. He moved on to the concepts and the calculations of higher order roots of perfect cubes and perfect fourth roots. Bill showed probing questions regarding why perfect squares have square roots on the smartboard. After discussing the computational aspect of square roots, he said, "the square root of four is two because two times two is four" (Bill, Video, 4-4-07), He revealed part of the screen on the Smartboard that had the inverse equation (exponential equation) for each problem. These equations were used as an answer to the question of why square roots of a perfect square are whole numbers. The definition of an *n*th root was given as the inverse of a power. "So, for any integer n greater than 1, if $b^n = a$, then b is an *n*th root of a, $b = \sqrt[n]{a}$" (Bill, Video, 4-4-07). This definition was written on the board, and Bill read it out loud to the class.

This mathematical activity was a procedural activity. The mathematics needed to find roots was presented using the smartboard as computational. Revealing parts of the smartboard page to answer the question of why began to show connections between roots and exponents, but the page was designed to show this relationship through computations. The definition of an *n*th root was presented through written and typed words on the smartboard. The definition was classified as a type of algebraic manipulation.

Fractional Exponents Activity

For this mathematical activity, Bill discussed the relationship between *n*th roots and fractional exponents. The relationship was also written on the smartboard as a definition. Example problems were worked on involving calculating higher order roots, roots of negative integers, and converting real numbers with fractional exponents to radical form. Bill both asked and answered questions to check for understanding before moving on. He presented a form of algebraic proof to show the equivalence of any integer with a fractional exponent to a radical (Figure 3).

If $a^{\frac{1}{n}}$ is an *n*th root of *a*, and *m* is a positive integer, then

$$a^{\frac{m}{n}} = (a^{\frac{1}{n}})^m = (\sqrt[n]{a})^m$$

$$a^{\frac{-m}{n}} = \frac{1}{a^{\frac{m}{n}}} = \frac{1}{(a^{\frac{1}{n}})^m} = \frac{1}{(\sqrt[n]{a})^m}$$

Figure 3. Bill's algebraic proof for rational exponents.

Bill explained the algebraic process of each part of the proof by referring to the exponent properties of real numbers. He told the students that they should refer to this proof while working on practice problems and homework today. "This should help guide you," he said (Bill, Video, 4-4-07).

This mathematical activity was procedural. The smartboard was used as a medium to present definitions and show algebraic manipulation. Bill discussed with the students the process of proving that a fractional exponent is a type of root by making connections to the exponent properties, presented a day earlier, but this connection was not supported by using the smartboard.

Odd and Even Roots Activity

The students are then told to copy down and read a chart pertaining to value of *n*th roots. These directions were typed on the smartboard. The rationale for writing down the table was because “we are going to start solving polynomial equations with all of these *n*th roots in them and we need to get an idea of what to expect, what we are going to look for” (Bill, Video, 4-4-07). The table gave the number of real solutions when the *n*th root is even or odd. Bill had the table on a ready-made slide displayed on the smartboard without the number of real number solutions filled in. Bill started with the number of solutions when n is odd and writes down one real solution. He asked students to read the answers from the table as for each of the categories. The even category was broken down into three subgroups, when the radicand is positive (greater than 0), equal to zero, or negative. The numbers of solutions were written next to each category and students were given problems from the book to work on for the remainder of class.

This activity was procedural activity. The smartboard was used as a tool to transfer the information from the text to the screen. The conceptual questions regarding the number of solutions for different scenarios were given verbally by the teacher. The smartboard was not used to ask or answer these questions. The smartboard was only used as a display.

Role of the Teacher When Using Technology

Bill’s role during this lesson was categorized as a mediator because of the lecture type of presentation and his primary use of the smartboard as a medium for demonstrations and rules.

The descriptive word used most frequently for Bill's role was that of a *director*. He wanted students to become comfortable with the terminology of roots and for students to be able to convert a number or variable expression in root form to exponential form. These topics were part of the review component of his goal. Bill said, "So, my plan for today is to go through some basic refreshers of some different powers. Sort of make the connect if you have something squared versus something cubed or something raised to the fourth power and sort of connect that to taking the roots of numbers instead, bring it in the back direction" (Bill, Interview, 4-4-07). Since several topics were seen as review, it can be inferred that Bill saw his role as the provider for the review information and the smartboard as a tool to present the information.

Observation Three (4/5)

Mathematics Topic

There were two topics for this lesson: solving equations that involve rational exponents and rational exponent properties. The definition of imaginary numbers as even roots of negative numbers and an exponent property of imaginary numbers was part of the solving equations. The rational exponent properties topic expanded the use of the exponent properties from only being used with integers to being used with rational numbers.

Mathematical Activities

Review Activity

This activity was designed to go back to the concepts of *n*th roots and answer questions students had from their homework problems, which involved calculating roots of different numbers. Bill brought up the concept of imaginary numbers as it related to the chart that was filled in the day before on the smartboard. He explained that since there were zero real solutions to a problem involving the even root of a negative number, there were imaginary solutions denoted by the symbol *i*. Bill used a blank smartboard page to show students the computation of *i* to the sixth power. This activity continued by students asking the teacher to show and explain the computations of other roots.

This mathematical activity was viewed as being procedural. The smartboard was used to display mathematical actions on numerical expressions. This display was also used to show the computations needed to complete the problem.

Calculator Activity

This activity began with Bill explaining the keystrokes needed to calculate roots using scientific calculators. Bill assigned six problems from the textbook for the students to solve using the scientific calculators. The students worked in groups while solving the problems. The page number and problem numbers were displayed on the smartboard. Bill and his intern walked around the classroom answering questions regarding the keystrokes needed to calculate the answer. Throughout the activity, Bill reminded students that they could check their answer by raising it to the power that was the root and that what they got should be the number under the radial. After the students had worked on the problems for about 20 minutes, Bill reviewed the answers and solutions to select problems using the smartboard to write down the steps. The smartboard was used to display multiple ways to solve one problem. Verbally, Bill made connections between roots with negative exponents and their different representations when calculating the value of a numerical expression.

This mathematical activity used more than one form of technology; scientific calculators and a smartboard. The technology use during this activity placed it in the procedural category.

The scientific calculators' purpose was that of a computational tool. This tool was not extended any further than its use for computations. The smartboard was used as a display for the teacher to write down the mathematical actions performed on the numerical expressions.

Properties of Rational Exponents Activity

This activity began with the title "Properties of Rational Exponents" displayed on the smartboard. The next slide on the smartboard displayed the names of the properties of exponents and their definitions using variables. These properties were taught earlier in the semester and were displayed for the purpose of review. Bill then moved on to a slide that listed the exponent rules and definitions as stated in the previous slide, but the new slide included a sample computation problem involving rational exponents for each property. The exponent properties were used to compute the solutions, which were written on the smartboard slide. After all of the solutions were filled in, Bill assigned five problems on computing values of numerical expressions with radical exponents by using exponent properties.

The properties of rational exponents activity was conceptual. Like the previous activities during this lesson, this activity was heavily computational, but there was considerable emphasis on displaying the connections between exponent properties and rational exponents. Before this activity, these two topics had been taught separately. The smartboard was used to display the properties and relate them to expressions with rational exponents. This relationship attempted to build on the structure of exponent properties so that they could include rational exponents. The descriptive words used most frequently for this activity were *defining* (or redefining) the property and *connecting* presentations.

Role of the Teacher When Using Technology

Bill's role while using the technology for this lesson was that of a mediator. The words used to describe his role when using technology were: *lecturer*, *demonstrator*, and *rule provider*. The term *lecturer* was used because of the way Bill interacted with the smartboard during the lesson. His main interaction with the smartboard was to deliver material to his students. The ready-made slides provided Bill with the curriculum content he presented to the students. There were also slides with ready-made exercises that the students worked on. Bill used the smartboard to write out the method of solving the expression next to the problem. This aspect of the lesson also brought out his role as a rule provider. He showed the students that there were set procedures when computing and using properties. Another observation that showed evidence of a lecturer was that the teacher was the only person who used the smartboard during this lesson.

Bill took on the role of a demonstrator when the class used scientific calculators to calculate the value of different roots. This part of the lesson was intended for students to learn how to do calculations with rational exponents. Bill showed the students on the smartboard the keystrokes needed, for each type of calculator, to find decimal approximations for any rational exponent. The students were able to mimic the keystrokes while Bill presented them in writing on the smartboard. The problems assigned for the students to use the calculator on were similar to the ones that Bill did with the class. The students were asked to do the same procedure on the given problems.

Observation Four (4/18)

Mathematics Topic

The mathematics topic presented during this lesson was an introduction to logarithms. Logarithms were presented as providing a way to solve equations for an unknown exponent. Bill presented the history of logarithms as "some math people invented logarithms" (Bill, Video, 4-18-07). The procedure of changing an exponential equation to a logarithmic equation and logarithmic properties were the highlights of the lesson. Other aspects of logarithms covered were common logarithm, natural logarithm, and the change of base formula.

Mathematical Activities

Introduction Activity

The class began with Bill handing out calculators (both graphing and scientific) to the students. The introduction to logarithms was displayed on the smartboard with the problem $2^x = 6$. Bill instructed the students to use their calculators to figure out what x would be. The students tested their predictions and gave possible answers to Bill to write on the smartboard. This process continued until a value of x produced a result with in one tenth of the desired answer. A ready-made slide was displayed on the smartboard which provided the typed out definition of logarithms as a change of representation from exponents.

This mathematical activity had aspects that were both procedural and conceptual. The overall classification of this activity was conceptual, which was determined because the procedural portions of the activity supported a conceptual use of technology. Calculators were used during the lesson to perform calculations, but those calculations were necessary to refine and test the predictions. The smartboard was used to display information, but that information was used in conjunction with the calculators to refine predictions.

