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UCSMP Teachers’ Perspectives when Using Graphing Calculators in Advanced Mathematics

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UCSMP Teachers’ Perspectives when Using Graphing Calculators
in Advanced Mathematics

by

Ilyas Karadeniz

A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy in Curriculum and Instruction
with a concentration in Mathematics Education
Department of Teaching and Learning
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ABSTRACT

Nowadays, technology plays a fundamental role in education, in general, and in mathematics education in particular. The graphing calculator has been an important technological tool in mathematics classrooms since its invention and introduction in 1985 by Casio. As graphing calculators provided so many uses, their contribution to the teaching and learning process has been investigated by many researchers who have shown the use of such technology can have a significant effect on improving mathematics teaching and learning.

Investigating the impact of graphing calculators on student learning is important. It is also essential to research teachers’ perspectives on how using graphing calculators in mathematics determines how such use affects their teaching and learning. However, there are few studies on this issue. Therefore, this dissertation study may fill the gap in the literature in terms of examining high school mathematics teachers’ perspectives when they teach a precalculus course with technology integrated in the curriculum materials.

In this study, I analyzed eleven teachers’ perspectives about using graphing calculator technology in a precalculus course, titled Functions, Statistics, and Trigonometry (FST). This study was a descriptive intrinsic case study in which I analyzed teachers’ perspectives about how they use graphing calculators in the FST course, specifically about their teaching and students’ learning with available graphing calculator technology. Additionally, I explored teachers' perspectives about the issues they face when using the available technology and for what topics teachers frequently used it. I used mixed methods to examine eleven mathematics teachers’ perspectives about their teaching, students’ learning, and issues that arise when they use
graphing calculator technology. In the quantitative part of the study, I created an Index of Teachers’ Initial Perceived Attitude and Experience Level and an Index of Teachers’ Use of Graphing Calculators to measure teachers’ perspectives on technology use at the beginning and end of the school year, respectively. In the qualitative inquiry, I analyzed teachers’ responses to semi-structured interview questions by using thematic analysis.

The results of this study showed eight of the eleven mathematics teachers’ students used graphing calculators with Computer Algebra System (CAS) capability loaned by The University of Chicago School Mathematics Project (UCSMP). Five teachers had a high initial perceived attitude and experience level and the other six teachers had a medium level. All teachers reported that helping students learn to use a symbolic manipulator was equally or less important than to use a graphing calculator. The themes (1) Teachers’ use of graphing calculators, (2) Teachers’ opinions about students’ use of graphing calculators, and (3) Teachers’ issues with graphing calculator technology were created to explain teachers’ responses to interview questions related to their graphing calculator perspectives throughout the year.

Teachers typically used graphing calculators almost every day for such purposes as exploring mathematics, solving problems, and checking work. Some teachers reported the benefits of using graphing calculators in terms of instruction were focusing on the concepts and showing additional solution approaches. Teachers who wanted their students to be able to do some work without graphing calculators used no calculator tests or questions on which graphing calculators were not allowed as part of their assessment process. Teachers mentioned the need for a manual showing the steps for using graphing calculators with CAS.

Teachers’ opinions about students’ use of graphing calculators included that students generally liked them. Teachers reported graphing calculators positively affected students’
learning because students were able to find the answers for problems and have better visualization opportunities. However, teachers reported some meaning was missing and students’ arithmetic skills were negatively affected because of the presence of graphing calculators. Additionally, five teachers indicated their students relied on the graphing calculators too much. The most common issue teachers had relative to graphing calculator technology was the liability issue of the graphing calculators sent by UCSMP for students to loan. Teachers were responsible for those loaned graphing calculators. Additionally, cheating, using features that minimized the mathematics, and not being familiar with the type of graphing calculators loaned from UCSMP were other issues teachers reported. Teachers’ graphing calculator use was demonstrated based on the index of teachers’ use of graphing calculators. Seven teachers were high in terms of their use of graphing calculators at the end of the school year and four teachers had a medium use of graphing calculators.

For implications of this study, mathematics teacher educators can use the results to improve professional development programs for teachers. They might create workshops based on teachers’ perspectives and their initial perceived attitude and experience level. Additionally, textbook developers can create more exploration activities with graphing calculators, especially with CAS.
CHAPTER ONE: INTRODUCTION

Technology plays a major role in today’s life. Its major influence is deeply felt in education. Over the past two decades, new technologies for school mathematics have developed rapidly. For instance, there are many well-constructed software programs for educational purposes, such as Cabri Geometry, Geometer's Sketchpad, and Fathom. Graphing calculators are also another technological tool used in today’s classrooms. They are small, portable, and battery-powered, and have a multi-line display on which graphic objects can be drawn. Graphing calculators have the ability to plot graphs, solve simultaneous equations, and perform operations with variables. Data analysis, function graphing, numerical equation solving, matrix arithmetic, and complex number arithmetic are some additional uses of graphing calculators. Finally, many graphing calculators are programmable to allow users to create customized programs, typically used for scientific or engineering and educational applications (Kissane, 2000).

As graphing calculators provide so many uses, many researchers have investigated their contribution to the teaching and learning process. For instance, Lee and McDougall (2010) examined the pathways used for mathematical problems with graphing calculators and concluded graphing calculators are useful tools for teachers to help their students construct their mathematical knowledge and understanding. Some graphing calculators have a computer algebra system (CAS), which is a software program capable of doing symbolic mathematics and is beginning to be used more in today’s mathematics classrooms. The most important feature of a CAS is its ability to manipulate mathematical expressions in symbolic form.
This manipulative ability provides some advantages for students of mathematics. For instance, Guyer (2008) demonstrated the features of some CAS and emphasized the importance of using CAS in college level mathematics courses. In another study, Powers, Allison, and Grassl (2005) analyzed student approaches to test items to determine patterns of problem-solving techniques with and without CAS. Although students’ scores were not statistically significantly different based on the use of CAS or not, students who used CAS employed a greater variety of problem-solving techniques than students who did not use CAS. Students’ achievement has also been compared in terms of teachers’ instructional style with or without technology. For instance, Smeal, Walker, Carter, et al. (2013) compared students’ achievement in finite mathematics classes in an Alabama university with traditional teaching methods, with calculator-enhanced instruction, and with distance learning. Students in the calculator-enhanced group performed significantly higher on the post-test than students in the traditional group.

Investigating the effects of graphing calculators on student learning is important. It is also essential to research teachers’ perspectives on using graphing calculators. However, few researchers have examined this potential issue. For instance, although graphing calculators are not commonly used in mathematics classes in Turkey, Baki and Celik (2005) investigated Turkish mathematics teachers’ perceptions about using graphing calculators in mathematics courses. Teachers brought the idea that using graphing calculators can be efficient to motivate students of mathematics. However, teachers in their study had concerns about using graphing calculators because students were not allowed to use graphing calculators on national standardized tests in Turkey. Because there are few studies on teachers’ perspectives on using graphing calculators in mathematics classes, it is of great importance to do more research and broaden our body of knowledge about their perspectives.
**Rationale**

Technology has a great impact on both teaching and learning. In the literature, many researchers have shown technology allows for improvements in the teaching and learning of mathematics. For instance, although technology has a negative effect on teaching lower-order thinking skills, Wenglinsky (1998) found it has positive effects on teaching higher-order thinking skills. Therefore, it seems mathematics teachers should use technology in their classrooms when they are teaching higher order thinking skills to improve teaching and students’ learning. In addition, students have more learning opportunities when they use graphing calculators because of increased student engagement with technology, potentially leading to better understanding of mathematical concepts. According to Ruthven and Hennessy (2002), it is possible to motivate students (especially lower ability students) to draw graphs with technology.

Precalculus is generally a prerequisite course for students who plan to take an advanced calculus course. The content of this course offers many opportunities for using graphing calculators. There are different kinds of functions included in the course content, such as logarithmic and polynomial functions. Therefore, this course provides a noteworthy opportunity for both teachers and students to use graphing calculators efficiently.

One of the main issues when using technology in K-12 classrooms is accessibility. Although accessibility is necessary to encourage teachers to use technology in their classrooms, it is not sufficient. Teachers’ perspectives also play an important role when they use technology. For instance, Hopkins and Kinard (1998) found students’ beliefs about the most influential factors of their learning are the teacher, the curriculum, and the CAS, respectively. Bandura (1997) also emphasized there is a strong relationship between teachers’ beliefs and their decisions for instruction and classroom practices. Although technical support and encouragement
by the school principal might influence teachers’ use of computers, teachers’ beliefs about how mathematics should be taught, as well as their classroom management skills and computer skills, were the major factors affecting their use of computers in the classroom (Veen, 1993).

There are some key points in the literature about teachers’ perspectives on using technology. For instance, teachers’ perceptions about the value of using computers in mathematics classes shifted positively once they started to use computers in their own classrooms (Thomas, Tyrrell, & Bullock, 1996). Therefore, it is important to provide teachers with the opportunities to use technology in their classrooms so that they can experience both the benefits and disadvantages of the technology. In another example, Forgasz (2006) showed secondary mathematics teachers are motivated to use computers in their classrooms if they perceive using computers will increase students’ motivation, enjoyment, and confidence. Teachers also seem to have the perspective that using technology in their classrooms might affect their teaching strategy. For example, Scrimshaw (2004) established technology might give an opportunity to teachers to implement more student-centered teaching. These research results underline the significance of teachers’ perceptions related to their use of technology in their classroom. However, there are not many studies on this critical issue; therefore, it is important to investigate teachers’ perspectives to see how using graphing calculators affects their teaching and learning in a precalculus course.

**Statement of the Problem**

In this research, I address teachers’ perspectives on using graphing calculators in a high school Functions, Statistics, and Trigonometry (FST) course developed by the University of Chicago School Mathematics Project (UCSMP) for 11th-grade students. The course combines precalculus topics, such as functions, with statistics and trigonometry. Throughout the course,
students are expected to use graphing calculators with CAS. Therefore, the course provides an opportunity to examine teachers’ perspectives about the use of technology when such technology is allowed. My study uses both quantitative and qualitative approaches to investigate the use of CAS-capable graphing calculators in the FST course. Although the third edition of FST textbooks assumes teachers use CAS-capable graphing calculators, some teachers might prefer to keep using their previous graphing calculators which are not CAS-capable. I analyzed teachers’ perspectives in terms of using graphing calculator technology (with or without CAS) in the course. There was considerable information about how teachers used available technology, the issues that arose with the technology, and how the presence of calculator technology influenced how teachers approached the course.

**Purpose of the Study**

The purpose of this study was to examine teachers’ perspectives when they use technology (graphing calculators). The National Council of Teachers of Mathematics (NCTM) recognized the importance of technology through the following Technology Principle: "Technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students' learning" (NCTM, 2000, p. 24). Specifically, I conducted secondary analysis on data related to teachers’ use of technology (graphing calculators) in the FST course. I selected that course because it assumes a constructivist environment related to functions, statistics, and trigonometry as some of the activities and concepts would have been too difficult to teach without technology. For instance, graphing calculators are useful to investigate the effects of changing parameters of a function on the shape of its graph. In addition, students can see and explore the relationships between the gradients of pairs of lines and the lines themselves (Tajuddin, Tarmizi, Konting, et al., 2009). In particular, I analyzed teachers’
perspectives about how they taught mathematics based on the available technology. Furthermore, I explored teachers' perspectives about their students’ difficulties using the available technology, and for what topics teachers frequently used the technology.

**Research Questions**

1. In what ways do eleven teachers use graphing calculators in an 11th-grade Functions, Statistics, and Trigonometry course?

2. What are eleven teachers’ perspectives on student learning when students use graphing calculators in an 11th-grade Functions, Statistics, and Trigonometry course?

3. What are eleven teachers’ perspectives on their teaching an 11th-grade Functions, Statistics, and Trigonometry course using graphing calculators?

**Significance of the Study**

In the literature, there are many studies about teachers’ knowledge and students’ achievement when they use technology in mathematics courses. Although there are some studies about elementary and middle school teachers’ perspectives on using technology, more specifically graphing calculators, there are only a few studies on high school mathematics teachers’ perspectives about using graphing calculator technology. Furthermore, few of these studies are qualitative, and deeply analyze teachers’ perspectives on using graphing calculators. Therefore, a qualitative study on investigating high school mathematics teachers’ perspectives on using graphing calculators is useful to give rich descriptions and a deeper understanding about how teachers perceived using graphing calculators to contribute to the literature.

In addition, this study might be a cornerstone for professional development and teacher education programs. This study provides detailed information about teachers’ perspectives on the use of graphing calculators in a precalculus class. Therefore, mathematics educators can utilize
the findings of this study to give research-based and more efficient suggestions and applications about use of graphing calculators in professional development and teacher education programs. Mathematics educators can also develop new strategies to deal with the challenges that occur when teachers use graphing calculators.

This study might also be useful for curriculum developers to create more efficient tasks for a precalculus course. Curriculum developers should consider teaching and learning issues that arise with teachers and their perspectives when they use graphing calculators to create more effective curriculum materials. Therefore, this study has implications for professional development, teacher education, curriculum development programs, and the related literature.

**Definitions of Terms**

**Graphing Calculator**

A graphing calculator is a hand-held device for computation, graphing of functions, graphical and numerical solutions for equations with or without CAS.

**Computer Algebra System or CAS**

A computer algebra system is “software that enhances numerical and graphic operations with tools for formal manipulation of symbolic expressions… [and that] perform a wide variety of the numeric, graphic, symbolic, and logical operations that form the core components of algebra” (Cuoco, Fey, Keiran, McMullin, & Zbiek, 2003, pp. 1-2). E.g.

\[(x^2 - 1) = (x - 1)(x + 1)\]

**Functions, Statistics, and Trigonometry or FST**

This course is the sixth of seven courses developed for secondary students by the University of Chicago School Mathematics Project (UCSMP) and is designed specifically for 11th-grade students. It focuses on the three main content areas in the title; namely functions,
statistics, and trigonometry. The creation of this course confirmed statistics can be naturally integrated with functions (Usiskin, 2007).

University of Chicago School Mathematics Project or UCSMP

This K-12 curriculum research and development project begun in 1983 is one of the longest-lived curriculum projects in mathematics education. The secondary component of UCSMP developed curriculum materials for students in grades seven through 12, and since 2005, for students in grades six through 12. The project’s aim has been to enhance mathematics for all students (Usiskin, 2003, 2007).

Summary

In this chapter, I presented the background of my study and rationale with the statement of the problem and purpose of the study. I also included the research questions, significance of the study, and definition of terms. In the next chapter, I provide information about relevant studies in the literature. I explain the methods for data collection and data analysis in Chapter Three and present the results in Chapter Four. I discuss possible implications and limitations of this study in Chapter Five.
CHAPTER TWO: LITERATURE REVIEW

The NCTM’s *Principles and Standards for School Mathematics* Technology Principle states: “technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students’ learning” (2000, p. 24). Thus, NCTM maintains technology has an important role to play in mathematics education. Indeed, it is hard to imagine a classroom today without technology. In addition, The International Society for Technology in Education (ISTE) standard for students states: “Students use critical thinking skills to plan and conduct research, manage projects, solve problems, and make informed decisions using appropriate digital tools and resources” (ISTE Standards for Students, n.d., p. 1). Additionally, ISTE standard requires teachers to “Engage students in exploring real-world issues and solving authentic problems using digital tools and resources” (ISTE Standards for Teachers, n.d., p. 1). These two sources suggest having technology in the classroom and using it appropriately in education, specifically for mathematics, has great significance.

At the Mathematics in Education and Industry (MEI) Seminar in 2008, it was stated the following could be offered by Information and Communications Technology (ICT): (1) “Dynamic and visual tools to explore mathematics in shared space;” (2) “Tools to outsource processing;” (3) “New representational infrastructures for mathematics that change what is learned;” (4) “Visual, dynamic connectivity with real-time interaction;” and (5) “Personal technology and mobility” (*Computer Algebra Systems in the Mathematics Curriculum*, 2008, p. 7). Therefore, I decided to conduct a study to investigate mathematics teachers’ perspectives when using technology, specifically graphing calculators with or without CAS.
In this chapter, I discuss graphing calculator technology and CAS in mathematics learning and teaching. I begin with general information about the features and some roles of graphing calculators in mathematics education. I then discuss teachers’ perspectives on using technology in teaching mathematics. I also discuss the benefits and challenges teachers have using graphing calculators or CAS in teaching and how the presence of technology within the curriculum materials motivates or inhibits teachers’ infusion of technology into their instruction. I also explain the thematic analysis method in this chapter. Finally, I present a summary of the literature review.

I used the University of South Florida library database of encyclopedias, searching with the terms “graphing calculators,” “mathematics teaching,” and “learning.” I read the abstracts and selected related ones on high school and higher-level mathematics courses. Furthermore, I used related books, including research on using technology in mathematics education, such as *Research on Technology and the Teaching and Learning of Mathematics: Volumes I, II* (Blume & Heid, 2008; Heid & Blume, 2008). I also found sources in the articles and book chapters included in the reference list.

**Graphing Calculators in Mathematics Education**

In this section, I describe the main features of graphing calculators, how graphing calculators are useful in terms of helping to improve students’ problem solving and thinking skills, advantages of using graphing calculators for student learning, and the role of graphing calculators in teaching mathematics. This information gives a better understanding of teachers’ perspectives about not only teaching with graphing calculators, but also students’ learning with graphing calculators.
Features of Graphing Calculators

In the mid-1980s, graphing calculators were introduced in mathematics classrooms following ten years of scientific calculator use (Lee & McDougall, 2010). Graphing calculators brought the opportunity to deal with mathematical concepts and provided access to mathematical problem solving, which, before that time, could only be done on a computer. Some characteristics and functions of all graphing calculators are computation, graphing of functions, viewing tables, and running programs and applications. There are also functions for computing roots, derivatives, and definite integrals. In addition, modern graphing calculators display geometric figures and integrative diagrams (Roschelle & Singleton, 2008). One of the noteworthy features of graphing calculators is they provide multiple approaches to studying functions, including graphical, numerical, algebraic approaches, and visualization of concepts (Committee on the Undergraduate Program in Mathematics, 2004). Some graphing calculators offer CAS with numerical solving, graphing, and symbol manipulating capabilities (Waits & Demana, 1998). These symbolic manipulation features may have an impact on teachers’ perspectives on using graphing calculators in their classes.

Usefulness of Graphing Calculators

The literature shows graphing calculators are commonly used as a technological tool in mathematics teaching and learning. Studies also indicate the pedagogical affordances of the graphing calculator are closely related to improved learning of mathematics (Choi-Koh, 2003; Leng, 2011; Roschelle & Singleton, 2008). Roschelle and Singleton (2008) listed the contributions of graphing calculators for problem-solving and reasoning as:

- Increasing attention to conceptual understanding and problem-solving strategies by offloading laborious computations.
• Enabling students to hone their understanding by tackling more than “textbook examples” [those that can be completed in less than five minutes with paper and pencil].

• Examining the related meanings of a concept through the display of multiple representations, such as exploring rate of change (i.e., slope) in a function definition, a corresponding graph and a table of values.

• Engaging students with interactive explorations, real world data collection, and more authentic data sets.

• Giving students more responsibility for checking their work and justifying their solutions.

• Providing a supportive context for productive mathematical thinking. (p. 954)

A study conducted by Choi-Koh (2003) demonstrated that using graphing calculators could promote students’ thinking. She conducted a case study with a 10th-grade student taking a trigonometry course with a computer and a calculator. She observed the student’s thinking through the learning process for trigonometry tasks. The study included three stages for student understanding; namely, intuitive, operative, and applicative. The student graphed functions with the calculator and observed relations with graphs in the intuitive stage. The operative stage consisted of explaining the reason why the effects occur, abstracting and comprehending the trigonometric algebraic equations, and systematizing (predicting and conjecturing the composite functions). Inductive generalizing by giving detailed examples, making formulas for the given graphs, and reflecting by constructing statements based on discovered properties formed the applicative stage. The student’s thinking process was observed to advance from the intuitive to the operative and, then, to the applicative stage with the usage of the graphing calculator. Choi-Koh also reported that at the beginning of the operative stage, graphing calculators affected the
student’s explanations. Choi-Koh argued that visual data promoted students’ motivation to explain the graphs and functions and concluded use of technology was beneficial for students to develop their thinking process.

Those studies show researchers recognized the improvement of student learning with graphing calculators. Although developing student learning with graphing calculators is important and significant, in this study I examined how teachers became aware of these improvements in students’ learning with graphing calculators and their perspectives on students’ learning using graphing calculators.

**Role of Graphing Calculators**

Doerr and Zangor (2000) described five different graphing calculator modes as “computational tool, transformational tool, data collection and analysis tool, visualization tool, checking tool” (p. 161). Their study demonstrated findings about how students used graphing calculators for each category in a precalculus course.

**Computational tool.** Graphing calculators were used as a computational tool generally to evaluate numerical expressions. Two issues appeared in the use of graphing calculators as a computational tool: entering symbols and parentheses correctly, and the precision of computational results. Students used mathematical reasoning to explain the errors appearing on their graphing calculator screen for the first issue. The second issue arose generally in rounding answers as students’ interpretations of rounding affected their problem solving strategies. In some real-world questions, students rounded the numbers for every step of the problem rather than at the end of the problem (Doerr & Zangor, 2000).

**Transformational tool.** As a transformational tool, the presence of graphing calculators forced teachers to change the forms of some questions asked of their students and/or students’
gains from the questions. For instance, the teacher used both paper-pencil and graphing calculators for a question asking about the rate of change of a function. With paper and pencil, students were only able to focus on a specific strategy to solve the question. However, in the calculator-based form, students were able to construct a “rate function” with the form of
\[ y_2(x) = \frac{y_1(x + \Delta x) - y_1(x)}{\Delta x} \]
In this form of the rate function, students showed the original function with \( y_1(x) \) and interval for the independent variable with \( \Delta x \). Students generally plugged the numbers 0.1 or 0.01 for \( \Delta x \). Therefore, students improved their global view of rate of change with calculators and the teacher was able to transform a numerical estimate of this function problem from a computational form to an interpretative form with graphing calculators (Doerr & Zangor, 2000).

Data collection and analysis tool. Graphing calculators were also used as a data collection and analysis tool in the study. Possible activities for this category were gathering data, controlling phenomena, and finding patterns. For instance, students were required to understand the context of the activity. Students also needed to conjecture, refine, negotiate and decide what constituted a satisfactory set of data (Doerr & Zangor, 2000).

Visualization tool. Students used graphing calculators as a visualization tool in four different ways:

1. to develop visual parameter matching strategies to find equations that fit data sets,
2. to find appropriate views of the graph and determine the nature of the underlying structure of the function,
3. to link the visual representation to the physical phenomena, and
4. to solve equations. (Doerr & Zangor, 2000, pp. 154-155)

Using graphing calculators as a visualization tool also reflected students’ ways of solving
equations and inequalities. For instance, the teacher explained all three available methods for solving an equation, including paper and pencil solutions, use of the calculator’s solve button and graphical solution. The researchers observed many students used the graphical approach, which was less computational and provided a more meaningful interpretation for the solution (Doerr & Zangor, 2000).

**Checking tool.** Students used graphing calculators as a checking tool in many tasks to check the conjecture for the problems. They generally posed a conjecture about a possible function as fitting a data set. Then, students checked how well it fit by using their graphing calculators. They also used graphing calculators to understand multiple symbolic forms as a checking tool (Doerr & Zangor, 2000).

Leng (2011) identified six different ways of using the TI-Nspire, an advanced graphing calculator, in a calculus class “as an exploratory tool, as a confirmatory tool, as a problem-solving tool, as a visualization tool, as a calculation tool, as a graphing tool” (p. 935). Three types; namely, confirmatory tool, visualization tool, and calculation tool were the same as the checking tool, visualization tool, and computational tool categories in Doerr and Zangor (2000), respectively, in terms of their definitions. The other three categories were exploratory tool, problem-solving tool, and graphing tool. Students used the TI-Nspire to explore and understand the concepts as an exploratory tool. The problem-solving tool meant trying diverse approaches while solving problems. The TI-Nspire was also used as a graphing tool to depict functions and problems graphically.

These roles of graphing calculators affect teachers’ teaching and students’ learning. Issues have also arisen because of the presence of graphing calculator technology. Ertmer, Addison, Lane, et al. (1999) expressed that how teachers perceive the role of technology is
related to how they use technology during instruction. In other words, these roles might affect teachers’ perspectives on teaching and student learning when using graphing calculators. Therefore, awareness of these roles for calculator use can be a starting point to create themes to analyze teacher interviews in terms of their perspectives of teaching, student learning, and issues when using graphing calculators.

**Teachers’ Perspectives on Using Technology**

Teachers’ perspectives on technology play an important role in their use of technology in teaching. “To understand how to achieve integration, we need to study teachers and what makes them use computers” (Marcinkiewicz, 1993, p. 234). In addition, students’ decisions whether to use graphing calculators could be affected by their perspectives on external effects, such as teachers' perspectives on using graphing calculators (McCulloch, 2011). Teachers have thoughts about technology in general, issues they face when they use technology in their teaching, and incentives for and barriers against using technology. The following literature review shows teachers’ perspectives on using technology in their classrooms. This section also provides information to guide my data analysis process.

Teachers first should have an appropriate environment and conditions to use technology efficiently in their classrooms. For instance, Almekhlafi and Almeqdadi (2010) made the following recommendations for teachers to integrate technology more effectively: There should be periodic planned professional development; there should be enhanced curriculum materials integrating technology; teachers should have increased collaboration from different schools country-wide, teachers should be free to decide their curriculum materials and their coverage in their lessons. They show teachers’ perceptions about using technology and suggest increasing technology integration into the classrooms in terms of the environmental conditions.
Zhao (2007) conducted a study with 17 social studies teachers to examine their perceptions and experiences about a technology integration training program. Zhao found three major categories of participant teachers’ perceptions: “efficiency-oriented view, enhancement-oriented view, relaxation or win-win view” (p. 317). Fourteen of the 17 social studies teachers made comments about efficiency. They generally stated technology facilitated paperwork and giving instructions in an efficient way. The enhancement-oriented category included ten teacher comments about enhancing instruction and students’ learning. Teachers revealed technology gave opportunities to supplement teaching materials, to improve students’ critical thinking, and to meet students’ varied needs. Two-thirds of the participant teachers commented they used technology on Fridays to engage students in the relaxation or win-win category because they had 90-minute block classes and students got bored, especially on Fridays. In addition, teachers pointed out that both teachers and students could learn technology skills from each other when they took a break from lectures by using technology. Those teachers stated that using technology in their classroom was helpful in terms of being a capable teacher, helping their students to gain more knowledge, and improving students’ skills to prepare students for a technology-oriented society.

Molenje (2012) conducted a mixed method study to investigate what secondary school mathematics teachers’ professed beliefs were about using graphing calculators, how they were used, and the relation between their professed beliefs and usage. Molenje used surveys to measure 81 teachers’ professed beliefs and also conducted observations and interviews to figure out how the teachers used graphing calculators. Molenje found that when teachers taught the course with teacher direction, the teachers viewed graphing calculators as a computational tool; when they taught with student exploration, they used graphing calculators as a visualization and
checking tool. In addition, Molenje found that teachers who used graphing calculators with high frequency let their students explore more than teachers who used graphing calculators with medium frequency.

Barriers can be defined as anything that restricts teachers’ use of technology (Ertmer et al., 1999). In the literature, barriers affecting technology integration can be grouped in four categories: resources, institutional and administrative support, training and experience, and attitude or personality. Barriers related to resources occurred frequently as technology started to be infused into lessons. The barriers were both quantitative and qualitative. Quantitative barriers included, for instance, inadequate number of computers and limited Internet connections. Out-of-date hardware and intermittent Internet connections were examples of qualitative barriers. The second category of barriers, institutional and administrative, comprised lack of time for teachers to prepare and inadequate professional development (Brinkerhoff, 2006). The third category emphasized teachers’ training and experience can also affect their use of technology in instruction. For example, experienced teachers’ negative perspectives about technology integration have negative effects on novice teachers’ use of technology (Hazzan, 2003). Teachers’ anxiety and fear were included as attitudinal or personality barriers.

Ertmer et al. (1999) classified barriers into two groups. First-order barriers were extrinsic, such as insufficient support, time, and accessibility issues. For instance, lack of equipment was a barrier for teachers, so although they could still use the technology, they were not able to use it to the extent they wanted to, or in effective ways. Findings related to lack of time showed teachers who used technology as part of scheduled classes did not perceive time as a barrier. Teachers who considered technology as an add-on to the curriculum perceived this as a time barrier, due to the need for learning new software and asking students to create products on the computer.

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Second order barriers were key to teachers, e.g., their beliefs about using technology and habitual traditional classroom practices. Most teachers who used technology as a supplement to the curriculum mentioned second order barriers (relevance and classroom organization). In contrast, second order barriers were not observed among teachers who had high-levels of technology use in their classes.