Characteristics of Logarithms

This activity began with Bill displaying two questions on the smartboard: "What is log base *b* of 1 and what is log base *b* of *b*?" Each problem was solved by writing it in exponent form on the smartboard. This characteristic of logarithms was presented to students as a definition by the smartboard. The difference between the common logarithms and natural logarithms was also presented on the smartboard as a definition. Bill explained that knowing the common logarithm is useful for putting it into the calculator (Bill, Video, 4-18-07). Calculators were used to compute several common logarithms and natural logarithms. The answers to the problems were written on the smartboard next to each problem.

This mathematical activity was procedural. The smartboard was used only to display information and provide written definitions. The calculator was used to perform calculations. Unlike the previous activity, there was no reference or connection to exponents.

Properties of Logarithms

Bill presented the product, quotient, and power properties of logarithms on a ready-made smartboard slide. While the students copied the information from the smartboard, Bill told them "These [the properties] hold true no matter what your base is" (Bill, Video, 4-18-08). All of the properties were presented as definitions. The ready-made smartboard slide did not explain why or how the properties were related. Even though the ready-made properties smartboard slide did not have anything on it concerning property connections, Bill did use the smartboard to solve a problem two ways: with the power property first and then with the product property (Bill, Video, 4-18-07).

After sample problems were demonstrated using the smartboard, the change of base formula was presented on a ready-made slide. This property was also presented as a definition. Bill introduced the formula and how to put it into the calculator as a way to change the base. It was written on the smartboard that the change of base formula could be used either with common logarithms or natural logarithms. Calculators were used to compute the values of several different logarithms with various bases.

Role of the Teacher When Using Technology

This lesson included more than one type of technology: a smartboard and both scientific and graphing calculators. The smartboard was the center for the information, explanation, and demonstration problems during the lesson. As in previous lessons, Bill used the smartboard as a template for teaching the lesson. He interacted with the ready-made slides by writing on them, drawing arrows to show placement of variables when using logarithmic properties, moving shapes to reveal the answers to questions and problems that were typed on the board, and writing out the steps needed to solve problems and use the properties of logarithms. The smartboard was used for the entire lesson. All of the information for instruction came directly from the smartboard.

The calculators were used for part of the first 30 minutes of the lesson and again during the last 20 minutes. Bill had students find the approximations for common logarithms and natural logarithms during both parts. First, students were given two problems to enter into their calculators. Bill confirmed that the majority of the students got the correct approximations by writing the solutions on the board. Several students then asked the teacher how they could approximate logarithms, by using their calculators if the logarithm had a different base. The inability to enter logarithms with bases other than 10 and *e* into the calculator gave Bill the opportunity to introduce the change of base property. The students used calculators during the end of the lesson to approximate the numerator, the denominator, and the quotient when performing the change of base property. The numerator and the denominator were found separately, written to the nearest thousandth, and then divided to get the approximation of a logarithm with a base other than 10.

The overall goal of the lesson was for students to be introduced to logarithms. Bill wanted students to be able to change from exponential form to logarithmic form, to see why logarithms are used, and to be able to estimate the values of logarithms. Bill went about accomplishing these goals in the form of a lecturer, a director, and a rule provider. These categorizations put him in the role of a mediator.

Lecturer and rule provider were the two most predominant aspects of the mediator role observed during the lesson. The majority of Bill's presentation of the curriculum was done through the use of talking and writing. The topics mentioned came directly from his interaction with the typed information presented on the smartboard. Solutions to ready-made problems and some example problems were hand written using the smartboard. Bill's aspect as a director came when he interacted with the calculators. Bill told the students what to type into their calculators and how to do it. He did not demonstrate how to do the calculations; he simply told them to use the "log" or "ln" button to perform the calculations.

Joanne

Joanne was more of a traditional teacher. In this case, a traditional teacher refers to her interactions with the class. Students were expected to stay seated at all times and raise their hands when asking and answering questions. She typically stood at the front of the class and lectured for the majority of the block. The bulk of her presentation came from the smartboard, which she rarely moved far from.

Joanne's classroom was partitioned down the middle of the room. Half of the students were on one side of the room facing the other half of the class on the other side of the room. The smartboard was at the front of the room, mounted over the middle of a large whiteboard. This arrangement provided Joanne with approximately 4 feet of whiteboard space on either side of the smartboard. The whiteboard was primarily used to display class work and homework assignments. Joanne's desk, where her laptop was located, was only a couple feet to the left of the smartboard. The walls around the classroom were relatively bare. Only a couple of news articles were hanging from the bulletin board that was to the right of the smartboard. At the back of the classroom there was an empty bookshelf.

The class that was observed for this study was Algebra 3, college preparatory. "The course is really basically like a college Algebra course, Algebra 1 and Algebra 2" (Joanne, Interview, 3-8-07). Students in this class had to have passed Algebra 1, Geometry, and Algebra 2 in order to be placed in Algebra 3. There were three juniors in the class and eighteen seniors. Algebra 3 was not needed for the students to graduate, but with a passing grade the students would receive a college seal on their diploma. Joanne believed therefore the students were not taking the material seriously and were underachievers. "A lot of them [the students] have come in with no algebra skills or knowledge at all", she said (Joanne, Interview, 3-8-07). "It's just a very low level class. There are a lot of discipline issues and attendance issues. A lot of them have gone over the limit for attendance. This is not a motivated group at all" (Joanne, Interview, 3-8-07). I observed this class four times throughout the second semester. The topics included rational functions, exponentials, and conic sections. Joanne taught another block of Algebra 3 and one Algebra 1 class.

Observation One (3/22)

Mathematics Topic

Conic sections were the main mathematical topics addressed in this lesson. This lesson was intended to introduce the conics through the geometric representation of slicing a double-napped cone. Interpreting and graphing rational functions had a dominant role for the majority of the class. Joan began the lesson with rational functions to review the concepts of asymptotes, which are also present in hyperbolas.

Mathematics Activities

Rational Function Activity

The lesson began with Joanne writing the function notation of a rational function on the smartboard. Joanne used an *xy*-chart to plot a set of points for the function $1/x$. While looking at the video display of the graph, which was a pre-made image on the smartboard, and discussing how to evaluate the function $1/x$ for $x = 0$, the students determined that the function is undefined and that there is a vertical asymptote. The procedures needed to calculate the horizontal and vertical asymptotes were handwritten on the smartboard. Joanne provided handwritten examples of rational functions with vertical and horizontal asymptotes, and the asymptotes were determined using the procedures listed on the smartboard. All of the examples were written and solved on the smartboard.

This mathematical activity was a procedural activity. The primary use of the technology was through writing on the smartboard. All of the mathematics that was done involved using the smartboard to display the information. Joanne used an image of the *xy*-plane, which was provided by the smartboard software in order to graph the rational function $1/x$. This feature of the smartboard was only used to plot the points and give a visual representation of the function.

Conic Sections Visualization Activity

The course moved on to the conic sections as they are defined by slicing a double-napped cone with a plane. A Microsoft Word document was displayed on the smartboard that contained pictures of a double-napped cone being sliced by a plane. Joanne pointed to the picture of the cone and told the class how to slice it to produce the different conics: circle, ellipse, parabola, and hyperbola. She also told the class there are three degenerate conics; a point, a line, and a double line. She explained where the plane would have to be sliced to produce each of these conics by pointing to the picture of the double napped cone that was projected onto the smartboard.

The way technology was used in this mathematical activity was categorized as procedural. Joanne did not use the smartboard to write on as in the previous activity; she used it to display a Word document. The video projector was the procedural tool used. The projector served as a way for Joanne to display a picture of a double-napped cone.

Parabola Activity

The mathematical focus on the conics then changed to looking only at the parabola. The geometric construction of a parabola was shown using Geometer's Sketchpad (GSP). The literal equation of a parabola was displayed on the GSP sketch as well as the equation for determining the focal length, the coordinates of the focus, the coordinates of the vertex, and the coordinates of the directrix. There were sliders next to each coefficient (*a*, *b*, and *c*) so that the values could be changed. Joanne used the touch-screen ability of the smartboard to change the value of each coefficient in the literal equation. As Joanne moved the sliders, she asked students to make conjectures of how each coefficient affects the graph. Joanne continually moving each slider tested students' conjectures.

This mathematical activity had aspects that were both procedural and conceptual. Overall this activity was classified as conceptual. The smartboard was used not as a writing device, but in conjunction with a different program, GSP. The smartboard and GSP were used to display information, show a geometric construction, and perform algebraic manipulations, but these actions were done in coordination with conceptual activities. The sliders were used to manipulate the equation algebraically and also gave the teacher the ability to make conjectures and connect the graphical representation of a parabola to its equation. GSP was used to test these conjectures and define the influence coefficients had on the graph.

Role of the Teacher When Using Technology

Joanne had demonstrated characteristics associated with both types of roles when she was using the technology. For the majority of the class period, Joanne took on the role of a mediator. This role was observed when her primary technological tool was the smartboard. The smartboard was the focus of most of the instruction. Joanne used the smartboard in three ways during this lesson: as a place to write down the information, to solve problems involving rational functions, and as a backdrop to display a Word document. Joanne did not use any ready-made slides to present the information, but she did refer to the book and the page numbers while she copied the definition of a rational function on the smartboard. This act was seen as that of a lecturer. Joanne presented the information to the students, writing it down on the smartboard and asking them to put that information into their notebooks. Another quality of a lecturer was that Joanne was the only person using the technology. She was always in control of how the technology was used. As Joanne used the smartboard to write down the procedures for vertical and horizontal asymptotes, she became a rule provider. She used the technology as a medium to write explicit rules for horizontal asymptotes.