Ertmer et al. (1999) found five main reasons why teachers used technology in their classes, four of which were related to student learning:

- Students are excited and motivated to learn with technology
- Students need to use technology in their future lives
- Technology makes the lesson more interesting with direct interaction or interesting materials
- Technology allows teachers to capture students’ attention, especially students who have attention problems
- Teachers enjoy using technology in their lessons. (p. 65)

Time, equipment, and training are significant factors when integrating technology into classroom instruction. Moreover, teachers who highly value technology use it more frequently even when resources are low compared with teachers who have low value of technology but high resources (Harrington, 1993).

ChanLin, Hong, Horng, Chang, Chu (2006) conducted a study to examine factors that impacted teachers’ use of technology. They categorized the factors into four groups as environmental, personal, social, and curricular issues. Accessibility and features of technology, such as hardware, software and Internet connections, were introduced as environmental factors related to teachers’ use of technology. Teachers reported in order to practice their students
needed access to technology in their homes. Personal factors included teachers’ beliefs and personalities. Technology use was important in teachers’ personal lives and was infused into their lessons. Social factors comprised teachers’ social environment and their connections with their colleagues and principals. Teachers stated technology-supportive principals encouraged them to apply innovative instruction related to technology. The final category, curricular issues, was related to time and effort needed, which teachers also indicated they needed in order to learn new skills and to create technology-oriented activities for their lessons. There were also some comments on the nature of learning objectives. Teachers expressed in some abstract conceptual tasks students’ analytic thinking and generating were more important than technology use.

Considering there was not enough detailed information about how and why graphing calculators were used often, Doerr and Zangor (2000) conducted a qualitative study to answer the question of how students and their teacher interpreted and made use of the graphing calculator as a tool in their mathematics class. An observational case study was conducted with a teacher and her two different precalculus classes. The participating teacher had 20 years of teaching experience and was proficient in using graphing calculators. The two precalculus classes in a suburban high school were in an enhanced technology environment and used graphing calculators with familiarity, since they had used graphing calculators before. The course activities varied from investigating modeling problems in small groups to whole class discussions on sharing progress, solution methods, and extending results. All class sections were observed by two or three research team members to collect data as extensive field notes, transcripts of audio-taped group work, transcripts of whole class discussions, interviews and planning sessions with the teacher (Doerr & Zangor, 2000).
Doerr and Zangor (2000) analyzed and coded both the teacher’s and the students’ patterns and modes of using the graphing calculator throughout the instructional units. Then, the researchers identified the links between the teacher's role, knowledge, and beliefs and the students' patterns and modes of calculator use. The results showed the teacher’s knowledge and capacities of using graphing calculators were reflected in her willingness to encourage her students to use graphing calculators. However, there were limitations of using graphing calculators for some students.

Several students did not have a meaningful strategy to use graphing calculators for a question. For instance, some students did not understand the random-number generator function as an alternative tool for the question asking them to design a simulation of the spread of a rumor. Another limitation was the use of graphing calculators as individual devices. The graphing calculator screen was not visible to share with others as a computer screen was. This influenced group work negatively when, for example, two or more students in a group checked their computations on their own calculators and then continued to work on their own calculators to explore possible solutions. Therefore, group communication was hindered and it was hard to re-open the discussion (Doerr & Zangor, 2000). In contrast, the teacher did use graphing calculators as a shared device via the overhead screen, which supported communication among students. The authors agree that sharing via overhead screen facilitated comparison and unification of ideas.

Teachers could also show development in their understanding of students’ learning when using technology. For instance, Zehavi and Mann (1999) conducted a study with 141 eighth graders in Israel to investigate students’ strategies when they used CAS to solve word problems related to the equation concept. Using CAS allowed students to enhance their reflection during
problem solving. Because students could apply their model (equation) as a solution of the problems and check to see if the solution was legitimate, they reflected immediately on their answers. Zehavi and Mann reported the solution of the word problems included not only equations but also implicit restrictions, which shows students recognized their importance. The authors found the balance between students’ interactions with CAS and their reflection was not sustained in constructing problems. Therefore, Zehavi and Mann discussed as essential that teachers provide opportunities for students to interpret implicit restrictions when solving the problems. They suggested combining both general equations and symbolic solutions of the equations can provide this opportunity for teachers, as they became more aware about cognitive aspects of learning when their students used technology.

**Benefits and Challenges for Teachers when Using Technology**

Research has suggested technology might improve students’ understanding of mathematics (e.g., Sandholtz, 2001; Zorfass & Rivera, 2005). To realize the effect of using technology in mathematics teaching, not only should the skillful development of the technology be considered thoroughly but also how technology is used by and with learners (Zbiek & Hollebrands, 2008). The literature shows mathematics teachers strive to infuse technology in various suggested ways (NCTM, 2000). Therefore, teachers have a significantly important role to play for students of all ages learning technology-based mathematics. Using graphing calculators efficiently in mathematics teaching provides an opportunity for teachers to create a supportive environment to help their students enhance their mathematical knowledge and understanding (Lee & McDougall, 2010).

**Time issues and duration of class.** Time could be either beneficial or challenging for teachers when using graphing-calculator technology in their mathematics lessons, as illustrated
by Lumb, Monaghan, and Mulligan’s (2001) study. The participants reported that, based on the subjects they taught, they needed more time to do the extra work to be more competent, to plan lessons with more detail, and to prepare testing worksheets. In addition, the teachers had a hard time finding suitable topics to use Derive and determining how to apply the software. Another time issue was the need of more time to prepare for certain topics to be able to integrate Derive into their mathematics instruction. Lumb et al. (2001) concluded extra work and time is needed to incorporate a CAS such as Derive into teachers’ lessons.

Another concern for teachers was the length of the class period to integrate graphing calculators into their mathematics lessons. Chamblee, Slough, and Wunsch (2008) showed mathematics teachers were not clear about how long it would take to use graphing calculators in their lessons, while other studies found the length of the class period was inadequate. In Leng’s (2011) study, the length of the mathematics lesson was one hour. Students generally spent the first ten minutes connecting their calculators to the classroom TI-Nspire navigator. This issue was a limitation of the study because the length of the lesson was not considered as sufficient to use graphing calculators effectively. In turn, Lee and McDougall (2010) found similar results. One of the participating teachers mentioned the class period (50 minutes) was a major drawback to incorporate graphing calculators into the classroom.

Using graphing calculators also allowed for a common starting point for students, as teachers had more time for students to discuss mathematical concepts. One of the participating teachers reported using graphing calculators to teach her students how to draw linear equations was time effective and increased the efficiency of the learning outcomes as well as teaching how to construct real-world connections more easily. Another teacher put forward if students became
proficient in using graphing calculators, it was possible to save time to calculate mathematical problems in the long run compared with paper-and-pencil methods (Lee & McDougall, 2010).

Kendal, Stacey, and Pierce (2004) explained the amount of time gained by using CAS differed among the participants and could be used for varied purposes, such as to include additional topics or to increase understanding. Benoit, a mathematics teacher in Kendal et al. (2004), used CAS for his class without any other equipment or new teaching strategy and reported it was possible to save time teaching with CAS and used the additional time for class discussion. Another mathematics teacher in that study allowed his students to use CAS freely to do activities instead of paper and pencil. Therefore, he was able to reduce time spent on those activities and used the extra time to teach calculator procedures. Another participant stated once the students became more skillful at using graphing calculators, the teacher started to use the saved time for exploratory projects to improve students’ mathematical understanding by using graphing calculators.

**Small group and peer learning.** Using graphing calculators enables mathematics teachers to design small-group work and/or peer teaching. For instance, Victoria, a mathematics teacher in Lee and McDougall’s (2010) study, preferred to allow her students to conceptualize mathematical ideas first individually and then in small groups to work on their graphing calculators. Therefore, the researchers found students had opportunities to communicate their ideas with others and to help construct their peers’ mathematical ideas by means of tasks.

**Curriculum and use of materials.** Finding or creating appropriate activities to use graphing calculators in mathematics instruction might pose another challenge for teachers, especially considering time restrictions. Most teachers do not prefer to use textbooks in Derive activities as the recommended textbooks integrating Derive do not address their pedagogic
needs. For example, the teachers in Lumb et al. (2001) did not use the textbook for Derive activities. One of the teachers indicated he used Derive with a “teach yourself” perspective (p. 11). Another teacher did not think the textbook fit his classes, so he preferred not to use the textbooks for his class activities and explained the two recommended textbooks were not useful because one textbook was traditional without lesson ideas and the other one provided activities appropriate for a cross-modular syllabus. Therefore, we can infer curriculum developers should be aware of teachers’ needs and strive to meet them when they develop technology-integration materials.

Based on the conclusion Chamblee et al. (2008) made, mathematics teachers were willing to learn how they could use graphing calculators for certain mathematics topics. However, as Zehavi and Mann (1999) contended, teachers had some concerns to rethink curricular and didactic aspects of mathematical learning. It is possible to meet mathematics teachers’ needs about how to use graphing calculators in their teaching for specific topics via professional development programs (Chamblee et al., 2008).

**Concerns and pressures of teachers.** Zbiek and Hollebrands (2008) explain concerns are affective when investigating technology implementations in the classroom. Familiarity and experience are positive factors for teachers when they integrate technology into their lessons, as personal experience in using technology facilitates being more open to use technology in their classroom (Lee & McDougall, 2010).

Chamblee et al. (2008) conducted a study to investigate the concerns of 22 mathematics teachers integrating graphing calculators into their mathematics classrooms in a year-long two-part professional development program. The first part of the program included 45 hours during the school year comprising data collection, analysis, interpretation, and presentation of data with
handheld technologies. The second part consisted of 60-hour summer workshops on integrated applications for mathematics and science to use handheld technologies. The participants’ concerns were measured by using a Stage of Concern questionnaire (SoCQ) including 35 Likert-scale items collected both on the first day of the in-service program and at the end of their final two-week summative summer workshop. The researchers identified seven types of concerns: “awareness, informational, personal, management, consequent, collaboration, and refocusing” (Chamblee et al., 2008, p. 185).

The initial results of SoCQ showed teachers had high awareness of using graphing calculators and they were eager to learn the impact of using graphing calculators in their classes. Chamblee et al. (2008) found high school mathematics teachers were willing to work with others to further their knowledge of using graphing calculators in their instruction. They also showed high school mathematics teachers had not established an understanding of the best usage of graphing calculators in the initial analysis. However, during the professional development program, the high school mathematics teachers developed better understanding of the best pedagogical practices to use graphing calculators in their lessons. In addition, they demanded additional applications to use graphing calculators in their teaching.

**Showing work to students.** The screen of a graphing calculator is generally small for students to share their work with each other. However, graphing calculators can be shared by the whole class by using a viewing screen. The mathematics teachers in Lee and McDougall (2010) used viewing screens to show their work to the class while using graphing calculators. Therefore, their students could see and follow what their teachers were doing on their graphing calculators. A mathematics teacher in Kendal et al. (2004) used a large screen for visualization and demonstration to share students’ work with the whole group as the screen of the hand-held
calculators was not sufficiently large for students to see each other’s work. In addition, Leng (2011) explained mathematics teachers could also monitor their students’ work on their advanced graphing calculator (TI-Nspire) screen. Teachers could also collect and analyze student work through graphing calculators to assess students’ comprehension.

Teachers’ Role

Most teachers undertake the role of an information provider while teaching mathematics (Leng, 2011). However, they might change their roles while using graphing calculator technology. For example, the study conducted by Leng (2011) with 35 secondary school students in a calculus course in Singapore demonstrated the use of the TI-Nspire, a type of graphing calculator, made it possible for teachers to act as learning facilitators. In order for the students to make instant and active interaction with their peers and teachers, a wireless classroom network system for the TI-Nspire was used in teaching mathematics. This allowed less lecturing and more opportunities to have class discussions. The researcher observed the students participated in discussions more actively and took an active role in their learning as a whole.

Teachers’ role is not limited to how they act during technology-infused instruction; their role also encompasses decision making about technology integration. Kendal and Stacey (2000) illustrated how teachers’ decisions in when to privilege technology impacted student learning. They conducted a study with three teachers teaching derivative concepts in their mathematics classes. Teacher A privileged technology, symbolic algebra, and procedures for standard tasks. Teacher B privileged conceptual understanding for algebra and paper-pencil activities. Teacher C privileged conceptual understanding and graphical methods. The students in Teacher A’s class showed more frequent use of computer algebra. Although those students were less successful in terms of their conceptual understanding, they were more successful in symbolic algebra. The
students in Teacher B’s and Teacher C’s classes gained more conceptual understanding. In addition, Teacher B’s students were more successful particularly with by-hand algebra, while the students in Teacher C’s class preferred to use graphical methods more frequently as an alternative to symbolic procedures. The teachers’ use of different representations resulted in diverse opportunities to learn for students and diverse preferences by students about how to approach a problem.

**Conceptual Understanding**

I conducted this study to investigate mathematics teachers’ perspectives on teaching mathematics and students’ learning when they use graphing calculators in a precalculus course. Some studies (Hegedus & Kaput, 2004; Roschelle & Singleton, 2008) related to student learning also showed teachers might develop positive perspectives about graphing calculators based on the development of students’ understanding as those teachers observed.

Graphing calculators have diverse capabilities, one of which is they can be used with a wireless network. This provides a good opportunity to use calculators for formative assessment. For instance, teachers can check students’ answers to a conceptual question and show the results immediately (Roschelle & Singleton, 2008). Therefore, graphing calculators can be utilized as a tool for teachers to improve their students’ conceptual understanding. Hegedus and Kaput’s (2004) study sets a good example as they investigated various features of dynamic representations and connectivity. They concluded the teachers were able to help students have a better understanding of core concepts of algebra and construct better relationships with mathematical objects. They also explained students gained more powerful understanding by making sense of their constructions publicly with the presence of graphing calculators.
It is possible to improve students’ conceptual understanding by using graphing calculators. For example, Leng (2011) interviewed eight students in his study and all eight students used demonstrations when they explained derivative concepts. Students’ verbal responses to the use of graphing calculators (TI-Nspire) in their calculus class were positive as the calculators enabled them to visualize the problems and concepts. Therefore, students had a chance to improve their conceptual understanding. Leng (2011) found students could solve problems by using graphical methods with graphing calculators rather than long computation.