The role of a facilitator came about during the parabola activity. During this activity Joanne relinquished the characteristics of a lecturer and became a questioner. GSP was used along with the smartboard for its interactive ability to manipulate the constants in the literal equation of a parabola. During the pre-interview, Joanne explained that she would be showing the unfamiliar properties of conics by using a GSP sketch. “We will be taking up conic sections, and I will be using a GSP thing to demonstrate that a bit” (Joanne, Interview, 3-22-07). Joanne was able to use the dynamic ability of GSP to pose questions to students while showing them visually how the graph changed. She was no longer telling students what mathematics was being done while using technology. Instead she was asking students to interpret the characteristics of the graph of a parabola while she manipulated it using technology. She said, “Well, hopefully they will understand.…When they do the parabolas today, they will be learning more about parabolas. We haven’t ever discussed foci and any of those kinds of relationships before. All they have ever seen, as far as I know, is the vertex and x and y intercepts. They are going to see a lot more” (Joanne, Interview, 3-22-07). Joanne did not want the students to calculate these values. She wanted students only to see and be exposed to the parts of a parabola they had not dealt with before.

Observation Two (4/4)

Mathematics Topic

The mathematics topic presented during the lesson was the graph of exponential functions. The relationship between the base of an exponential function and its graph was examined. The method of graphing an exponential function by hand was also shown.

Mathematical Activity

This lesson contained only one mathematical activity, which will be called a graphing exponential functions activity. Joanne began the lesson by writing a general exponential function $f(x) = a^x$ on the smartboard. She then used the smartboard to open a GSP sketch that graphed the function a^x for different values of a. The values were controlled by a slider. Joanne moved the slider and told the class that positive values made the graph go upward and negative values made the graph go downward. Joanne used the point tool to select a point on the graph and calculate its x and y values. These values were then substituted into the exponential equation by writing the numerical values next to the graph. Joanne closed GSP and went back to the smartboard page from the beginning of the lesson. She added to the page by writing the function 2^x. An *xy*-chart was drawn next to the function and values were substituted. Points were plotted on a hand drawn *xy*-plane, and Joanne sketched the curve.

This mathematical activity was categorized as procedural. Joanne used the smartboard in coordination with GSP unlike her previous lesson. Both of these tools were used to display information and perform calculations. Joanne told the class what was happening to the exponential function while she was using the slider. Because of her monolog, this action could only be viewed as using the technology to display information. The smartboard was treated in a similar way when graphing the function 2^x by hand. It displayed the information of what Joanne was saying.

Role of the Teacher When Using Technology

Joanne had one consistent role for the duration of the lesson: that of a mediator. While using the smartboard, her oral words were written on the board. Using the smartboard as a written form of her lecture, she told the class the procedure to be done. Joanne acted as a director when she was interacting with the GSP sketch. She told the class what the exponential graph was doing as she performed the actions on it.

<u>Observation Three (5/2)</u>

Mathematics Topic

This lesson revisited conic sections. The focus of this lesson was on identifying and graphing different conics (parabolas, ellipses, and hyperbola) using their equations. The equations did not have any phase shifts; they were all centered at the origin. The sketches of the graphs for all of the conics were done by hand.

Mathematics Activities

<u>Identifying Conics Activity</u>

The class began with identifying the type of conic section when given the equation. The general equation of a parabola, circle, ellipse, and hyperbola were defined by writing their equations on the smartboard. Each sample problem was worked out orally and written on the smartboard. Joanne showed the class how a circle is also an ellipse by using the general equation of a circle and dividing by the radius squared. She then compared this equation to the general equation for the ellipse to show their similarities. The circle and ellipse comparison was done by writing the information and performing the algebraic manipulation on the smartboard. The example problems came from the book and were assigned for homework the night before.

This activity was categorized as a procedural activity because of its heavy reliance on the smartboard to display spoken words. The smartboard was also used as a way to project the information given in the textbook to the class.

Graphing Parabolas Activity

The mathematics moved on to determining and calculating the equation of a parabola for two different situations: using the graph with ordered pairs and then given the focus. Joanne used a drawing on the smartboard to explain how to determine which equation fits the graph by pointing at two ordered pairs. She said, "Which one is it? … Because it has two *y*-values for each *x*" (Joanne, Video, 5-2-07). The coefficient *a* was determined by substituting one ordered pair into the equation. This process was done by writing the substitution and algebraic manipulation on the smartboard. The lesson then moved on to calculating the equation of a parabola given the vertex and the focus. The equation of a parabola involving the focus was taken from the book and written on the smartboard. Joanne attempted to explain the relationship between the distance of the focus to a point on the parabola and the distance from that point to the directrix. This explanation was primarily performed by drawing a line segment from the focus to the point and drawing a segment from the point to the directrix. All of the drawing was done using the smartboard.

This mathematical activity was procedural. The smartboard was used to write down the information from the textbook and make a sketch of the graph. The only actions using technology in the parabola activity were to display the information needed to complete the task.

Graphing Ellipses Activity

The graphing ellipses activity was used to determine the graph and equation of an ellipse given the graph, the major axis and foci, or the major axis and an ordered pair on the ellipse. The graph of an ellipse was drawn on the smartboard were and the major axis and minor axis were determined from the drawing. The values were substituted into the general equation of the ellipse using the smartboard to display the final answer. The next example was one in which the major axis and the foci were used to determine the equation of the ellipse. The Pythagorean Theorem was mentioned by many students, but Joanne said, "It's sort of like that" (Joanne, Video, 5-2-07). She told the students to look in their book for the different formulas to find the value of the minor axis. She wrote the formula on the smartboard and substituted the values. She then sketched a graph of the ellipse using a pre-made *xy*-plane from the smartboard software and wrote its equation underneath the graph. The last procedure for determining the graph and equation for an ellipse was done by using the major axis and point on the ellipse. Joanne used the general equation of the ellipse to substitute in the given values and solve for the value of the minor axis. The substitution and algebraic manipulation were presented through speech and written on the smartboard.

This mathematical activity heavily stressed using the smartboard to display information and procedures and was seen as a procedural activity.

Graphing Hyperbolas Activity

One method of determining the equation of a hyperbola was then shown. Joanne drew the graph of a hyperbola with the values of the major axis given using the pre-made *xy*-plane. She then referred to the textbook for the equations of the asymptotes and wrote them on the smartboard. Using the fact that the slope of the asymptote is *b* divided by *a*, the minor axis is determined she and the class completed the equation. All of this information was written on the smartboard as the problem was solved.

This activity used the smartboard to show procedures and display a sketch of the graph. These actions make the hyperbolic activity a procedural activity.

Role of the Teacher When Using Technology

This lesson was intended for students to review the concepts of conic sections. Joanne wanted the students to be able to realize that there is a correlation between an equation of a conic section and its graph. She wanted the students to correctly perform the calculations and mimic the solutions of the problems shown in class (Joanne, Interview, 5-2-07). The smartboard was used in the way she intended, which gave her role when using technology the characteristics of a mediator. Joanne used the technology to further her ability to lecture to the students and have the information in the form of written communication.

Mary

Mary's teaching style involved asking many questions. She was constantly asking students to figure out the solution of a problem and then explain how they got their solution. She tended to walk around the classroom to assess students understanding concepts. Since Mary's class was small there were only 11 students, she was able to focus more on individual attention then whole class instruction.

Mary's situation was different than that of the other two participants in many ways. She was hired as a part-time teacher teaching only one class, Algebra 1. The teaching position became available when a mathematics teacher left halfway through the school year. The mathematics courses that the teacher was scheduled to teach had been distributed among three mathematics teachers, two part-time teachers taught one course each and one full time teacher picked up the other course. This meant that Mary had begun teaching at University High School for only 1 month before she participated in this study. Because of her late arrival at University High School, Mary had to be placed in a room that did not come equipped with a smartboard. The classroom that Mary was given to teach in was not a mathematics teacher's classroom and did not have a smartboard installed in it. She was the only mathematics teacher in the school who did not have access to this technological tool. She did have access to all of the other technological resources.

I conducted four observation of Mary's Algebra 1 class. Only two observations could be analyzed using the mathematical activity lens. The other two observations could not be used because the lessons were review lessons for the end-of-course examination. These lessons did not have a clear mathematics topic or mathematics activities. The students worked on an old end-of-year examination while Mary walked around the classroom helping individual students.

It was very difficult to conduct pre-interviews and post-interviews with Mary because of her schedule. She taught her class in the middle of the day and was not required to be at school at the beginning of the day. She was also an early morning college class that coincided with the scheduling of interviews. Because of this conflict, Mary was unable to be interviewed for the first observation. Mary did provide a written agenda for that day's lesson to compensate for missing the interview.

Observation One (3/8)

Mathematics Topic

During this lesson the students were working with square roots of positive integers and constructing areas of squares that did not have perfect square areas. Each student had been assigned a laptop computer, and all mathematical constructions were done using GSP. Most of the lesson revolved around constructing a square with area of 24.

Mathematical Activities

Area and Side Length of Squares Activity

The lesson began with Mary drawing a square with an area of 10 on the whiteboard. Through Mary's questioning, the class determined that the side length of the square was the square root of 10. By investigating squares with areas that were and were not perfect squares, the class found a pattern: the side length of a square is the square root of its area. All of the investigating was done by Mary drawing squares with given areas on the whiteboard and students conjecturing on what the side length would be.

This mathematical activity was conceptual. It involved displaying information in the form of geometric constructions and measurement so the class could connect representations, find patterns, and define a property. The square figures drawn on the whiteboard were used to connect a geometric figure's area to a measurement, square roots by looking at the side lengths. This activity was used to define the pattern associated with the area of a square and its side length.