Tiwari (2007) conducted a quasi-experimental study with 88 calculus students. The experimental group had access to Mathematica, a computation and visualization software program, and a development environment and deployment engine (Wolfram Research, n.d.). Students in the control group were taught in traditional ways. The students’ test scores were analyzed using ANCOVA. The study demonstrated there was a significant difference between the teaching methods of the control and experimental groups in the visualization of concepts through graphs, in favor of the experimental group. The results of the study also indicated students in the experimental group had higher scores in both conceptual and computational parts of the exam. Lastly, it was found that a higher percentage of the students in the experimental group had better understanding of what a derivative was than students in the control group did.

Three Big Projects and Studies in which Technology was Integral

Ertmer et al. (1999) found teachers considered technology was important “to support, to reinforce, to enhance, to enrich” (p. 63) their existing curriculum. The following three curriculum projects have integrated technology into their curriculum materials. The studies conducted on the curriculum projects and student achievement are included to understand how these curriculum materials differ from traditional curriculum materials, specifically in terms of
technology support for teachers and the expectations of technology use during instruction.

I conducted a study to investigate teachers’ perspectives on using graphing calculators when teaching the University of Chicago School Mathematics Project (UCSMP) materials. I also examined the issues that arose with the graphing calculator technology. Therefore, I included these three big projects to compare differences and similarities of technology integrated materials in terms of the potential impact of teachers’ perspectives on using technology, such as expectations, activities, and students’ learning when teachers use technology during instruction.

**The University of Chicago School Mathematics Project or UCSMP**

The UCSMP is a K-12 curriculum research and development project. This project started in 1983 to promote student achievement, to modernize curriculum to cover important content and appropriate technology for the 21st century, and to raise the number of students enrolling in high school mathematics beyond algebra and geometry (Thompson, Senk, & Yu, 2012). Thompson and Senk (2001) investigated students’ achievement in classes in which students used the second edition of UCSMP *Advanced Algebra* compared to students’ achievement in classes using more traditional non-UCSMP materials. The authors explain UCSMP materials created for secondary schools included reading and problem solving, realistic applications, technology, and a multi-dimensional approach to understanding.

The participants were eight pairs of Advanced Algebra classes across the United States in four schools from different states. Two mathematics teachers were selected from each high school, with one teaching from the second edition of the UCSMP *Advanced Algebra* textbook and the other from the textbook already being used at the school. Students from two different classes were matched based on their pretest scores. Four different dimensions were emphasized in the UCSMP textbook: skills, properties, uses, and representations. The lessons typically
started with realistic contexts or some graphical representations. Most chapters included all four dimensions roughly equally. Although non-UCSMP textbooks also included these four dimensions, they emphasized skills more frequently than the other three dimensions. Real contexts and applications were rarely included in the non-UCSMP textbooks (Thompson & Senk, 2001).

UCSMP and non-UCSMP textbooks were different in terms of opportunities for using technology. The UCSMP textbook writers developed the second edition based on the assumption that all students had graphing calculators, and used them at all times, while there were only some optional activities to use scientific calculators in non-UCSMP textbooks (Thompson & Senk, 2001). The authors found no significant differences between pretest scores of students in the eight pairs of Advanced Algebra classes. However, on the multiple-choice post-test, five pairs of classes showed higher scores in favor of UCSMP classes. The difference in achievement between these two curricula was significant. The Conservative Test measured and compared the achievement of both UCSMP classes and non-UCSMP classes based only on the items covered by all eight teachers. There were 15 items, many of which assessed students’ algorithmic skills. Based on the results, the idea that using a curriculum including less algorithmic skills, more real-world applications, graphical representations, and use of technology decreases student achievement on procedural skills was not supported. Thompson and Senk (2001) found using graphing calculators did not decrease student achievement in terms of procedural skills even in a school where the UCSMP teachers used graphing calculators frequently. Furthermore, students who were in the UCSMP classes showed higher scores than students who were in the non-UCSMP classes on the posttest regardless of the data analyses conducted in terms of controlling
for opportunity to learn. The authors also recommended longitudinal research be conducted to see how curriculum impacts learning mathematics over time in schools.

**Core-Plus Mathematics Project or CPMP**

The CPMP, funded by the National Science Foundation, started in 1992. Its purpose was to develop an integrated curriculum for all high school students and to prepare students for college mathematics. Because the idea behind creating the CPMP curricula was to make sense of mathematics around us, real world applications, mathematical understanding, and skills were important characteristics of the new mathematics curricula (Huntley, Rasmussen, Villarubi, Sangtong, & Fey 2000).

The CPMP curriculum emphasized the ideas of algebra through modeling of quantitative relationships with contextual problems. Graphing calculators played an important role in teaching algebra within that curriculum, in which extensive use of graphing calculators was emphasized for students to explore algebraic ideas and solve algebraic problems. The CPMP curriculum particularly gave opportunities for students to use multiple representations in three categories (numeric, graphic, and symbolic) to develop their mathematical understanding (Huntley et al., 2000). Symbolic manipulation procedures in the CPMP algebra curriculum were reduced.

Huntley et al. (2000) conducted a study to examine standards-based mathematics education with the CPMP curriculum, specifically with regards to functions. They aimed to compare achievement of students who were taught through a traditional curriculum with students who were taught through the CPMP curriculum in terms of students’ understanding, skills, and problem-solving ability. Data were collected from six high schools from the U.S. with students randomly assigned to the CPMP and control treatments during April and May of 1997. Two
types of data were collected. First, Huntley et al. interviewed both CPMP and control teachers about their instructional practices and curriculum coverage. In the interviews, there were questions about additions or deletions from the intended curriculum, using calculators, and assessments. Then, the researchers measured student understanding of mathematics, skills, and problem solving abilities in algebra through an achievement test. There were specific test questions in three separate parts to measure students’ achievement. Part One included questions about formulating and using algebraic models, and relationships among variables. The students were allowed to use graphing calculators for this section. Part Two questions were about equivalence of algebraic expressions and solution of equations and inequalities. There were no real-world applications or access to calculators for this part. Part Three had open-ended questions in an applied context. Students typically worked with pairs for this part and were allowed to use scientific or graphing calculators, graph paper, and rulers for these questions.

In Part One, the students in the CPMP classes attained higher, but not significantly higher, scores than students in the control classes. Huntley et al. (2000) concluded using graphing calculators might be helpful for students to deal with traditionally difficult problems about algebraic expressions. Even though students in CPMP classes were expected to do symbolic algebra without graphing calculators, results of the study showed students taught with conventional curriculum outperformed the CPMP students in symbolic algebra questions. However, detailed analysis showed students taught with the CPMP curriculum performed better on problems involving movement among symbolic, tabular, and graphic representations than the students in the control classes. In addition, both CPMP students and control students performed almost equally on the calculation items involving do-interpret pairs. However, CPMP students
were generally better in interpretation of calculated results. Furthermore, students in CPMP classes tended to have better results in Part Three than students in conventional classes.

**Computer-Intensive Algebra or CIA**

CIA is a beginning algebra curriculum for “the concepts of functions, variables, equations, inequalities, and equivalence in the context of mathematical modeling” (Heid, 1996, p. 240). Real world situations take an important role in this curriculum to develop and evaluate mathematical modeling. Students taught with this curriculum are provided with access to computing tools for numerical, graphical, and symbolic representations of functions. Technology-intensive procedures for reasoning about algebraic expressions are available in the curriculum and the CIA text included a chapter for calculators, computers, and functions. By-hand symbolic manipulation is not centered or included in the CIA as a formal part of the curriculum. However, there are contexts for students to use symbolic manipulation as a tool to manage symbolic rules. Therefore, students are supposed to develop their “symbol sense” (p. 243) in alternative ways.

Zbiek and Heid (1989, as cited in Heid, 1996) conducted a study with CIA students. There were a variety of tools available for CIA students, “computers with function-graphing, symbolic manipulation software, graphing calculators, scientific calculators, paper-and-pencil” (Heid, 1996, p. 251). The researchers found significant differences in the fluency of computer use in the CIA classrooms compared with student using scientific calculators and paper-and-pencil. They concluded CIA students were not only better able to learn to use a variety of tools and representations but also to learn how to use those tools easily.
Do Curriculum Materials Facilitate or Hinder Teachers’ Use of Graphing Calculators?

Graphing calculator technology use is recommended in national and state standards and is embedded in some curricula (Roschelle & Singleton, 2008). Teachers should know the benefits of using graphing calculators in different parts of the curricula. Then, teachers could develop their own ways to integrate graphing calculators into their teaching for optimal learning outcomes (Lee & McDougall, 2010). However, teachers might face some inhibitors or motivators to implement opportunities to use graphing calculators included in the course materials into their instruction.

Inhibitors

Students can react negatively to a certain type of technology. One of the main reasons for that negative reaction might be the standard assessment issue. Lumb et al. (2001) asserted the main pressure on teachers who used computer algebra in their classes was to ensure computer algebra supported formally assessed work. The first teacher of their study had concerns that students were not very motivated to use Derive because they had doubts that Derive would help them in the exams.

Huntley et al. (2000) found conventional curriculum was more appropriate for teachers to practice for equivalence of algebraic expressions and solution of equations and inequalities by hand. They also determined Core-Plus Mathematics Project (CPMP) students were not as good as comparison students in symbolic manipulations by hand. Even though the comparison textbook materials did not include graphing technology in mathematics, some comparison teachers also used graphing technology. Hence, some comparison teachers used additional materials to teach based on reform-oriented practices. The instruction seemed less effective with the absence of curriculum materials, which supported those practices. The situation poses a
challenge for teachers and may hinder them from adopting graphing calculators in their classrooms.

**Motivators**

Curriculum materials with extensive use of graphing calculators may increase teachers’ competence at implementing technology in their classes. For example, UCSMP Advanced Algebra textbooks provide opportunities for teachers not only to lecture to introduce the content, but also to engage students with questions for class discussion, to encourage students to read texts to learn the content, to do small group work, to review some questions for certain skills and deep understanding, and to investigate and write reports for given topics with extended projects (Thompson & Senk, 2001). Therefore, appropriate technology integrated curriculum materials can be a good motivator for teachers to implement technology in their classes effectively.

The purposes of using calculators may change among teachers. In Thompson and Senk (2001), although all teachers used calculators for computations, UCSMP classes used calculators for the purposes of solving problems, taking tests, making graphs, analyzing data, and finding equations to model data. The authors also reported the UCSMP teachers used small group and whole class discussions more frequently than comparison teachers did. Similarly, in Huntley et al. (2000), it was found there were frequent uses of collaborative small-group activities during instruction with the technology-infused CPMP curriculum. CIA is another curriculum example containing motivators for teachers to implement algebra instruction with graphing calculators. In that curriculum, there are classroom organization assumptions, such as use of collaborative pairs working together on the computer and class discussions intended for course content explorations. Problems represented graphically or in applied settings are included with a greater percent of class discussion in CIA classes. In addition, CIA classes spend more time conceptualizing
problems and interpreting answers than traditional classes do. These work to help teachers adopt more student-centered instruction (Heid, 1996).

Huntley et al. (2000) underlined the CPMP curriculum brought opportunities for teachers to do more practice for formulating and using algebraic models, relationship among variables, and open-ended questions related to real-world applications with the access of graphing calculators. CPMP students learned a variety of alternative ways by using graphing calculators to accomplish the solution of equations and inequalities. This demonstrates mathematics teachers might have a chance to deal with the problems related to their students’ personal calculation skills with graphing calculator technology. Heid (1996) showed the CIA curriculum seems to provide opportunity for different classroom activities, various teacher roles (e.g., facilitator, technical assistant, catalyst), and reconceptualized responsibilities for teachers and students (e.g., new responsibilities, new goals). The author reached the conclusion that curriculum developers can make some changes and teachers can adapt implementations of those materials in their lessons in order to improve students’ learning.

**Thematic Analysis**

Qualitative researchers use thematic analysis to identify, analyze, and report themes (patterns) within data. Thematic analysis allows researchers to organize and describe their data in detail. Furthermore, researchers can interpret various aspects of their research topic by using this method. The purpose of thematic analysis is to develop patterns of meaning in data that include the answer to research questions (Boyatzis, 1998). It is important to know how researchers analyze their data and what assumptions they have before they start thematic analysis in terms of the evaluation of the study and to improve related research topics (Attride-Stirling, 2001).
There are different approaches to thematic analysis. The inductive way is coding and theme creation based on content of the data, while the deductive way is coding and theme development based on already existing ideas and concepts. Although the semantic way reports the codes and themes representing the data content explicitly, the latent way reports the codes and themes by underpinning the content of the data. Thematic analysis can be the essentialist or realist way when it investigates experiences, meanings, and the reality of the participants. However, thematic analysis can also be the constructionist way if it explores the ways in which events, realities, meanings, and experiences develop (Boyatzis, 1998; Braun & Clarke, 2006).

Themes can be defined as important parts of the data related to the research questions. Themes include the patterned responses and meaning of the data (Braun & Clarke, 2006). It is possible for analysis to see a theme several times in some data items and rarely or never in other data items. In addition, another theme might appear less often in the data set. In qualitative studies, it is not necessary to find themes based on their prevalence in the data. In some cases, considering the themes in terms of the relationship with the research questions might be more useful. Furthermore, the researcher should make judgments about a theme and have an active role to play with themes and their interpretation.

The researcher should be aware of his/her purpose in doing thematic analysis. For instance, one purpose is to provide a valuable descriptive thematic analysis and to inform the reader about significant themes, requiring the entire data set to be analyzed. This method is useful to examine under-researched areas or participants whose perspectives about the topic are not known. Another purpose of using thematic analysis is to inform about one particular theme or group of themes in the data with more detail. In this case, the study might be about a specific question or area of interest within the data (Braun & Clarke, 2006).
Braun and Clarke (2006) demonstrated some drawbacks of thematic analysis. First, the analysis should be done for all the data. Therefore, data extracts coming from the original data set should represent the researcher’s understanding of the data set. In addition, the researcher should provide clear explanations about the data. For instance, the researcher can mention what the participants mean by a certain sentence, possibly reasoning why they said that. A second pitfall occurs if the researcher reports the data collection items as the themes. In this case, the researchers might skip the main part of thematic analysis, which is to deeply analyze the data to describe the themes across the data set. Another drawback is inconclusive analysis, which might exist when the themes overlap too much or when there are inconsistent themes. A fourth downside is not matching the data with analytic claims. Therefore, researchers should be careful to make consistent interpretations and analytic points based on data extracts.

**Summary and Conclusion**

In this chapter, I indicated some features and roles of graphing calculators. I also synthesized teachers’ perspectives on using technology in their lessons, according to which it is possible to promote students’ conceptual understanding by using graphing calculators. Furthermore, there are benefits and challenges when using graphing calculators in instruction. In addition, the relevant literature demonstrates various motivating and inhibiting features of graphing calculators and the utilization of curricula with extensive use of graphing calculators for mathematics instruction.