<u>Constructing New Square Roots Activity</u>

The lesson moved on to constructing the area of new squares using squares that had already been constructed. Mary asked the class how to construct the length of the square root of 24. The radical was simplified to 2 multiplied by the square root of 6, using the whiteboard to display the calculations. Mary explained that if they could make a square with area of 6 and double its side length, the construction would be done. Mary began by drawing a square of area 1 on the whiteboard. The class mimicked these constructions using GSP on the laptops. Using the Pythagorean Theorem, they calculated the diagonal of the square to be the square root of 2. (The Pythagorean Theorem was not explicitly mentioned during the calculations.) This construction showed the class how to make a square with an area of 2. Rotating the segment whose length was the square root of 2 by ninety degrees three times yielded a square with area of 2. Mary asked the students to think of a sum of two numbers that would produce the radicand, which was 6. She explained that these two numbers must be areas of squares that the students had already constructed.

Through questioning the students, she helped them see that the two squares that fit the conditions were the squares of areas 4 and 2. The two squares were connected so that only one vertex was common. From there, the top left vertices of the two squares were connected, constructing the desired length. In Mary's discussion of the construction, she used the terms *grid, snap points, rotation,* and *translation*. These terms applied to items and commands found in GSP.

The students had the task of constructing the square of area 6 and then making a square of area 24. While the students worked on the task of constructing the square of area 6, Mary explained that they would need to translate the squares constructed so that their picture looked like the one on the board (Figure 4). For the remainder of the class, Mary walked around the room helping students with questions.

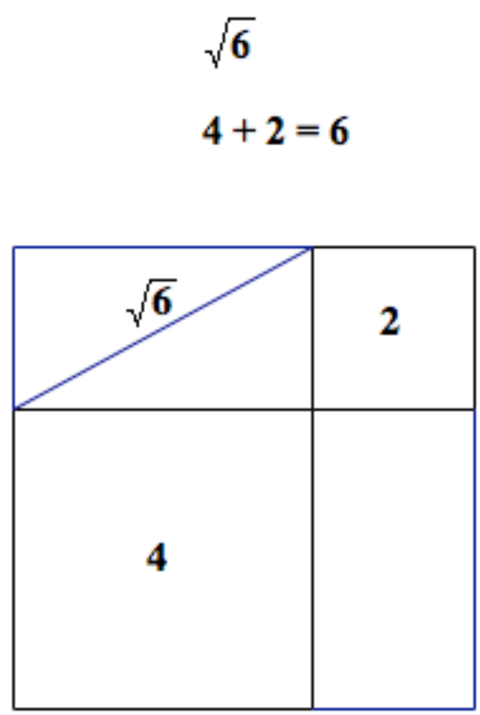

Figure 4. Mary's geometer's sketchpad construction of the square root of 6.

This activity began with students mimicking constructions done on the board using GSP. The activity began procedural due to the emphasis on displaying information and procedures.

Most of the geometric constructions were performed on the whiteboard, and the students' task was to produce the construction using GSP. After demonstrating how to construct a square with area of 6, Mary had the students construct a square with area of 24. The mathematical activity for the rest of class was coded as being conceptual. Students had to make connections to previous constructions to complete their task. The mathematical activity also had students testing and refuting constructions to work through the task. The overall this mathematical activity was conceptual since students needed to use conceptual actions to complete the task and procedural actions were only done to get the students started on the activity.

Role of the Teacher When Using Technology

Mary did not explicitly use technology while discussing with the class how to construct the squares. She used the terms associated with GSP, but used a whiteboard only to display information. The teacher's interaction with the technology came through students' use. Through this interaction, Mary took on the role of a facilitator. She acted as a supporter, consultant, and questioner while walking around the room. The facilitator role shifted between a supporter, a consultant, and a questioner throughout the time Mary was interacting with the technology. The supporter role became apparent when Mary was asked questions concerning where to find certain tools on GSP. An example was observed when the class had begun their constructions. One student asked where to find the snap points feature. Mary responded with the name of the menu heading where it could be selected (Mary, Video, 3-08-07). The consultant and questioner roles emerged when students were performing parts of the task but having difficulties getting to the next step. Mary advised the students to perform actions using GSP to help further the task. She advised the students to rotate points forty-five degrees instead of ninety if the construction was not looking right (Mary, Video, 3-08-07).

Observation Two (4/13)

Mathematics Topic

Factoring second-degree binomials was the mathematics topic presented during this lesson. The only binomials factored were those that were sums or differences of monomials with a common variable. In the previous lesson, the students had worked on factoring the sum of two positive monomials, but for this lesson the activity was to factoring the difference of two positive monomials. Visual models were used to represent each binomial. The visual models were made using algebra tiles constructed on GSP. The area of the constructed rectangle was then written in terms of variables and compared with the expression used to make the construction. This lesson took place in a computer lab where each student had access to a computer with GSP.

Mathematics Activity

This lesson contained one mathematical activity involving the creation of visual models of binomials and writing expressions for those visual models. The lesson began with Mary instructing the class to make a square with area x squared and color it in. Students were able to use the custom tools menu to make the square instead of constructing one. After the majority of the class had their square constructed, Mary asked the class how to build x squared plus $3x$. As the students responded, Mary drew a square with three rectangles, 1 by x, to the right of it. Mary explained that the area of this rectangle represented x square plus $3x$ (Figure 5).

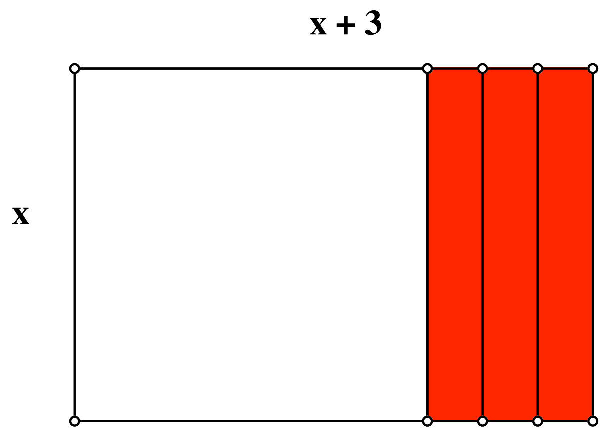

Figure 5. Construction of x squared plus $3x$

The students were asked to construct a square with an area of x squared and to subtract three rectangles with area x from the x squared. As the class worked on this problem, Mary walked around the room helping students by answering questions and directing them what to do next. She then used the whiteboard to draw a sketch of what the figure would look like, using student input to make the rectangle. The side lengths were then written on the figure. Mary wrote the equation $x^2 - 3x = x\,(x - 3)$ under the figure, explaining that the left side of the equation was the instructions of what to do and the right side was the area of the rectangle above (figure 6). The class was given three exercise problems, $x^2 - 1x$, $x^2 - 7x$, and $x^2 - 2x$ to construct on their own. The task also involved using the constructions to write each binomial in factored form.

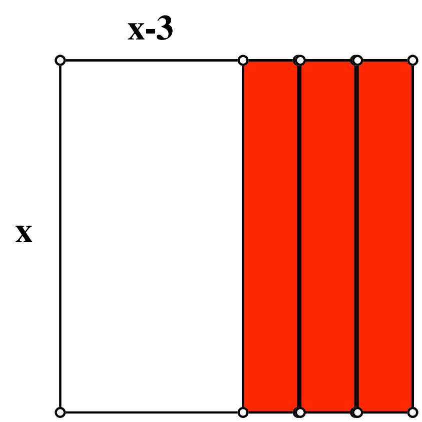

Figure 6. Construction of *x* squared minus 3*x*

This mathematical activity was a conceptual activity. During the activity, Mary used the whiteboard to display the information and procedures needed to perform the geometric construction. If the mathematical activity had ended there, this activity would have been procedural, but the information and procedures were used to make connections between representations. The connection between an area model and the algebraic representation of factoring variables was the main goal for this lesson. Mary explained that her intent for the lesson was not on using algebra to manipulate equations, but rather on the conceptual understanding of the meanings behind variables and their operations.

> I'm going to have them write down the problem and the solution so to speak, at the end. I think we are going to try to do four, but I mean, who knows? We may only be able to get through one. But I am going to have them write down what we did with variables on paper, but I'm not going to expect them…. Like on Monday we are going to be doing this again, so I'm thinking after another day that's when I'm really [expecting] them to be able to do this. Make the connecting big time between pencil and paper and what they are doing on the computer. So today is more of a non-exploration, but giving them

> experience with what it might mean to have *x* squared minus seven *x*. What would that look like? (Mary, Interview, 4-13-07)

Role of the Teacher When Using Technology

Mary was able to teach with the use of technology, but she was not directly using the technology during this lesson. Before the technology was in use, Mary was in the role of a mediator. Instructions and demonstration of the procedures needed to construct the geometric representation were done on the whiteboard. Once the demonstration was completed and technology was being used to solve problems, Mary took on the role of a facilitator. Two of the categories that define a facilitator, consultant and questioner, were observed. Mary did not act as a supporter while the technology was in use. When Mary walked around the room, the students' questions concerned the constructions and the determination of the area. Mary said, "You want to do *x* squared minus 1*x*. What is going to be different? (Mary, Video, 4-13-07)" This quotation was a good example of how Mary acted as a questioner. She did not show the student how to make the construction. Instead, she used questions so that the student could relate his difficulties to something that was already done. Mary was able to use questions to act as a consultant. She said, "When you're looking at the part that is left over, you've got *x* squared you took off 1*x*. What's the part that is left over here? How big is it?... *x* tall, and how wide is it?... Everyone agree? (Mary, Video, 4-13-07)"

CHAPTER 5

DISCUSSION OF FINDINGS

In this chapter, I present connections between the type of mathematical activity and teacher roles while teaching secondary mathematics using technology. The teachers' primary source of the mathematical activity influence on the roles of a mediator and facilitator are the focus for my findings. The analysis and findings were guided by the following questions:

1. How are mathematical activities developed by secondary mathematics teachers from a technologically rich mathematics education program categorized when they use technology?
2. What roles, mediator or facilitator, do teachers from a technology rich mathematics education program take when using technology?
3. How do these roles fit into different mathematical activities?