In conclusion, graphing calculator technology has an important role in mathematics teaching and learning. There should be sufficient support for both teachers and students to use this technology efficiently in mathematics classes. Essentially, the curriculum materials should be powerful in terms of activities related to such technology. Professional development and
assessment should also be motivating for effective use of graphing technology in mathematics education.
CHAPTER THREE: METHODOLOGY

This chapter provides information about the design of this study, research questions to be investigated, and context of the study (background information of UCSMP and course as the context). In addition, I provide information about the school selection procedures, data collection tools, and data analysis procedures at the end of this chapter.

I investigated teachers’ perspectives on using graphing calculator technology in the FST course and used existing data to answer the research questions. Data were collected as part of an evaluation study of FST in the 2007-2008 school year. Therefore, I conducted secondary analysis on the existing data set. (For further details of the evaluation study, see Thompson and Senk, in preparation, or access http://ucsmp.uchicago.edu/resources/evaluation-reports)

Research Design

This study used a mixed method design to answer the research questions. Until recently, qualitative and quantitative research designs were applied separately in educational research. Lund (2012) showed the differences of these two methods by stating that, although generally qualitative research has an advantage of giving a greater depth of understanding, quantitative research has advantages in terms of objectivity and generalizability. Mixed method is the combination of quantitative and qualitative methods. Therefore, it is thought mixed method gives more enhanced understanding for the research problems and questions than using one of the methods independently (Creswell, 2012; Frels & Onwuegbuzie, 2013; Hong & Espelage, 2011).

I used both quantitative and qualitative approaches in this study to examine eleven mathematics teachers’ perspectives about their teaching, students’ learning, and issues that arose
when they used graphing calculator technology. Teachers’ perspectives on using graphing
calculators in a precalculus course were examined based on their responses to semi-structured
interview questions. There was also additional information about teachers’ perspectives from the
beginning- and end-of-the-year teacher questionnaires to extend the qualitative data. In addition,
I analyzed teachers’ comments on using graphing calculators while teaching each chapter of the
textbook.

Descriptive Intrinsic Case Study

I conducted a descriptive intrinsic case study to describe the phenomenon of teachers’
perspectives on using graphing calculators. When the researcher has an intrinsic interest to gain
better understanding of a particular case, the study becomes an intrinsic case study. In other
words, it is undertaken not because the case represents other cases, or symbolizes a problem, but
because the case itself is of interest. Intrinsic case studies are exploratory in nature. In addition,
the researcher makes this exploration with his or her interest in the case instead of in extending
theory (Grandy, 2010; Stake, 1995, 2008; Yin, 2003). I have conducted this study with the
primary interest of the specific group of teachers who taught FST (third edition, field-trial
version).

Research Questions

1. In what ways do eleven teachers use graphing calculators in an 11th-grade Functions,
   Statistics, and Trigonometry course?

2. What are eleven teachers’ perspectives on student learning when students use graphing
   calculators in an 11th-grade Functions, Statistics, and Trigonometry course?

3. What are eleven teachers’ perspectives on their teaching an 11th-grade Functions,
   Statistics, and Trigonometry course using graphing calculators?
Context of the Study

I analyzed perspectives of teachers about using graphing calculator technology in a precalculus course, titled Functions, Statistics, and Trigonometry (FST, 3rd edition, Field Trial Version) developed by the University of Chicago School Mathematics Project (McConnell, et al., 2007).

An Overview of the University of Chicago School Mathematics Project or UCSMP

The UCSMP is the largest university-based mathematics curriculum project in the U.S. and was founded in 1983. UCSMP claims basic computation skills are not enough to meet societal needs. In addition to basic computation skills, there should be more sophisticated understanding of mathematics to meet the needs of society. Therefore, the aim of the project was to develop K-12 mathematics curriculum based on changing societal needs. For instance, real-world applications, reading, problem-solving, and the use of technologies are among the characteristics of the UCSMP curriculum materials. Furthermore, these educational materials do not include unnecessary repetition and review so that even the diligent average student might have a chance to learn mathematics once reserved only for honors students by the end of high school.

There were three editions of UCSMP secondary component materials for students in grades seven to 12 during the years 1983 to 2010. The following were three main goals of all three editions of the Secondary Component materials: (1) “to upgrade students’ achievement in mathematics,” (2) “to update the mathematics curriculum in terms of content,” and (3) “to increase the number of students who take mathematics beyond algebra and geometry” (Thompson, et al., 2012, p. 5).
The third edition materials differ from the first and the second edition materials in terms of use of technology. For instance, although using CAS was recommended in the second edition of UCSMP FST, students are expected to use CAS in the third edition. Consequently, teachers were provided with CAS-capable calculators in sufficient numbers so that technology access would not be an issue.

**Course Content**

In UCSMP, precalculus content is divided into two courses. The *Functions, Statistics, and Trigonometry* course is the first course, including the topics of functions, statistics, and trigonometry and is designed for 11\(^{th}\)-grade students. The course is described as follows:

*Functions, Statistics, and Trigonometry* (Year 6) integrates the three content areas in the title, with connections made between functions and statistics and with trigonometry. Both descriptive and inferential statistics are studied along with combinatorics and probability. Modeling with statistics, functions, and trigonometry is a major feature of the course. Significant work with computer algebra systems and with statistical software (either computer or calculator) is integrated into the course. Enough work with trigonometry is available to constitute a typical course in trigonometry and circular functions as preparation for precalculus. (Thompson, et al., 2012, p. 7)

The FST includes functions, statistics, and trigonometry content with integration of CAS.

**Procedures**

**School Selection**

In spring 2007, UCSMP solicited schools to participate in a study of FST (3\(^{rd}\) edition) through a call made available on the UCSMP website and various mathematics education outlets. UCSMP and participating schools’ requirements were included in the call. For instance, UCSMP
would provide curriculum materials and calculators for students and teachers in field-test classes as well as instruments (questionnaires and tests) for students and teachers. The participating schools were supposed to provide teachers with UCSMP materials, permit classroom observations, and allow five days of testing. Schools were selected taking into consideration their population and their locations in terms of representing as much diversity as possible. This school selection procedure was also the procedure used in this study because I used the data collected in those schools.

Initially, 11 schools were selected to participate in the study. One school dropped out of the study before the school year began because the teacher had some concern about the curriculum materials; a second school dropped out of the study shortly after the school year began because the teachers determined the curriculum materials were not appropriate for their students. A third school dropped out of the study in the spring when the teacher had concerns with students’ participation in the study. Therefore, for the study reported here, participants are eleven teachers in eight different schools in six states. Five schools were in the Midwest, one was in the West, one was in New England, and one was in the South. Two of the schools had classes using both second and third editions of UCSMP materials to permit some comparisons. Yet, the present study only explored teacher perspectives for those using the third edition.

**Data Collection**

During the 2007-2008 school year, researchers interviewed each teacher using a semi-structured interview protocol in which teachers explained their thoughts about the curriculum materials for the course. Although the interviews included ten main questions, I focused only on the question and sub-questions related to using technology and analyzed the teachers’ responses to those questions. Teachers also completed beginning- and end-of-the-year teacher
questionnaires about their teaching experiences, plans for the mathematics class, typical lesson activities, and calculator technology use in class. In addition, the teachers completed chapter evaluation forms for each chapter taught. The teachers commented not only on the use of technology by teachers but also by students to address the content of the chapter.

**Instruments**

Interviews with the teachers who taught the FST course were the main data collection instrument. In addition to the interviews, an initial teacher questionnaire and an end-of-year questionnaire were used to collect data. Finally, chapter evaluation forms were used to gather data about teachers’ perspectives on using graphing calculators on a chapter-by-chapter basis.

**Teacher Interview Protocol**

Each teacher who taught the FST course was interviewed for about an hour as part of the visit to the school to observe classes. A semi-structured interview protocol (see Appendix A) was used for this step of the evaluation study. The purpose of the interview was to clarify and confirm information about the class that we [UCSMP] have obtained thus far from you or from the district, to check to see how things are going, to answer any questions you may have about the study, or in the case of UCSMP teachers about the curriculum, and to probe for additional insights related to the lessons or classes observed (Thompson, et al., 2012, p. 214).

There were ten open-ended questions about the FST course. The teachers were asked how their students were assigned to this course, what they would like their students to learn, any issues that arose during teaching the FST course, typical classroom structure, use of their curriculum materials, features of curriculum materials, use of technology, and thoughts comparing the third edition with the second edition. However, for this study, I only analyzed teachers’ answers to
question eight, related to technology. Although this question had ten sub-questions, I analyzed only the sub-questions listed in Table 1 because these possibly had data to answer the research questions in my study.

Table 1. *Items Used from Teacher Interview Protocol.*

<table>
<thead>
<tr>
<th>Number</th>
<th>Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>We have asked you about the use of technology on the chapter evaluation/coverage forms as its use relates to that chapter. (Ask this question depending on technology responses to the form, possibly asking this question only of UCSMP Third Edition teachers.)</td>
</tr>
<tr>
<td>8a</td>
<td>What kind of technology is available to students in this class?</td>
</tr>
<tr>
<td>8b</td>
<td>(Depending on response to 8a) In what ways are you using the available technology?</td>
</tr>
<tr>
<td>8c</td>
<td>(Depending on the response to 8a) In a broad sense, how has the presence of calculator technology influenced how you have approached the course? (Probe for influence on both content taught and instructional strategies. Probe for differences due to graphing calculator technology compared to scientific calculators.)</td>
</tr>
<tr>
<td>8d</td>
<td>What issues, if any, have arisen because of the presence of the technology?</td>
</tr>
<tr>
<td>8f</td>
<td>To what extent has the use of technology influenced students' learning of mathematics? (Probe for positive and negative influences for the types of technology available, including graphing calculator, CAS, spreadsheets, geometric drawing tool, fraction calculator, etc.)</td>
</tr>
<tr>
<td>8g</td>
<td>What, if anything, can your students do well because they have the technology that they would not be able to do without it?</td>
</tr>
<tr>
<td>8h</td>
<td>What, if anything, can your students not do well because they have had access to the technology?</td>
</tr>
</tbody>
</table>

I used sub-question (8a) to gain information about what kind of technology the teacher and his/her students used. Then, I analyzed sub-question (8b) to determine the ways teachers used graphing calculators, and (8c) and (8d) to answer the first research question, which examined teachers’ perspectives on using graphing calculators in the teaching of the FST course. In addition, sub-questions (8f), (8g), and (8h) were related to teachers’ perspectives on students’ learning with graphing calculators. Therefore, I sought an answer for the second research question in this study, which analyzed the teachers’ responses to these sub-questions.

**Beginning-of-the-Year Teacher Questionnaire**

Teachers who were in the evaluation study completed a questionnaire at the beginning of the 2007-2008 school year (see Appendix B). This questionnaire started with teachers’ personal
information, such as gender, education degrees, and teaching experiences. There were 16 sub-questions on a four-point Likert scale about teachers’ expected teaching strategies. There were also 16 sub-questions on a four-point Likert scale about teachers’ thoughts about their plans for this mathematics class for the entire year. In addition, there were seven sub-questions on a three-point Likert scale about teachers’ experiences with the features of a graphing calculator or computer software. There were also two open-ended questions at the end of the questionnaire about the teachers’ expectations on the greatest challenge teaching this course and their participation in this evaluation study. I analyzed teachers’ personal information, questions (1), (2), (3), and (5), and the items related to the use of technology, particularly graphing calculators, sub-questions (6n), (6o), (6p), and question (8), as shown in Table 2.

**End-of-the-Year Teacher Questionnaire**

Teachers who were in the evaluation study completed a teacher questionnaire at the end of the 2007-2008 school year (see Appendix C) consisting of 24 questions. There were questions examining the teachers’ perspectives on class time spent for some types of classroom arrangements, and activities, as well as about the marking period, homework, available technology, and activities included in the textbook. Three questions included sub-questions. These questions investigated the components important to their teaching (16 sub-questions on a four-point Likert scale), the frequency of instructional activities (16 sub-questions on a four-point Likert scale), and issues about the textbook (ten sub-questions on a five-point Likert scale). There were also questions about a state test, particularly in relation to content that might be included in the FST course. There were three open-ended questions about teachers’ greatest challenge in teaching, willingness to teach the same textbook again next school year, and special circumstances related to this class. I used teachers’ responses to questions (6), (7), (8), (9), (10),
(17n), (17o), (19g), (19h), (19i), and (19j) inquiring about the teachers’ perspectives and use of technology as shown in Table 3.

**End-of-Chapter Evaluation Form**

Teachers who taught the FST course with the 3rd edition were asked to complete chapter evaluation forms after each chapter they taught (see Appendix D). They were asked to indicate the lessons they taught, questions they assigned, and comments about the lessons. One question asked the teachers to rate the chapter from 1 (disastrous) to 5 (excellent). There were also open-ended questions asking whether they and their students used graphing calculators, computers, and the test included in the teacher materials. In addition, there were specific questions based on the chapter content. I used the teachers’ comments and thoughts about their technology use in each chapter. Then, I categorized those chapters into functions, statistics, and trigonometry based

**Table 2. Items Used from Beginning of the Year Teacher Questionnaire.**

<table>
<thead>
<tr>
<th>Number</th>
<th>Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Education: Degrees/Majors/Minors</td>
</tr>
<tr>
<td>2</td>
<td>List your teaching Certifications</td>
</tr>
<tr>
<td>3</td>
<td>[List your] teaching experience</td>
</tr>
<tr>
<td></td>
<td>Number of years teaching prior to this year</td>
</tr>
<tr>
<td></td>
<td>Number of years teaching mathematics prior to this year</td>
</tr>
<tr>
<td></td>
<td>Number of years teaching at present school prior to this year</td>
</tr>
<tr>
<td>5</td>
<td>How many minutes does this class meet each day?</td>
</tr>
<tr>
<td>6n</td>
<td>Think about your plans for this mathematics class for the entire year. How important to you in your teaching are each of the following?</td>
</tr>
<tr>
<td></td>
<td>Circle one: Of little importance, Somewhat important, Quite important, or Of highest importance.</td>
</tr>
<tr>
<td></td>
<td>Help students learn to use a graphing calculator as a tool for learning mathematics</td>
</tr>
<tr>
<td>6o</td>
<td>Help students learn to use a symbolic manipulator as a tool for learning mathematics</td>
</tr>
<tr>
<td>8</td>
<td>Think about your experiences with the following features of a graphing calculator or computer software. Describe your experience using the following scale.</td>
</tr>
<tr>
<td></td>
<td>Circle one: Never used, Seldom used (some experience but not proficient), Use frequently (enough experience to be proficient)</td>
</tr>
<tr>
<td></td>
<td>a. graphing features</td>
</tr>
<tr>
<td></td>
<td>b. table features</td>
</tr>
<tr>
<td></td>
<td>c. statistics features</td>
</tr>
<tr>
<td></td>
<td>d. equation modeling features</td>
</tr>
<tr>
<td></td>
<td>e. symbolic algebra features (e.g., computer algebra systems)</td>
</tr>
</tbody>
</table>
Table 3. Items Used from End-of-the-Year Teacher Questionnaire.