The two types of mathematical activity offered by Zbiek, Heid, Blume, and Dick (2007) – procedural and conceptual – provide a framework for answering the questions concerning mathematical activities. The two categories for the role of a teacher when using technology offered by Monaghan (2004) – mediator and facilitator – provide a framework for answering the questions concerning teacher roles. The descriptions of the participants' mathematical activities and roles presented in chapter 4 were used to describe and analyze the findings. At the end of this chapter, three models are presented to explain the influence the mathematical activities had on the roles of the mathematics teachers who taught with the use of technology.

Mathematical Activities When Using Technology

To discuss mathematical activities as they pertain to the first research question, this section is separated by participant. A discussion of each participant's mathematical activities and their coding is presented in the section. Similarities and differences between participants' mathematical activities and the type of technology used are discussed at the end of the section.

Bill

The majority of Bill's mathematical activities dealt with defining properties and performing calculations. The smartboard was the predominant technological tool used during all of the observations. Bill had used this tool to display information and procedures pertaining to each mathematical activity. The information displayed on the smartboard was aligned with the textbook. An example of this alignment was when Bill referred to the textbook by having students' copy and fill in a table displayed on the smartboard. Field notes from pre-interviews indicated that Bill had typed information (headings, definitions, and sample problems) from the textbook into the smartboard and used it to guide class instruction. During two pre-interviews, Bill described his mathematical activities as "traditional" (Bill, Interview, 3-7-07), and "follow[ing] the pacing guide" (Bill, Interview, 4-4-07). These data were used to conclude that the textbook acted as the primary source for the mathematical activities of the course.

The mathematical activities relating to roots and logarithms gave Bill an opportunity to use other technological tools: scientific and graphing calculators. These mathematical activities used calculators in a procedural, computational manner. When calculators were part of a mathematical activity, Bill used the smartboard was used in conjunction with them to display problems and procedures.

According to the Zbiek et al. (2007) framework for mathematical activities when using technology, the majority of Bill's activities were procedural activities. Performing calculations and displaying information fit directly into the category of a procedural activity. The interaction the mathematical activity had with the smartboard was used to represent the material in the textbook. In the mathematical activities coded as conceptual, Bill used the smartboard to make connections from one topic from the text to another. The smartboard made it possible for him to quickly display and manipulate (draw on and hide) the mathematical activities found in the textbook. Each mathematical activity used the smartboard as a guide or framework for the mathematics covered. Bill's interaction with the curriculum through the use of technology was similar to the use of a whiteboard or chalkboard.

Joanne

Joanne's mathematical activities can be summarized by three predominant actions while teaching with technology: computations, graphing, and displaying information and mathematical procedures. The smartboard was the predominant technological tool used during Joanne's mathematical activities. Every lesson and mathematical activity observed used the smartboard. She used this technological tool to display information and mathematical procedures. The textbook was the source of the information and mathematical procedures displayed on the smartboard. During two mathematical activities (conic sections (Joanne, Video, 5/2/07) and rational functions (Joanne, Video, 3/22/07)), I observed that Joanne looked to the textbook for the mathematical procedures and examples to be written on the smartboard. For these mathematical activities, the textbook acted as the mathematics curriculum for the course.

When Joanne used the smartboard in conjunction with GSP during the parabola activity, the interaction between the curriculum and the technology was different than in previous mathematical activities. The textbook was no longer guiding the curriculum. Joanne's knowledge and actions had taken over as the curriculum. She was no longer referring to the textbook for guidance or directions. She was able to use her knowledge of the mathematics and the GSP sketch to present the mathematical activity. This action opened the possibility for her to present conjectures to the students, look for patterns, and test the conjectures. During the parabola activity, the mathematics curriculum interacted with the technology in a dynamic and investigational manner. (This was an internal source of mathematical activity because the participant was the primary source of the mathematical activity.)

According to the coding of Joanne's mathematical activities, the majority of the activities were procedural activities. Joanne's mathematical activities, excluding the parabola activity, used the technology only as a tool to present information and mathematical procedures through the textbook. The interaction between the mathematical activities and the smartboard was similar to the interaction between mathematical activities and a chalkboard or whiteboard. The interaction between the mathematical activities and GSP, used with the smartboard, during the parabola activity was dynamic and investigational.

Mary

The mathematical activities observed in Mary's lessons involved conjectures, patterns, mathematical constructions, and connecting mathematical concepts. The only technological tool Mary used for her mathematical activities was GSP. A smartboard was not used. All of the activities began with an explanation of the task students were to complete using GSP. The curriculum was presented as a set of tasks for students to work on. Mary did not use a textbook to guide the mathematical activity; instead, she used her knowledge of the topic along with GSP to present the mathematics curriculum. Mary was the source of the curriculum because she began the explanation and presented the task. The curriculum was influenced directly through the use of technology. This influence was due to the fact that the task had to be completed with the use of GSP. Mary's mathematical activities were conceptual activities.

Similarities Between Mathematical Activities and the Type of Technology Used

The mathematical activities presented by Bill and Joanne had several commonalities, whereas Mary's activities differed. The majority of Bill's and Joanne's mathematical activities were procedural activities; while the majority of Mary's mathematical activities were conceptual activities. During Bill and Joanne's activities, the actions they selected were computations, display information, and mathematical procedures. Mary's activities included the action of displaying information and procedures, but connecting representations played a significant part in the mathematical activities. Bill and Joanne used the same technological tool, a smartboard, to present mathematical activities. Mary did not have access to a smartboard, but she displayed information and procedures using a white board in the same manner. The technological tool Mary used was GSP, which was on student computers (laptops and desktops).

A similarity found among the participants concerning the mathematical activities that were conceptual activities. Bill's, Joanne's, and Mary's conceptual activities had both conceptual and procedural actions. The conceptual activities began as procedural actions, but technological tools were used to connect representations, find patterns, conjecture, and predict. All of the conceptual activities contained at least one procedural action. I concluded that the conceptual activities included some procedural actions. Conceptual activities building upon procedural ones have also been found by Lagrange (1999), Artigue (2002), and Hoyles, Noss, and Kent (2004).

An interesting finding came as a result of asking the question: Why did the participants interact with the mathematical activities through the use of technology as they did? The answer was found by looking at the mathematical activities each participant was presenting. Procedural activities were observed when Bill and Joanne used the technology to display information and mathematical procedures from the textbook. All procedural activities focused on the mathematics textbook. When the source of the mathematical activities was internal, mathematical activities were conceptual. The mathematics curriculum was built through the interaction with the technological tools during these conceptual activities. Since Bill's conceptual activities used the textbook as the primary source of the curriculum, I could not conclude that the primary source of the mathematical activities for all conceptual activities was internal.

The mathematics teachers from a technologically rich mathematics program interacted with their mathematical activities thought the use of technology both ways, conceptually and procedurally. The deciding factor on which way the participant interacted with the technology came down to the source of the mathematical activities. When the primary source of the mathematical activities was external, the textbook, the mathematical activities were either conceptual or procedural. An internal primary source for the mathematical activities, the teacher's knowledge, gave rise to conceptual mathematical activities only. Figure 7 shows this finding.

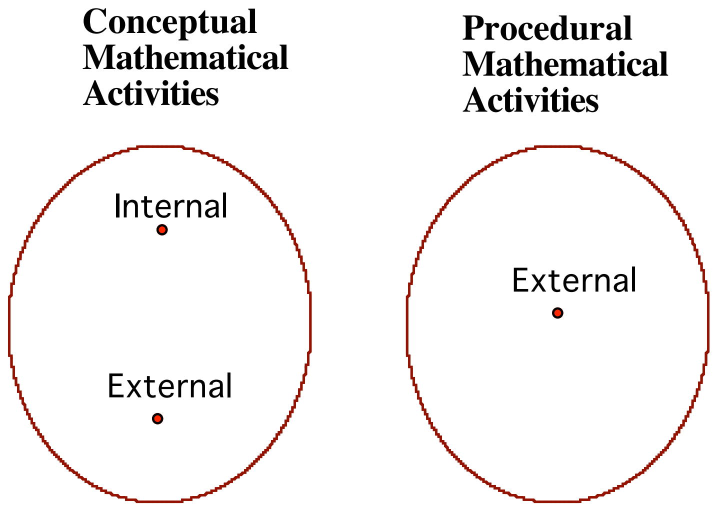

Figure 7. Mathematical activities model.

Teacher Roles When Using Technology

The teachers from a technology rich mathematics program took on the roles of facilitator and mediator. Each participant took on one role for the majority of the lessons observed, Bill and Joanne as mediators and Mary as a facilitator. To fully explain and understand the participants' roles while using technology, the use of technology needs to be interpreted. When examining the participants' roles of facilitator and mediator, I found that the topic of teacher use of technology could be interpreted in more than one way. This study's strict focus on mathematics teachers' interaction with technology in his or her classroom showed that a teacher's role while using technology had an association with how the technology was used. In many instances, when the participants had direct use of the technology they took on the role of mediator. When a participant was indirectly using the technology, they took on the role of facilitator.

Direct Use of Technology

Bill and Joanne both used a smartboard as a technological tool to instruct their classes. In each case, the participant was the only person who interacted with the technology. Bill's and Joanne's roles while using technology were predominantly as mediators. The direct interaction with the technology put the participants' focus on direct presentation of the material. Lecturing and demonstrating occurred and were supported through the use of this technology. Direct contact with the technology permitted the participant to take on the role of mediator.