<table>
<thead>
<tr>
<th>Number</th>
<th>Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>What calculator technology was available for use by the majority of students during this mathematics class?</td>
</tr>
<tr>
<td></td>
<td>_____ calculators not available</td>
</tr>
<tr>
<td></td>
<td>_____ a class set of scientific calculators</td>
</tr>
<tr>
<td></td>
<td>_____ student-owned scientific calculators</td>
</tr>
<tr>
<td></td>
<td>_____ class set of graphing calculators without computer algebra system capability</td>
</tr>
<tr>
<td></td>
<td>_____ student-owned graphing calculators without computer algebra system capability</td>
</tr>
<tr>
<td></td>
<td>_____ class set of graphing calculators with computer algebra system capability</td>
</tr>
<tr>
<td></td>
<td>_____ student-owned graphing calculators with computer algebra system capability</td>
</tr>
<tr>
<td></td>
<td>_____ the loaner calculators provided by UCSMP</td>
</tr>
<tr>
<td></td>
<td>_____ other (Please specify. _________________________________________)</td>
</tr>
<tr>
<td>7</td>
<td>About how often did students use calculator technology during this mathematics class?</td>
</tr>
<tr>
<td></td>
<td>_____ almost every day</td>
</tr>
<tr>
<td></td>
<td>_____ 2-3 times per week</td>
</tr>
<tr>
<td></td>
<td>_____ 2-3 times a month</td>
</tr>
<tr>
<td></td>
<td>_____ less than once a month</td>
</tr>
<tr>
<td></td>
<td>_____ almost never</td>
</tr>
<tr>
<td>8</td>
<td>For what did your students use calculator technology in this mathematics class? (Check all that apply.)</td>
</tr>
<tr>
<td></td>
<td>_____ checking answers</td>
</tr>
<tr>
<td></td>
<td>_____ doing computations</td>
</tr>
<tr>
<td></td>
<td>_____ solving problems</td>
</tr>
<tr>
<td></td>
<td>_____ graphing equations</td>
</tr>
<tr>
<td></td>
<td>_____ working with a spreadsheet</td>
</tr>
<tr>
<td></td>
<td>_____ making tables</td>
</tr>
<tr>
<td></td>
<td>_____ analyzing data</td>
</tr>
<tr>
<td></td>
<td>_____ finding equations to model data</td>
</tr>
<tr>
<td></td>
<td>_____ simplifying algebraic equations</td>
</tr>
<tr>
<td></td>
<td>_____ other features of CAS</td>
</tr>
<tr>
<td></td>
<td>_____ other (specify) ____________________________________________</td>
</tr>
<tr>
<td>9</td>
<td>If you had students use the computer algebra system capability on this calculator, if applicable, about how often did your students use the calculator for this purpose in your mathematics class?</td>
</tr>
<tr>
<td></td>
<td>_____ almost every day</td>
</tr>
<tr>
<td></td>
<td>_____ 2-3 times per week</td>
</tr>
<tr>
<td></td>
<td>_____ 2-3 times a month</td>
</tr>
<tr>
<td></td>
<td>_____ less than once a month</td>
</tr>
<tr>
<td></td>
<td>_____ almost never</td>
</tr>
<tr>
<td>10</td>
<td>How helpful was this calculator for students learning mathematics in this mathematics class?</td>
</tr>
<tr>
<td></td>
<td>_____ very helpful</td>
</tr>
<tr>
<td></td>
<td>_____ somewhat helpful</td>
</tr>
<tr>
<td></td>
<td>_____ not very helpful</td>
</tr>
<tr>
<td>17n</td>
<td>Think about your mathematics class this past year. How important to you in your teaching were each of the following? Of little importance, Somewhat important, Quite important, or Of highest importance. Help students learn to use a graphing calculator as a tool for learning mathematics</td>
</tr>
<tr>
<td>17o</td>
<td>Help students learn to use a symbolic manipulator as a tool for learning mathematics</td>
</tr>
<tr>
<td>19g</td>
<td>For each of the following, give your opinion about each of the statements related to the textbook you are using for this class. Strongly agree, Agree, No opinion, Disagree, Strongly disagree</td>
</tr>
<tr>
<td></td>
<td>This textbook provides good suggestions for the use of calculators.</td>
</tr>
<tr>
<td>19h</td>
<td>This textbook provides good suggestions for the use of graphing features of a calculator.</td>
</tr>
<tr>
<td>19i</td>
<td>This textbook provides good suggestions for the use of table features on a calculator.</td>
</tr>
<tr>
<td>19j</td>
<td>This textbook provides good suggestions for the use of computer algebra systems.</td>
</tr>
</tbody>
</table>
on their content. As a result, I was able to compare the teachers’ comments and thoughts about the use of graphing calculators for the questions in Table 4 considering the three main content areas: functions, statistics, and trigonometry.

Table 4. Items Used from Chapter Evaluation Form.

<table>
<thead>
<tr>
<th>Number</th>
<th>Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>8a</td>
<td>Did you as the teacher demonstrate or use a calculator with this chapter? Yes _____ No ____</td>
</tr>
<tr>
<td>9a</td>
<td>Did your students use a calculator with this chapter? Yes _____ No ____</td>
</tr>
</tbody>
</table>

**Data Analysis**

In a qualitative study, the data analysis process is a productive way to investigate research questions. Researchers should receive a deeper understanding of the data, explain their interpretations, and clarify their experience with settings and documents (Taylor & Bogdan, 1984). Many researchers who have no qualitative data experience have a difficult time to notice patterns that appear in the data. Therefore, it is fundamental to create themes by investigating the data in different ways (Taylor & Bogdan, 1984).

To answer the research questions, I used the data collected through the semi-structured interviews, chapter-evaluation forms, and beginning- and end-of-year teacher questionnaires related to teachers’ perspectives on using graphing calculators. I used a thematic analysis strategy to analyze teachers’ interview responses. Before analyzing the data collected from UCSMP, I read previous studies regarding teachers’ perspectives when they used graphing calculators in their classes. As a result, related literature gave me some ideas about teachers’ perspectives on using graphing calculators when analyzing the data from the interviews. The most common issues, concerns, and perspectives pointed out by teachers in the interviews were identified as the answers for the research questions. Then, the data gathered from chapter evaluation forms were also presented through descriptive statistics.
There are some steps in the thematic analysis method. First, I listed the patterns of experiences from the transcribed interview conversations. I used direct quotes or paraphrased the common ideas to list those patterns. I read and reread the data during this process. Then, I combined related patterns into sub-themes. Themes could be defined as the units coming from patterns, such as conversation topics, or vocabulary. In order to form a comprehensive picture of the participants’ collective experience, emerging themes from their stories were brought together. After that I analyzed the sub-themes to form a comprehensive view of the data. The themes from the related literature helped to build a valid argument for choosing the themes for the present study (Aronson, 1994).

The data collected on the teachers’ responses to the items from the beginning- and end-of-year teacher questionnaires related to using graphing calculators formed the last step of the analysis, during which the teachers’ responses to the open-ended questions were analyzed through thematic analysis. The teachers’ responses to the questions with the Likert scale were analyzed using descriptive statistics. This kind of information was helpful to analyze teachers’ perspectives on using graphing calculators and it might bring additional outlooks to investigate teachers’ perspectives on using graphing calculator technology after analyzing the data from the teacher interviews. In other words, this information might give opportunity to find possible reasons for certain themes created based on the teachers’ responses in the teacher interviews and chapter evaluation forms.

To answer the first research question, I did thematic analysis based on the teachers’ responses to sub-questions (8b), (8c), and (8d) from the teacher interviews and (8a) from the chapter evaluation forms. In addition, teachers’ responses to questions (5) and (8) and sub-questions (6n) and (6o) in the beginning-of-the-year teacher questionnaire and sub-questions
(17n), (17o), (19g), (19h), (19i), and (19j) in the end-of-the-year teacher questionnaire gave more opportunity for a better analysis of teachers’ perspectives on their teaching with graphing calculators and their perspectives on issues, if any, that had arisen because of the presence of the technology. I used the responses to those questions in terms of their descriptive statistics. In their responses, I investigated how the teachers’ answers to those questions influenced their perspectives on using graphing calculators.

I did thematic analysis based on teachers’ responses to sub-questions (8f), (8g), and (8h) from teacher interviews and sub-question (9a) from the chapter evaluation form to answer the second research question. In addition, teachers’ responses on both beginning- and end-of-year teacher questionnaires for some questions were used to gain more information about their perspectives on students’ learning with graphing calculators. For instance, questions (6), (7), (8), (9), and (10) from the end-of-the-year teacher questionnaire were used to better understand teachers’ perspectives on students’ learning with graphing calculators. Again, descriptive statistics analysis gave a big picture of the teachers’ perspectives about how and how often their students’ used graphing calculators in their classes. Based on the teachers’ responses to those five questions on the end-of-year teacher questionnaire, I considered possible reasons for teachers’ perspectives about students’ learning with graphing calculators.

**Thematic Analysis Procedure**

Thematic analysis provides opportunities for researchers to identify, analyze, and report themes (patterns) within data. For example, a researcher might employ thematic analysis to come to understand the meaning of repeated patterns in a data set, such as in a number of interviews and focus groups. Inductive analysis of themes does not require a researcher to provide a pre-existing coding frame; rather, the themes arise from the data themselves. In this inquiry, I used
an inductive approach to data analysis. According to Boyatzis (1998), the study should be conducted based on the semantic or explicit level, or latent or interpretive level. Researchers should only focus on what the data include and should analyze what participants said straightforwardly and directly at the semantic level. In contrast, researchers should go beyond the surface meaning of participants’ talk and explain and investigate hidden ideas that affect the semantic content of the data at the latent level.

For this study, I did a thematic analysis of 11 teachers’ responses to most of the semi-structured interview questions with the semantic level and realistic method. According to Boyatzis (1998) and Braun and Clarke (2006), the semantic themes and realistic approach usually band together in thematic analysis. I used the inductive approach, which analyzes the data and develops themes based on only the participants’ responses. Furthermore, I enhanced my study with the related literature in the early stages of analysis.

One important feature of thematic analysis is flexibility. There are different ways to conduct themes and prevalence of themes. It is significant I was consistent within any particular analysis. I used the constant comparative method to develop concepts by coding and analyzing data continuously. I identified the concepts and analyzed the relationships between concepts. Then, I associated the concepts in a meaningful explanatory model (Taylor & Bogdan, 1984).

**Steps of thematic analysis.** Thematic analysis is a common and basic method for qualitative studies. Its steps are not only used for thematic analysis but also in other qualitative analytic approaches. Thematic analysis is a non-linear process for the researcher from the moment he or she looks for interesting points and meaning of patterns in the data to the moment he or she reports the content and meaning of the patterns. Rather than linear, it is a recursive process (Ely, Vinz, Downing, & Anzul, 1997). Therefore, it requires the researcher to go back
and forth between the original data, the coded extracts of data, and the analysis of the data. Writing is an essential part of thematic analysis. Therefore, writing should begin with the first step of thematic analysis and continue until the last step of the study (Braun & Clarke, 2006). According to Braun and Clarke, there are six steps when doing thematic analysis, which I followed.

**Phase one: Familiarizing with the data.** Before I started to analyze the data for my study, I read similar studies and related literature. Therefore, I had some knowledge to prior analyzing the data. First, I read the entire data set before doing any coding. I took notes to show the interesting points of the data for coding. This was helpful for the next phase. Data were transcribed by an individual familiar with mathematics, who was hired to complete the transcriptions and then verified by the UCSMP Director of Evaluation. Therefore, I spent more time familiarizing myself with the data. I did repeated reading of the data in an active way to explore the patterns and meanings in the data.

**Phase two: Developing initial codes.** After I familiarized myself with the data and had an initial list of what the data were about and what the interesting points of data were from the first phase, I generated initial codes from the data. Codes are “the most basic segment, or element, of the raw data or information that can be assessed in a meaningful way regarding the phenomenon” (Boyatzis, 1998, p. 63). I coded the data as part of my analysis to organize them into meaningful groups. The coded data are more constricted than the themes, which I generated in the next phase. I worked systematically through the entire data set to determine the interesting points of the data. I paid equal attention to every item in the data set during the coding phase. I did coding manually and took notes on the texts, including transcripts of teacher interviews. Individual extracts of data could fit into more than one theme. Therefore, I used more than one
code for individual extracts of data. I identified the codes and matched them with data extracts. I checked the data extracts to make sure that all of them were coded. Then, I copied extracts from original transcripts and collated them together within each code to save them in separate computer files.

**Phase three: Exploring themes.** I had all data coded and I had a list of all codes developed and identified during the previous phase. At phase three, I re-focused the analysis to generate themes, which are broader than codes. I analyzed my codes and considered combining them into themes. I used a visual thematic map including all the codes and definitions of them to play around and explore themes. It is possible for some codes to be main themes or sub-themes, and some can be discarded. I collected the codes which seemed not to belong anywhere together to review later. At the end of this phase, I collected the main themes, sub-themes, and collated all extracts of data that had been coded into them.

**Phase four: Evaluating themes.** This phase is designed to clarify the themes, which were generated during the previous phase. I decided to divide some themes into two themes according to coded data extracts and made clarifications and identifications of distinctions between themes. Therefore, I was able to bring a coherent and meaningful coverage for every theme by identification. In this phase, I followed two consecutive steps: reviewing and refining themes. First, I read though all the collated extracts for each candidate theme. Then, I considered whether each theme was coherent with included data extracts. If I decided themes were coherent, then I applied the second step. If they were not coherent, I considered whether the problem was the theme itself or that the extracts did not fit into the theme. For each case, I reshaped the theme or found a new theme. I selected and kept those extracts that did not currently fit into a candidate theme. Then, I decided to put them in if they fit into another theme or discard them from the
analysis. Once I had decided the themes embodied the contours of the coded data and created a
candidate thematic map, I continued to the second step. The refining step of this phase is similar
to the previous step but it is done in the entire data set. I considered both the relevance of the
individual themes with the whole data set, and whether the candidate thematic map represented
the significant circumstances in the data set as a whole accurately. To ensure an accurate
representation, I re-read the entire data with two purposes. The first purpose was my decision
about how the themes were associated with the entire data set. My second purpose was to capture
any missing non-coded data within the themes. If I found any missing data, I coded them.
Recoding is an ongoing process in thematic analysis. I did further reviewing and refining in this
phase until I decided the thematic map worked and represented the entire data set. It is hard to
clarify when to stop doing further reviewing and refining steps. However, I stopped when my
adjustments were not bringing anything essential to the analysis. When I completed this phase, I
had a good idea about my different themes, how they fit together, and the story the themes told
about the entire data set.

Phase five: Defining and naming themes. In the previous phase, I constructed the
thematic map. After that, I not only paraphrased the collated data extracts but also presented
interesting points and why they were interesting. I described each theme story, the contribution
to the overall story, and the relation to the other themes. I also considered whether the themes
should include any sub-themes, as sub-themes are essential, especially for large and complex
themes to have a better guiding structure to demonstrate the meaning within data. At the end of
this phase, I was sure what my themes were and I wrote a definition and a title for each theme. I
considered titles that were concise and explanatory of the theme for the reader.
Phase six: Producing the report. I wrote the report for the analysis in this phase. I told the complex story about the data in a proper way to show the reader the merit and verisimilitude of my analysis; i.e., comprehensive and coherent both within and between themes. I presented enough data extracts, vivid examples to show the prevalence for each theme. In general, I wrote the results as an analytic narrative to present the story about the data with the embedded data extracts. I included not only the description of the data but also an argument based on my research questions.

In conclusion, I used thematic analysis method to analyze the data for my study. Although I did a semantic level analysis, I went beyond the surface of the data and analyzed deeply the ideas of the themes, behind the themes, their implications, the conditions and reasons for what people said, and the contributions of the themes to the topic.

Index of Teachers’ Initial Perceived Attitude and Experience Level

Myers and Halpin (2002) showed preservice teachers’ positive attitudes of using technology influenced future use and successful technology integration. In addition, Lee and McDougall (2010) concluded teachers with more instructional practices and personal experiences with technology were more inclined to use technology in their classroom. Additionally, the authors noted teachers’ proficiency with technology and the extent to which technology was integrated into the curriculum can impact the likelihood for technology to be effectively used to facilitate learning. Thus, I decided to create a teachers’ initial perceived attitude and experience level index using their responses to two questions on the beginning-of-the-year teacher questionnaire about the importance of using calculators as well as their experience with particular features of graphing calculators. In designing the index, I wanted to ensure their initial perceived attitude and experience level had equal weight.
In consultation with the UCSMP Director of Evaluation (Dr. Denisse Thompson), I divided the features of graphing calculators into two groups based on their importance level in terms of teaching the FST course. The important features for teaching the course were graphing, table, statistics, equation modeling, and symbolic algebra features; the other two features (dynamic geometry and spreadsheet) were less important. I scaled their experience using features of a graphing calculator as: 0 = never used; 1 = seldom used; and 2 = use frequently (see Table 5). In addition, I weighted the important calculator features by a factor of two. Thus, the maximum score for experience would be 24. The following data set illustrates the coding and calculation process:

Table 5. Calculation of Teachers’ Initial Experience Level.

<table>
<thead>
<tr>
<th>Features</th>
<th>Teacher Rating</th>
<th>Scores obtained due to teacher rating</th>
<th>Ranking of Features</th>
<th>Calculation to determine experience level: Score obtained due to teacher rating × Ranking of features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graphing features</td>
<td>Use frequently</td>
<td>2</td>
<td>Important</td>
<td>2 × 2 = 4</td>
</tr>
<tr>
<td>Table features</td>
<td>Use frequently</td>
<td>2</td>
<td>Important</td>
<td>2 × 2 = 4</td>
</tr>
<tr>
<td>Statistics features</td>
<td>Use frequently</td>
<td>2</td>
<td>Important</td>
<td>2 × 2 = 4</td>
</tr>
<tr>
<td>Equation modeling features</td>
<td>Use frequently</td>
<td>2</td>
<td>Important</td>
<td>2 × 2 = 4</td>
</tr>
<tr>
<td>Symbolic algebra features</td>
<td>Use frequently</td>
<td>2</td>
<td>Important</td>
<td>2 × 2 = 4</td>
</tr>
<tr>
<td>Dynamic geometry</td>
<td>Use frequently</td>
<td>2</td>
<td>Less Important</td>
<td>2 × 1 = 2</td>
</tr>
<tr>
<td>Spreadsheet</td>
<td>Use frequently</td>
<td>2</td>
<td>Less Important</td>
<td>2 × 1 = 2</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>4+4+4+4+4+2+2 = 24</td>
</tr>
</tbody>
</table>

Therefore the calculation for experience with using the calculator can be written as the summation of the ranking of features multiplied by the frequency of use. As noted previously, a weight of two is given to features deemed important and one is given to features deemed less important. Furthermore, for this study, I treated experience and attitude as equally valuable.
Hence, the maximum calculation for the experience was 24 points and, likewise, the maximum calculation for attitude was 24 points.

To calculate teachers’ attitude, I used data garnered from the beginning-of-year teacher questionnaire, from which I used teachers’ responses to the sub-questions related to their attitudes about graphing calculator usage, i.e., how important is it to help students learn to use a graphing calculator as a tool for learning mathematics, and how important is it to help students learn to use a symbolic manipulator as a tool for learning mathematics. Responses were scaled 1 = of little importance; 2 = somewhat important; 3 = quite important; 4 = of highest importance (see Table 6). If teachers responded of highest importance to both questions they would have a score of eight; so their initial perceived attitude score was multiplied by a factor of three in order for the maximum attitude score to be 24, the same as the maximum score for experience. The following data set illustrates the coding and calculation process:

Table 6. Calculation of Teachers’ Initial Perceived Attitude Level.

<table>
<thead>
<tr>
<th>Features</th>
<th>Teacher Rating</th>
<th>Scores obtained due to teacher rating</th>
<th>Calculation to determine attitude level: Score obtained due to teacher rating ( \times ) Attitude factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Importance of graphing calculator</td>
<td>Of highest importance</td>
<td>4</td>
<td>( 4 \times 3 = 12 )</td>
</tr>
<tr>
<td>Importance of symbolic manipulator</td>
<td>Of highest importance</td>
<td>4</td>
<td>( 4 \times 3 = 12 )</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>12 + 12 = 24</td>
<td></td>
</tr>
</tbody>
</table>

To calculate teachers initial Perceived Attitude and Experience Level Index, the scores of teachers both for attitude and experience were added together \( (24 + 24 = 48) \).

**Index of Teachers’ Use of Graphing Calculators**

An index for graphing calculator use over the course of the year was created from teachers’ perspectives on how frequently and in what ways their students used graphing calculators, how helpful and important the graphing calculator was, and the suggestions of using
graphing calculators in the textbook. All questions related to how frequently their students used graphing calculators, importance of graphing calculators in their teaching, the suggestions for using graphing calculators in the textbooks, in what ways their students used graphing calculators, helpfulness of graphing calculators in terms of their students’ learning were included in the index. All five categories of teachers’ perspectives have equivalent weight in the index with the exception of the more important graphing calculator features for the course (graphing equations, making tables, analyzing data, finding equations to model data, and simplifying

Table 7. Calculation of Index of Teachers’ Use of Graphing Calculators.

<table>
<thead>
<tr>
<th>Features</th>
<th>Teacher Rating</th>
<th>Scores obtained due to teacher rating</th>
<th>Ranking of Features</th>
<th>Calculation to determine experience level: Score obtained due to teacher rating x Ranking of features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency of calculator used by students</td>
<td>Almost every day</td>
<td>5</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Frequency of CAS used by students</td>
<td>Almost every day</td>
<td>5</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Importance of graphing calculators</td>
<td>Of highest importance</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Importance of symbolic manipulator</td>
<td>Of highest importance</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Textbook suggestions to use of calculators</td>
<td>Strongly Agree</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Textbook suggestions for graphing features</td>
<td>Strongly Agree</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Textbook suggestions for table features</td>
<td>Strongly Agree</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Textbook suggestions for computer algebra systems features</td>
<td>Strongly Agree</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Checking answers</td>
<td>Yes</td>
<td>1</td>
<td>Less Important</td>
<td>1</td>
</tr>
<tr>
<td>Doing computations</td>
<td>Yes</td>
<td>1</td>
<td>Less Important</td>
<td>1</td>
</tr>
<tr>
<td>Solving problems</td>
<td>Yes</td>
<td>1</td>
<td>Less Important</td>
<td>1</td>
</tr>
<tr>
<td>Graphing equations</td>
<td>Yes</td>
<td>1</td>
<td>Important</td>
<td>2 × 1 = 2</td>
</tr>
<tr>
<td>Working with spreadsheet</td>
<td>Yes</td>
<td>1</td>
<td>Less Important</td>
<td>1</td>
</tr>
<tr>
<td>Making tables</td>
<td>Yes</td>
<td>1</td>
<td>Important</td>
<td>2 × 1 = 2</td>
</tr>
<tr>
<td>Analyzing data</td>
<td>Yes</td>
<td>1</td>
<td>Important</td>
<td>2 × 1 = 2</td>
</tr>
<tr>
<td>Finding equations to model data</td>
<td>Yes</td>
<td>1</td>
<td>Important</td>
<td>2 × 1 = 2</td>
</tr>
<tr>
<td>Simplifying algebraic expressions</td>
<td>Yes</td>
<td>1</td>
<td>Important</td>
<td>2 × 1 = 2</td>
</tr>
<tr>
<td>Other features of CAS</td>
<td>Yes</td>
<td>1</td>
<td>Less Important</td>
<td>1</td>
</tr>
<tr>
<td>How helpful calculators</td>
<td>Very helpful</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>52</td>
<td></td>
</tr>
</tbody>
</table>
algebraic expressions; see Table 7 above), which had two as a multiplier. The following data set illustrates the coding and calculation process.

Credibility

Validity in qualitative research “refers to gaining knowledge and understanding of the true nature, essence, meanings, attributes, and characteristics of a particular phenomenon under study” (Leininger, 1985, p. 68). Lincoln and Guba (1985) used the term “credibility” (p. 213) instead of validity for qualitative research. There are some strategies to make credibility stronger for a study, such as triangulation, member checking, and peer examination (Johnson, 1997; Krefting, 1991). I used the triangulation strategy using multiple procedures and sources to do “cross-checking” to increase the credibility of my study (Johnson, 1997, p. 283). I used different sources (beginning- and end-of-the-year teacher questionnaires, end of chapter evaluation forms, and teacher interview protocol) to collect and analyze data. In addition, I used peer review as a strategy to conduct a valuable study in terms of credibility. Peer review is a strategy to discuss with a peer who is not an involved researcher in the study. This peer forces the researcher to find solid evidences for any interpretation and conclusion during the discussion (Johnson, 1997). Therefore, I found one volunteer peer (a doctoral student with Mathematics Education concentration) to discuss my analysis and conclusion of two participants’ responses.

I informed my peer about steps in thematic analysis, the research questions, and the study broadly and I asked her to code two teachers’ interviews. I created a code pool for the peer review strategy based on my initial codes coming from four different teachers. Therefore, my peer was able to use those codes in the code pool. I also asked her to collect her codes into the themes and sub-themes using my thematic map. Thus, I was able to compare her results with mine to complete a peer review for teacher interviews. After her initial coding, we agreed around
75% of the time on codes for themes and sub-themes. We reviewed and discussed disagreements, resulting in final agreement on 95% of theme and sub-theme codes.

Summary

In this chapter, I included information about the research design by giving details about thematic analysis steps, calculation for Index of Teachers’ Initial Perceived Attitude and Experience Level, and calculation for Index of Teachers’ Use of Graphing Calculators. In addition, I reported school selection procedures and data collection instruments. Lastly, I provided information of methods to enhance the credibility of the study.
CHAPTER FOUR: RESULTS

This study was a secondary analysis of data collected as part of an evaluation of Functions, Statistics, and Trigonometry (Third Edition, Field Trial Version) developed by UCSMP. Data were collected by Dr. Denisse Thompson, Director of Evaluation. Initially twelve teachers taught the FST third edition materials during the 2007-2008 school year. However, Kate (all names are pseudonyms) left the study during the school year and I did not include her as a participant in the data analysis. I analyzed eleven teachers’ responses relative to graphing calculators from the beginning- and end-of-year teacher questionnaires, teacher interviews, and chapter evaluation forms, and based the results on their answers. In particular, I investigated the following research questions:

1. In what ways do eleven teachers use graphing calculators in an 11th-grade Functions, Statistics, and Trigonometry course?

2. What are eleven teachers’ perspectives on student learning when students use graphing calculators in an 11th-grade Functions, Statistics, and Trigonometry course?

3. What are eleven teachers’ perspectives on their teaching an 11th-grade Functions, Statistics, and Trigonometry course using graphing calculators?

I report results in three sections: teachers and classroom demographics; initial perspectives on using graphing calculators; and graphing calculator perspectives throughout the year.

Teacher and Classroom Demographics

This section provides background information about the participating teachers, including teachers’ gender, years of teaching mathematics, years of teaching a course at the level of FST,
and years of teaching with a UCSMP textbook. There were five female teachers (Anna, Ella, Fifi, Gina, and Isla) and six male teachers (Brad, Carl, Duke, Hugo, John, and Lane). The teachers’ experience teaching mathematics ranged from two to 35 years (median = 18 years) as reported in Table 8. Although four teachers (Ella, Fifi, Hugo, and Isla) had never taught this level course before, the other seven teachers (Anna, Brad, Carl, Duke, Gina, John, and Lane) had taught this course from two years to 14 years (median = 5 years).

Table 8. Teachers’ Background Information.

<table>
<thead>
<tr>
<th>Teachers</th>
<th>Anna</th>
<th>Brad</th>
<th>Carl</th>
<th>Duke</th>
<th>Ella</th>
<th>Fifi</th>
<th>Gina</th>
<th>Hugo</th>
<th>Isla</th>
<th>John</th>
<th>Lane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>F</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>M</td>
<td>F</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>Years of teaching mathematics</td>
<td>25</td>
<td>25</td>
<td>18</td>
<td>8</td>
<td>12</td>
<td>20</td>
<td>18</td>
<td>2</td>
<td>22</td>
<td>35</td>
<td>14</td>
</tr>
<tr>
<td>Years of teaching FST type course*</td>
<td>14</td>
<td>NA</td>
<td>3</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>Years of teaching UCSMP text</td>
<td>14</td>
<td>14</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5</td>
</tr>
</tbody>
</table>
*NA indicates questions not answered.