Indirect Use of Technology

Indirect use of technology occurred when the participant used technology that permitted student interaction. The participant did not have to be physically touching the technology to be using it during the lesson. Mary used GSP indirectly when teaching her students. During each observation of indirect use of technology, the student had to make decisions on how to use the technology to complete the task. The indirect use of technology gave Mary the opportunity to take on the role of facilitator. She was not put in the position of lecturing, directing, or demonstrating to the students; instead, the indirect use of technology helped her to become more mobile. This mobility helped her to support, consult, and question students on the use of technology as it pertained to the mathematics topic. In turn, the indirect use of technology permitted the role of facilitator.

Teacher Roles and Mathematical Activities

As explained in chapter 2, the mathematical activities presented by the participants were used in this study as a backdrop in order to investigate teacher roles while using technology in a mathematics classroom. The mathematical activities were also examined to make connections and show influences on teacher roles while using technology. Such connections and influences were found while analyzing the data. The connection between mathematical activities and teacher roles while using technology can be seen in figure 8.

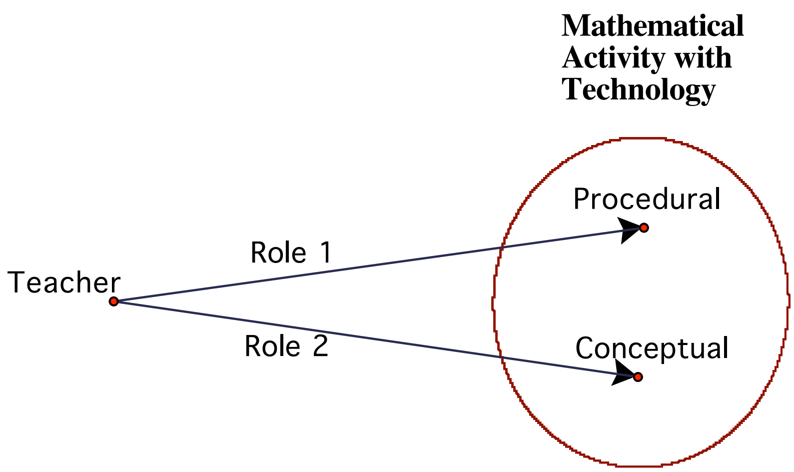

Figure 8. Mathematical activities and teacher roles.

Procedural mathematical activities encouraged the teacher to take on the role of mediator. Conceptual activities tended to encourage the teacher to take on the role of facilitator. For the majority of the mathematical activities observed, this model represented the influences mathematical activities had on a teachers' role. I found that several of Bill's activities (quotient property of powers, zero property of powers, property of rational exponents, and the parabola activity) were conceptual, but the role he took on while using technology did not fit this model.

The activities were conceptual, but Bill took on the role of mediator. To explain this occurrence, I further examined the source of the mathematical activity. Through an analysis of mathematical activities, I came to the ideas of internal and external sources of curriculum. The analysis of internal and external sources of curriculum directly related mathematical activities and teacher roles when using technology. I found that when a participant's source of mathematical activities was external, he or she took on the role of mediator. The role of facilitator arose when the participant's source of mathematical activities was internal. I observed that conceptual activities used both external and internal sources of curriculum, whereas I observed procedural activities as having external sources of the mathematical activities. This description is shown in figure 8. According the analysis of this data, facilitators will emerge when the mathematical activity is conceptual and the participants' source of their mathematical activities is internal.

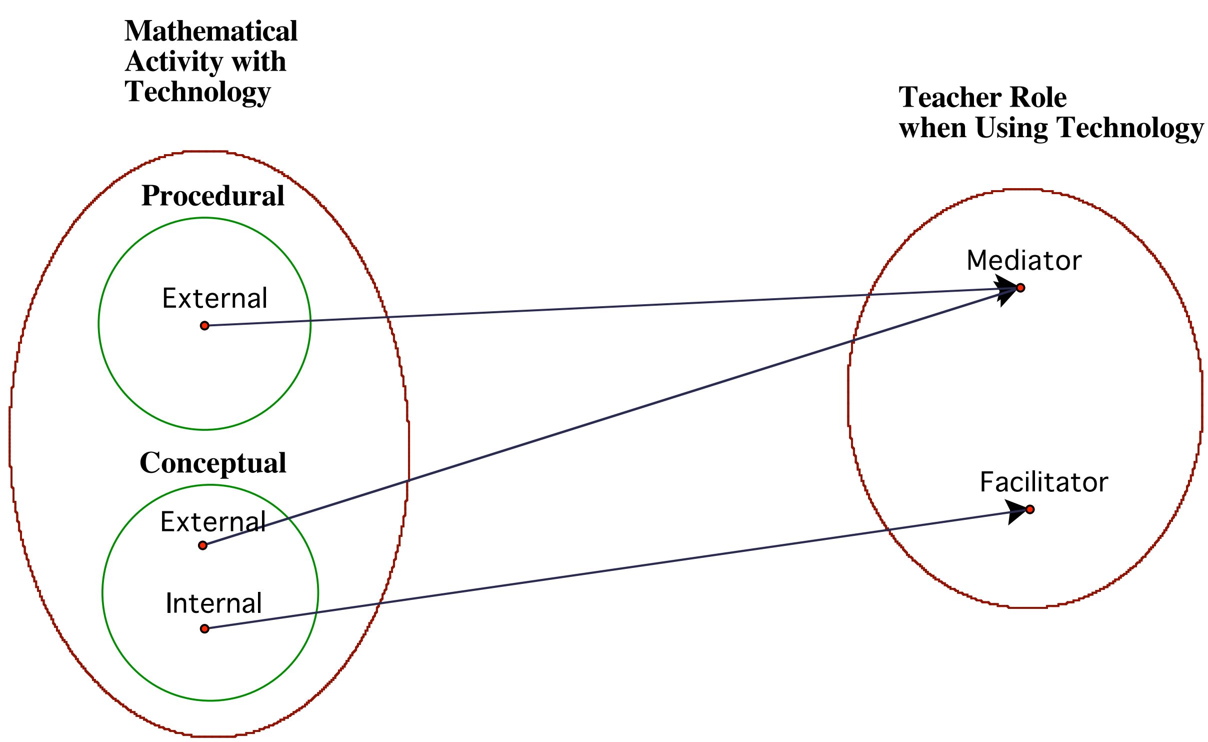

Figure 9. Detailed connection between mathematical activities and teacher role using the source of mathematical activities.

I observed that the participants' use of technology, direct or indirect, followed a similar trend as the model presented in Figure 9. Participants who made direct use of the technology (Bill and Joanne) tended to take on the role of mediator, whereas the participant who made indirect use of technology (Mary) took on the role of facilitator. The parabola activity presented by Joanne did not fit this pattern. During that activity, Joanne was using the technology directly, but her source of the mathematical activities was internal, and she took on the role of facilitator. Teachers' direct or indirect use of technology may be related to the roles they take on when using technology, but the findings in this study were inconclusive. Further examination of this occurrence in other teachers who use technology may provide a better model.

Connections to Past Research

"The right questions about technology are not broad ones, about which hardware or software to use, but about how each works in a certain curriculum" (Goldenberg, 2000, p. 1). The aspect of curriculum that I believe Goldenberg is referring to can be seen as broad. My findings indicate that viewing the mathematical activities through the lens of its source affects the roles teachers take on while using technology.

I believe that the debate over whether or to use technology in a secondary mathematics classroom is over. Technology, in the sense of graphing calculators and interactive whiteboards, has become a permanent fixture in mathematics classrooms. Investigating teachers' source of mathematical activities as internal and external gave insight into past research on student learning with and without the use of technology. The use of the model in figure 9 may help clarify why CIA students had a better knowledge of the individual components of modeling, interpreting, and translating as well as better overall understanding of the function concept in

O'Callaghan's (1998) study. The model may have also been able to explain some of the differences found in Hollar and Norwood's (1999) extension of O'Callaghan's (1998) study. As suggested in several research studies on students' knowledge when technology was used (Christou, Mousoulides, & Pitta-Pantazi, 2004; Edwards, 1997; Goos, Galbraith, Renshaw, & Geiger, 2003; Hoyles, Noss, & Kent, 2004; Owston, 1997; Ruthven, 1990) the findings of the present study show a different avenue to explore and develop that could give insight into how mathematics teachers' role while they use technology affect students' understanding of mathematical concepts.

For teachers from a technological rich mathematics education program the sources of mathematical activities had a direct impact on the role that they took on while teaching with technology. These findings are in agreement with Monaghan's (2004) statement that mathematics teachers will not relinquish other roles and move to become facilitators. Simply giving mathematics teachers technology to teach with, even mathematics teachers who have knowledge of the use of technology, will not insure that they move to become facilitators. The role of a facilitator is a complex one, with the source of the mathematical activity and type of mathematical activity influencing a teachers' role when using technology much more than the access to the technology.

CHAPTER 6

SUMMARY AND IMPLICATIONS

This chapter provides an overview of the purpose, research framework, methodology, and findings of the study. Implications and recommendations for research conclude the chapter.

Purpose of the Study

The purpose of this study was to understand the roles teachers from a technology rich mathematics education program take on while teaching with technology and the connection that the secondary mathematical activities had to the roles. Teacher roles while using technology were defined through the use of symbolic interactionism. Symbolic interactionism, a theory that human beings act toward things on the basis of the meanings that these things have for them, provided a foundation for examining mathematics teachers' use of technology. I collected data from three practicing secondary mathematics teachers as a means of addressing the following research questions:

- How are mathematical activities developed by secondary mathematics teachers from a technologically rich mathematics education program categorized when they use technology?
- What roles, mediator or facilitator, do teachers from a technology rich mathematics education program take when the use of technology is observed?
- How do these roles fit into different mathematical activities?

By viewing mathematics teachers' use of technology as a form of symbolic interactionism, I assumed that teachers would interact with the technology based on the meaning that they had made for it for certain mathematical activities. The source of the mathematical activities participants used to teach the mathematics provided connections between mathematical activities and teacher roles when using technology.

Research Framework

The framework used in this study was adapted from a model presented by Monaghan (2004) on the roles of teachers who use technology in the mathematics classroom. Monaghan's model highlighted two roles mathematics teachers took on while using technology, that of a mediator or a facilitator. To analyze secondary mathematics teacher roles, I used the model presented by Zbiek, Heid, Blume, and Dick (2007) on mathematical activities to view mathematical activities in a classroom that used technology. The mathematics curriculum was seen as a collection of mathematical activities that were either procedural or conceptual. This model provided an opportunity to view mathematical activities presented by each participant even though that the participants did not teach the same course.

These two models made up the framework of mathematics teacher roles while using technology guided the design, data collection, and analysis of this study. First, I took the model for mathematical activities as the background for the study, defining procedural mathematical activities as mechanical and involving the use of procedures and skills and conceptual mathematical activities as involving understanding, communicating, and using mathematical connections. Using the Zbiek et al. (2007) descriptions of these mathematical activities, I developed descriptive actions for each mathematical activity. Second, I took the model for mathematics teacher roles when using technology as the basis for this study, defining facilitators as teachers who lead discussions between themselves and students with a computer display as the focus and mediators as teachers who play an active role in students learning through social interactions between teacher and students (Monaghan, 2004). Using descriptions of these roles presented in Farrell (1996), Fraser, Burkhardt, Coupland, Phillips, Pimm, & Ridgeway (1987), and Monaghan (2004), I developed descriptions for each type of role. Finally, both of the adapted models were uploaded into the Video Analysis Tool (VAT) for coding. The mathematical activities model was used first to partition and code the video data. Then the teacher role while using technology model was used to code the data previously coded by the mathematical activities model. The coding was done in this manner for the potential to inform me about the overall teacher's mathematical activities and roles while using technology as well as connections between mathematical activities and teacher roles.

While analyzing the data, I observed that the participants were had relied on two different sources of mathematical activities while they taught the mathematics with the use of technology. To further understand the connection mathematical activities and the role of technology, I offer the following terms for sources of mathematical activities while using technology:

1. *External source of the mathematical activities* is when a teacher relies primarily on the textbook or other outside resources to teach the material for the course.
2. *Internal source of the mathematical activity* is when a teacher relies primarily on his or her own knowledge of mathematics and self-made mathematical activities to teach the material for the course.

Methodology of the Study

This study was centered on three in-service secondary mathematics teachers in a high school with readily available technological resources. Such resources included a smartboard, an overhead video projector, computer labs, and laptop computers with Geometer's Sketchpad. The selection of the participants was based upon their recent attendance or completion of a degree from a university that is considered to have a technologically rich mathematics education program. Data was collected during a 3 month period at the second half of the year. Observation protocol asked participants to conduct pre-interviews and post-interviews for each observation. Video observations, field notes, and pre- and post-interviews were the primary data sources. Video data were digitized and uploaded into the VAT the same day of the observation. On going analysis helped to refine the observation schedule to include several observations of each participant on consecutive days.

Research Findings

What follows is a discussion organized around the roles of teachers who use technology in their classroom. I discuss what can be learned about secondary mathematics teachers' roles while using technology and give a critique of the research framework.

The Mediator Role

Bill, Joanne, and Mary showed evidence of the mediator role at some point during my observations. I identified their roles, type of mathematical activities, and source of curriculum while teaching with technology. Some important observations can be made in these cases about the mediator role while using technology. First, the mediator role was observed in both conceptual and procedural mathematical activities. Also, the mediator role was the only role observed during procedural mathematical activities. These findings do not support the hypothesis that there is a straightforward connection between one type of mathematical activity and the mediator role. The findings raise questions about how to think about individual teacher roles. Rather than being a predictable product of the content of the curriculum, I found it was up to the teacher's strategy.

Second, the mediator role was always observed when the participants used an external source of mathematical activities. For example, Joanne was observed relying directly on the textbook while teaching a lesson on conic sections. Her reliance on an external source of mathematical activities, reading from the textbook and copying the information on the smartboard, put her in the position of a demonstrator and rule provider. Both are descriptions of a teacher in the role of mediator. Likewise, Bill's reliance on the textbook to prepare smartboard slides and present the mathematical activity made the instruction lecture oriented and his role as mediator emerged. Rather than the teacher taking the external source of the mathematical activity and adapting it, these examples show how teaching directly from an external source can be conducive to using technology as a mediator. External sources of mathematics activities are important in the act of teaching with technology, but how the teacher uses them affected the mediator role.

The Facilitator Role

Joanne and Mary were observed in the role of facilitator during certain mathematics lessons. Some important observations can be made about the facilitator role from these cases. First, the mathematical activities presented during these lessons were always conceptual. Simply having conceptual mathematical activities did not guarantee that the participant would be in the role of facilitator. Several mathematical activities presented by Bill were conceptual, and he was in the role of a mediator. I did not find a correspondence between conceptual mathematical activities and the role of facilitator.

Second, when a participant was observed to be conducting a conceptual mathematical activity in the role of facilitator, he or she used an internal source of mathematical activities. The use of internal sources of mathematical activities along with conceptual mathematical activities made it possible for the participants to teach using conjectures, patterns, and connected representations. I concluded that the facilitator role was directly connected to the teachers' use of internal source of mathematical activities. Figure 8 shows these connections.

Critique of Research Framework

Although possible extensions of this study were purposely excluded to allow concentration on the questions guiding the study, research could have profited from data including other sources. More consistent post-interviews with participants would have given insight into how participants viewed the mathematics activities and the use of technology. This would have enhanced and further verified my views of the mathematical activities. Focusing on teachers from a technologically rich mathematics education program who taught the same class would have provided the possibility of further contributing to the description of each framework. Including participants with the same teaching experience and the same educational degree from different technologically rich mathematics education programs would have made it possible to look at the influence each program had on the teachers' role of technology in a mathematical activity.

I purposely designed the study to incorporate and infuse two frameworks. One unified organizational structure might have resulted in less confusion of how everything was aligned. The use of one framework could have given further developed and added to past research, which used the framework. The analysis could have been improved through the use of a team consensus when it came to coding and interpreting. My unilateral interpretation could have overlooked certain trends in the data.

In the present study, mathematical activities and teacher roles while using technology did not have the connections that I had expected. Nonetheless, my search for a connection between the two contributed to the emergence of internal and external sources of mathematical activities. The topic of instructional strategies did appear in the pre-interview protocol, but because of my preconception that there were connections between the mathematics activities and the teacher roles, the significance of the strategies was minimal. My initial focus on the use of technology in the secondary mathematics classroom prevented my undertaking more detailed research on internal and external sources of the mathematical activities.

My concentration on teachers from the same technology rich mathematics program helped to keep some consistency in the participants' knowledge of technology and its use in the mathematics classroom. Observing participants at different stages in their teaching careers, with different degrees, contributed to being able to make implications concerning teacher preparation at the university level. Even though the participants had recently attended a technology rich mathematics education program, their previous use of technology and training still differed. Mary and Joanne had both participated in inservice training using GSP before they had attended the same university. Bill had used GSP, but only at the university. Mary had taken more courses on the use of technology in the mathematics classroom than Joanne. Joanne was the only participant who had previously used a smartboard while teaching secondary mathematics. Each participant's knowledge on the use of technology in the mathematics classroom was different. I was aware of these differences and concluded that a study could not be done with the participants having the same experiences and the same knowledge of teaching mathematics with technology. By observing teachers from different technologically rich mathematics education programs, I could have used the differences in their preparation as a way to analyze and interpret the data and included more participants in the study. A longitudinal study would have been informative, but two of the three participants did not continue to teach at University High School the following school year.

Because of my teaching position at University High School, some pre-interviews and post-interviews had to be cut short. More time to conduct the interviews could have helped me develop more insight into the connections between mathematical activities and teacher roles while using technology.

Implications and Recommendations for Research

The implications of this study concern teacher practice and teacher preparation. There has been a push from the NCTM (2000) for mathematics teachers to become more like facilitators with and without the use of technology. The connections between mathematical activities, the source of mathematical activities, and teacher roles can help practicing mathematics teachers who use technology or want to use technology in their classroom to begin the process of teaching as a facilitator. My findings also imply that if teacher preparation, both inservice and preservice, intends to develop facilitators, these programs should focus on teachers developing conceptual mathematical activities and adapting external sources of mathematical activities so that they can develop internal sources of mathematical activities. Along with the identification of conceptual mathematical activities, methods courses can show preservice teachers ways to use technology as facilitators.

Research recommendations from studies investigating teacher roles while using technology and mathematical activities include further investigation of the complexity of integrating technology into mathematics teachers' classrooms (Artigue, 2002; Monaghan, 2004), need for longitudinal studies with mathematics teachers who use technology (Farrell, 1996), and the effect of technology on mathematical activities and the interaction between teacher and curriculum content (Zbiek et al., 2007).

Recommendations also include an enhancement of the use of symbolic interactionism (Crotty, 1998) for teaching with technology. The study of how mathematics teachers interact with the technology based on the meaning that they had made for it deserves further consideration. This would involve a study of preconceptions and beliefs that teacher bring with them as they interact with technology. If researchers investigate teachers' knowledge of the use of technology and what motivates teachers to integrate technology into their mathematical activities, more can be said about the meaning they make for it.

There is a great need for longitudinal studies of teachers who use technology in their classroom, especially those with teachers who have similar knowledge of the use of technology. In the present study, the practicing teachers were observed teaching 4 lessons each. My approach provided insights into their roles during a short period of their teaching. Follow-up studies of emerging themes concerning mathematical activities and sources of mathematical activities could provide greater understanding of the development of roles and may provide insight into role progression and role change.

Additional research into internal and external sources of mathematical activities might extend the perspective that emerged from the present study and provide more insights into the development of teacher roles with the use of technology. Deeper research on internal and external sources of mathematical activities as they pertain to the integration of technology might bring further understanding into the development of teacher roles. Such research might increase the understanding of how and why different sources of mathematical activities impact teacher roles. It might also shed light into how knowledge of technology and knowledge of mathematics (Niess, 2005) affect the development of teacher roles.

REFERENCES

Adams, T. (1997). Addressing students' concept of function: Applying graphing calculators and a model of conceptual change. *Focus on Learning Problems in Mathematics, 19(2)*, 43-57.

Artigue, M. (2002). Learning mathematics in a CAS environment: The genesis of a reflection about instrumentation and the dialectics between procedural and conceptual work. *International Journal of Computers for Mathematical Learning, 7(3)*, 245-274.

Bitter, G., & Pierson, M. (2002). Using technology in the classroom (5th ed.). Boston: Pearson Education.

Brown, C., & Borko, H. (1992). Becoming a mathematics teacher. In D. A. Grouws (Ed.), *Handbook of research on mathematics teaching and learning*, (pp. 209-239). New York: Macmillan.

Christou, C., Mousoulides, M. P., & Pitta-Pantazi, D. (2004). Proofs through exploration in dynamic geometry environments. *International Journal of Computers for Mathematical Learning*, *9(2)*, 339-352.

Crotty, M. (1998). *The foundations of social research: Meaning and perspective in the research process.* Thousand Oaks, CA: Sage.

Cyrus, V. F., & Flora, B. V. (2000). Don't teach technology, teach with technology. *Mathematics Teacher, 93*(7), 564-567.

Dion, G. (1990). The graphics calculator: A tool for critical thinking. *Mathematics Teacher, 83*(7), 567-571.

Edwards, L. D. (1997). Exploring the territory before proof: Students' generalization in a computer microworld for transformation geometry. *International Journal of Computers for Mathematical Learning*, *2(3)*, 187-217.

Eron, M. B., & Rachlin, S. L. (2005). Middle math: Improving the undergraduate preparation of teachers of middle grades mathematics (Vol. 2). San Diego, CA: Association of Mathematics Teacher Educators.

Farrell, A. (1996). Roles and behaviors in technology-based precalculus classrooms. *Journal of Mathematical Behavior, 15(1)*, 35-53.

Fraser, R., Burkhardt, H., Coupland, J., Phillips, R., Pimm, D., & Ridgeway, J. (1987). Learning activities and classroom roles with and without computers. *Journal of Mathematical Behavior*, 6(3), 305-338.

Goldenberg, E. (2000). Thinking (and talking) about technology in math education [Electronic Version]. *Issues in Mathematics Education.* 1 – 8.

Goos, M., Galbraith, P., Renshaw, P., & Geiger, V. (2003). Perspectives on technology mediated learning in secondary school mathematics classrooms. *Journal of Mathematical Behavior, 22(1)*, 73-89.

Guin, D., & Trouche, L. (1999). The Complex process of converting tools into mathematical instruments: The case of calculators. *International Journal of Computers for Mathematical Learning, 4*(3), 195-227.

Hand, V., Williams, C., & DeAnda, P. (2007). *"What counts as a mathematical activity and who decides?": Challenging the discourse of mathematics in mathematics education.* Paper presented at the North America Chapter of the International Group for the Psychology of Mathematics Education, Lake Tahoe, Nevada.

Hativa, N. (1988). Sigal's ineffective computer-based practice of arithmetic: A case study. *Journal for Research in Mathematics Education, 19*(3), 195-214.

Heinich, R., Molenda, M., Russell, J. D., & Smaldino, S. E. (2002). Instructional media and technology for learning (7th ed.). Saddle River, NJ: Merrill Prentice Hall.

Hollar, J. C., & Norwood, K. (1999). The effects of a graphing-approach intermediate algebra curriculum on students' understanding of function. *Journal for Research in Mathematics Education, 30*(2), 220-226.

Hoyles, C., Noss, R., & Kent, P. (2004). On the integration of digital technologies into mathematics classrooms. *International Journal of Computers for Mathematical Learning, 9*(3), 309-326.

Kaput, J. (1992). Technology and mathematics education. In D. A. Grouws (Ed.), *Handbook of research on mathematics teaching and learning* (pp. 515-556). New York: Macmillan.

Kaput, J., & Thompson, P. (1994). Technology in mathematics education research: The first 25 years in the *JRME*. *Journal for Research in Mathematics Education, 25*(6), 676-684.

Lagrange, J. (1999). Complex calculators in the classroom: Theoretical and practical reflections on teaching pre-calculus. *International Journal of Computers for Mathematical Learning 4(1)*, 51-81.

Lavy, I., & Lebron, U. (2004). The emergence of mathematical collaboration in an interactive computer environment. *International Journal of Computers for Mathematical Learning, 9*(1), 1-23.

Masalski, W. J. (2005). *Technology-supported mathematics learning environments*. Reston, VA: National Council of Teaching of Mathematics

Meltzer, B. N., Petras, J. W., & Reynolds, L. T. (1975). *Symbolic interactionism*. London: Routledge and Kegan.

Monaghan, J. (2004). Teachers' Activities in Technology-Based Mathematics Lessons. *International Journal of Computers for Mathematical Learning, 9(3)*, 327-357.

National Council of Teacher of Mathematics (1989). *Curriculum and evaluation standards for school mathematics.* Reston, VA: Author.

National Council of Teacher of Mathematics (2000). *Principles and standards for school mathematics.* Reston, VA: Author.

Niess, M. L. (2005). Preparing teachers to teach science and mathematics with technology: Developing a technology pedagogical content knowledge. *Teaching and Teacher Education, 21*, 509-523.

O'Callaghan, B. (1998). Computer intensive algebra and students' conceptual knowledge of functions. *Journal for Research in Mathematics Education, 29*(1), 21-40.

Owston, R. (1997). The World Wide Web: A technology to enhance teaching and learning. *Educational Researcher, 26*(2), 27-33.

Palmitter, J. (1991). Effects of computer algebra systems on concept and skill acquisition in calculus. *Journal for Research in Mathematics Education, 22*(2), 151-156.

Porzio, D. (1999). Effects of differing emphases in the use of multiple representations and technology on students' understanding of calculus concepts. *Focus on Learning Problems in Mathematics, 21*(3), 1-29.

Recesso, A., Hannafin, M., & Khosha, V. (2003). Video analysis tool (VAT). Retrieved April 5, 2009, from http://vat.uga.edu/About_VAT.html

Ruthven, K. (1990). The influence of graphing calculator use on translation from graphic to symbolic Forms. *Educational Studies in Mathematics, 21*(5), 431-450.

Sandstorm, K. L., Martin, D.D., & Fine, G.A. (2001). Symbolic interactionism at the end of the century. In G. S. Ritzer, B. Hutchinson, S.A. (Ed.), *Handbook of social theory*. London: Sage.

Senk, S. L., & Thompson, D. R. (2003). *Standards-based school Mathematics Curricula: What are they? What do students learn?* Mahwah, NJ: Erlbaum.

Shelly, G. B., Cashman, T. J., Gunter, R. E. & Gunter, G. A. (2002). Teacher discovering computers: integrating technology in the classroom (2nd ed.). Boston: Thompson Learning.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4-14.

Wilson, J. W. (2000, December). *Technology in secondary school mathematics*. Paper presented to the department of mathematics at University of Kansas, Lawrence.

Zbiek, R. M., Heid, M. K., Blume, G. W. & Dick, T.P. (2007). Research on technology in mathematics education. In F. K. Lester Jr. (Ed.), *Second handbook of research on mathematics teaching and learning.* (pp. 1169-1207). Charlotte, NC: Information Age Publishing.

APPENDIX A: LENS FOR MATHEMATICAL ACTIVITIES (MAL)

- Procedural Activity
  - Definition (Check box)
  - Display Information and procedures (Check box)
  - Geometric Construction (Check box)
  - Measurement (Check box)
  - Computation (Check box)
  - Algebraic manipulation (Check box)

  (Text Box)

- Conceptual Activity
  - Finding Patterns (Check box)
  - Defining (Check box)
  - Conjecturing (Check box)
  - Generalizing (Check box)
  - Connecting representations (Check box)
  - Predicting (Check box)
  - Testing (Check box)
  - Refuting (Check box)

  (Text Box)

APPENDIX B: LENS FOR TEACHER ROLE WHEN USING TECHNOLOGY (TRWT)

- <u>Mediator</u>
    - Lecture (Check box)
    - Director (Check box)
    - Demonstrator (Check box)
    - Rule provider (Check box)

  (Text Box)

- <u>Facilitator</u>
    - Supporter (Check box)
    - Consultant (Check box)
    - Questioner (Check box)

  (Text Box)

APPENDIX C: SEMI-STRUCTURED INTERVIEW PROTOCOL

Pre-Observation Interview Protocol

1. What is the topic you are going to teach today?
2. What is your goal/objective for this lesson?
3. How many days have you been working on this topic/section?
4. What types of teaching strategies are you planning to use during the lesson and why?

Post-Observation Interview Protocol

1. Do you think you meet your goal or objective?
2. Where there any parts of the lesson that you diverged from the strategies that you had planned?
3. What type of answers where you looking for from students?
4. What did you like about your lesson?
5. What did you not like from the lesson and what changes will you make next time?