Table 9. Classroom Background Information.

<table>
<thead>
<tr>
<th>Teachers</th>
<th>Anna</th>
<th>Brad</th>
<th>Carl</th>
<th>Duke</th>
<th>Ella</th>
<th>Fifi</th>
<th>Gina</th>
<th>Hugo</th>
<th>Isla</th>
<th>John</th>
<th>Lane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calculators provided by UCSMP*</td>
<td>Nspire</td>
<td>Nspire</td>
<td>89</td>
<td>89</td>
<td>89</td>
<td>Class-Pad</td>
<td>Class-Pad</td>
<td>89</td>
<td>89</td>
<td>89</td>
<td>89</td>
</tr>
<tr>
<td>Teacher loaned CAS by UCSMP</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Calculators typically used</td>
<td>Nspire</td>
<td>Nspire</td>
<td>83</td>
<td>89</td>
<td>84</td>
<td>84</td>
<td>89</td>
<td>84</td>
<td>83</td>
<td>89</td>
<td>84</td>
</tr>
<tr>
<td>Length of class weekly (minutes)</td>
<td>250</td>
<td>250</td>
<td>165</td>
<td>250</td>
<td>250</td>
<td>264</td>
<td>264</td>
<td>200</td>
<td>240</td>
<td>400</td>
<td>215</td>
</tr>
</tbody>
</table>
*All graphing calculators were Texas-Instruments, except for ClassPad from Casio. Nspire, 89 and ClassPad are CAS capable calculators loaned by UCSMP, TI83 and TI84 do not have CAS, and were personal calculators of students or provided by the schools.

As indicated in Table 9 above, the length of the class period differed across schools, varying from 165 minutes to 400 minutes per week (median=250 minutes). Four teachers’ classes (Anna’s, Brad’s, Duke’s, and Ella’s) were 50 minutes each day. Hugo’s class met only twice a week for 100 minutes per class. John’s class met 80 minutes each day per week. The table reports the type of graphing calculators provided by UCSMP and typically used in class.
Students in all classes had access to graphing calculators. In classes of Fifi, Gina and John, students did not have regularly reported access to CAS calculators. In classes of Carl, Duke, Ella and Lane, students had access to both CAS and non-CAS calculators. In the classes of Hugo and Isla, students typically used graphing calculators with CAS. In the classes of Anna and Brad, students typically used a beta version of the CAS TI-Nspire.

**Teachers’ Initial Perspectives on Using Graphing Calculators**

Teachers’ initial perspectives on using graphing calculators were derived from their initial perceived attitudes about planned graphing calculator use and their prior experience with graphing calculator features, both reported on the beginning year teacher questionnaire. From their responses, I created an index of teachers’ initial perceived attitude and experience level (see Chapter Three for the development of the index).

**Teachers’ Initial Perceived Attitudes Related to Graphing Calculator Use**

Table 10 reports teachers’ responses to two sub-questions on the questionnaire: How important is it to help students learn to use a graphing calculator as a tool for learning mathematics, and how important is it to help students learn to use a symbolic manipulator as a tool for learning mathematics. Two teachers (Brad and Isla) considered helping students learn to use a graphing calculator as somewhat important, seven teachers (Anna, Carl, Duke, Fifi, Gina, Hugo, and Lane) as quite important, and two teachers (Ella and John) as of highest importance. Gina and Isla considered helping students learn to use a symbolic manipulator of little importance; Brad, Carl, Hugo, and Lane as somewhat important; and Anna, Duke, Ella, Fifi, and John as quite important.
Table 10. *Teachers’ Initial Attitudes about their Teaching with Graphing Calculators.*

<table>
<thead>
<tr>
<th>Items</th>
<th>Anna</th>
<th>Brad</th>
<th>Carl</th>
<th>Duke</th>
<th>Ella</th>
<th>Fifi</th>
<th>Gina</th>
<th>Hugo</th>
<th>Isla</th>
<th>John</th>
<th>Lane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Importance of graphing calculator</td>
<td>Q</td>
<td>S</td>
<td>Q</td>
<td>Q</td>
<td>H</td>
<td>Q</td>
<td>Q</td>
<td>S</td>
<td>H</td>
<td>Q</td>
<td></td>
</tr>
<tr>
<td>Importance of symbolic manipulator</td>
<td>Q</td>
<td>S</td>
<td>S</td>
<td>Q</td>
<td>Q</td>
<td>L</td>
<td>S</td>
<td>L</td>
<td>Q</td>
<td>S</td>
<td></td>
</tr>
</tbody>
</table>

*L=Of little importance, S=Somewhat important, Q=Quite important, H=Of highest importance.

**Teachers’ Initial Experiences Using Features of Graphing Calculators**

Teachers were also asked about their experience with features of a graphing calculator, such as graphing, tables, statistics, equation modeling, and symbolic algebra features using a scale of Never used, Seldom used (some experience but not proficient), Used frequently (enough experience to be proficient). Table 11 displays teachers’ reported experience with the features of a graphing calculator. Teachers’ responses indicated their experiences with graphing and table features were very similar in terms of mostly having enough experience to be proficient. Fifi had never used statistics features, three teachers (Ella, Hugo, and John) had some experience but were not proficient, while seven teachers (Anna, Brad, Carl, Duke, Gina, Isla, and Lane) considered themselves proficient. Carl had never used the equation modeling features of a graphing calculator, two teachers (Fifi and Hugo) had some experience with modeling but were not proficient, and the other eight teachers considered themselves proficient with equation modeling. Symbolic algebra features were the least familiar features in terms of teachers’ experience level. All these types of features are significant in terms of the content of FST.

**Index of Teachers’ Initial Perceived Attitude and Experience Level**

Table 12 shows teachers’ initial perceived attitude and experience level index. For instance, Anna’s initial perceived attitude and experience level index was computed as follows: For initial experience level (see Table 11), Anna had enough experience to be proficient for the graphing, table, statistics, equation modeling, and symbolic algebra features, so all these five
Table 11. *Teachers' Initial Experience Using Features of a Graphing Calculator.*

<table>
<thead>
<tr>
<th>Features</th>
<th>Teachers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Anna</td>
</tr>
<tr>
<td>Graphing features</td>
<td>F</td>
</tr>
<tr>
<td>Table features</td>
<td>F</td>
</tr>
<tr>
<td>Statistics features</td>
<td>F</td>
</tr>
<tr>
<td>Equation modeling features</td>
<td>F</td>
</tr>
<tr>
<td>Symbolic algebra features</td>
<td>F</td>
</tr>
<tr>
<td>Dynamic geometry</td>
<td>F</td>
</tr>
<tr>
<td>Spreadsheet</td>
<td>F</td>
</tr>
</tbody>
</table>

*N=Never used, S=Seldom used, F=Use frequently.*

features were multiplied by two because they are more important \((2 + 2 + 2 + 2 + 2) \times 2 = 20\).

Anna had enough experience to be proficient for the dynamic geometry and spreadsheet features; those two features were multiplied by one because they are less important \((1 \times [2 + 2] = 4)\). Then I added all the points to find Anna’s total index score for initial experience level \((20 + 4 = 24)\).

For initial perceived attitude level (see Table 10), it was important for Anna both to help students learn to use a graphing calculator and a symbolic manipulator as a tool for learning mathematics; so I added both ratings and multiplied by three because those two attitude questions had three as a multiplier \((3[3 + 3] = 18)\). Thus, Anna’s final index score was \(24 + 18 = 42\).

Table 12. *Index of Teachers’ Initial Perceived Attitude and Experience Level.*

<table>
<thead>
<tr>
<th>IPAE</th>
<th>Teachers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Anna</td>
</tr>
<tr>
<td>Attitude and experience level</td>
<td>42</td>
</tr>
<tr>
<td>Teachers’ level</td>
<td>H</td>
</tr>
</tbody>
</table>

Overall, the score for the index ranged from six to 48. Teachers’ levels of initial perceived attitude and experience were grouped into three categories based on the possible scores. I divided the whole scale, which ranged from a minimum of six to a maximum of 48 into thirds. Therefore, the scores between six and 19 were identified as low attitude and experience level, scores between 20 and 33 as medium attitude and experience level, and scores between 34
and 48 as high attitude and experience level. Six teachers’ (Brad, Carl, Fifi, Gina, Hugo, and Isla) initial perceived attitude and experience level was medium and the other five teachers’ initial perceived attitude and experience level was high.

**Teachers’ Graphing Calculator Perspectives throughout the Year**

Teachers completed a questionnaire at the end of the school year indicating the calculator technology available for use by the majority of their students during class as well as the frequency and nature of use. Teachers’ reports about how frequently students used graphing calculators, how students used them, how helpful and important graphing calculators were, and the textbook suggestions for using graphing calculators were all included in their perspectives throughout the year. In addition, I analyzed teachers’ comments from the semi-structured interview questions about graphing calculators using thematic analysis. I extracted the following themes and sub-themes regarding teachers’ perspectives on graphing calculators from the teacher interviews.

**Teachers’ Use of Graphing Calculators**

**Teachers’ frequency of graphing calculator usage.** This sub-theme showed how frequently the teacher used or planned to use graphing calculators.

**Teachers’ purposes for using graphing calculators.** Teachers’ thoughts about for what purposes they used graphing calculators were aggregated in this sub-theme.

**Teachers’ instructional views about graphing calculators.** Teachers’ points of view about teaching approaches of the course with using graphing calculators and how they used them in their teaching were combined in this sub-theme.

**Teachers’ use of graphing calculators based on topics.** In this sub-theme, teachers’ and their students’ usage of graphing calculators in terms of topics were included.
Teachers’ use of graphing calculators in assessment processes. Teachers’ assessment process and their teaching were affected depending on whether or not their students were allowed to use the graphing calculators on tests were collected in this sub-theme.

Teacher support to use graphing calculators more effectively. Teachers’ opinions and expectations about teaching materials and professional development components to use graphing calculators more effectively in their teaching were combined in this sub-theme.

Teachers’ Opinions about Students’ Use of Graphing Calculators

Students’ reactions to using graphing calculators. Teachers reported their thoughts about how their students reacted to the integration of graphing calculators were collected in this sub-theme.

Effects of using graphing calculators on students’ learning. Teachers’ ideas about how using graphing calculators impacted their students’ learning were included in this sub-theme.

Effects of graphing calculators on students’ skills. Teachers’ thoughts about what student skills were affected positively and negatively by the existence of graphing calculators were collected in this sub-theme.

Students’ dependency on the graphing calculators. Teachers’ ideas about students’ dependency on graphing calculators in the course and their daily life were combined in this sub-theme.

Teachers’ Issues with Graphing Calculator Technology

Teachers brought some existing issues in their teaching with graphing calculators, such as liability and cheating.
Teachers’ Use of Graphing Calculators

**Teachers’ frequency of graphing calculator usage.** Table 13 displays students’ frequency of use of graphing calculators and CAS as reported by teachers. Teachers’ responses about the frequency of students’ calculator use showed Carl’s and Fifi’s students used calculators two to three times a week; however, the other nine teachers’ students used graphing calculators almost every day. In contrast, teachers generally used CAS rarely. For instance, Fifi and Isla, both of whom had a medium level initial perceived attitude and experience (IPAE) index, reported their students almost never used CAS capabilities. Four teachers used CAS features two to three times in a month or less than once a month. Anna and Duke, both of whom had a high level IPAE index, reported their students used CAS features almost every day.

Table 13. *Type and Frequency of Graphing Calculator Usage.*

<table>
<thead>
<tr>
<th>Frequency of Use</th>
<th>Anna</th>
<th>Brad</th>
<th>Carl</th>
<th>Duke</th>
<th>Ella</th>
<th>Fifi</th>
<th>Gina</th>
<th>Hugo</th>
<th>Isla</th>
<th>John</th>
<th>Lane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency of calculator used by students</td>
<td>Almost everyday</td>
<td>Almost everyday</td>
<td>2-3 times per week</td>
<td>Almost everyday</td>
<td>Almost everyday</td>
<td>2-3 times per week</td>
<td>Almost everyday</td>
<td>Almost everyday</td>
<td>Almost everyday</td>
<td>Almost everyday</td>
<td>Almost everyday</td>
</tr>
<tr>
<td>Frequency of CAS used by students</td>
<td>Almost everyday</td>
<td>2-3 times per week</td>
<td>2-3 times a month</td>
<td>Almost everyday</td>
<td>2-3 times a month</td>
<td>Almost never NA</td>
<td>2-3 times a month</td>
<td>Almost never NA</td>
<td>Less than once a month</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

I also analyzed teacher interviews for comments about frequency of graphing calculator usage for data triangulation purposes. Using constant comparative methods, I extracted the sub-theme “teachers’ frequency of graphing calculator usage” based on how frequently the teacher used or planned to use graphing calculators. Only Anna, Ella, Gina, Hugo, and Isla informed how frequently they used graphing calculators in their classes during the interviews. All five teachers indicated they used graphing calculators daily. Interestingly, three of the five (Gina, Hugo, and Isla) were in the medium level in terms of the IPAE index. Hugo said:
The calculators, daily. Definitely if there is ever any activity or anything within the book that shows how it can be done using the 89, we always do that. And then I always try to show additional ways, for instance when we were doing sigma notation, they had never seen that before, and so we did some general examples that were not related to data, and then I showed them how you can do that on the 89. In class today when we were doing the probability, showing them how to do \textit{permutations} and so forth on it.

Similarly, Ella said, “I use the technology every day. That’s one of the standards in the state, is that they can work and solve problems with and without technology. I think they learn a lot more math using technology.”

\textbf{Teachers’ purposes of using graphing calculators.} During the interview, teachers also talked about how they used graphing calculators. Based on their responses, I generated the sub-theme, “teachers’ purposes for using graphing calculators.” Teachers’ thoughts about the purposes for which they used graphing calculators were aggregated in this sub-theme. One of the most common purposes was to explore mathematics. Anna, Brad, and Lane noted graphing calculators were useful to explore something in mathematics, such as patterns. Two of these three teachers (Anna and Lane) had a high level IPAЕ index. Anna said:

The calculator is used not only to do the problem, but to explore the formula for example. What we did—chi squared. We looked at how is the formula being developed and rather than doing it by hand we did it in their spreadsheet. They noticed, “Oh yeah, look! This is the formula!”

In addition, Brad, Gina, and Lane reported graphing calculators were beneficial for students to check their work. Anna and Gina also mentioned they used graphing calculators in doing
problems. Brad and Gina were at the medium level, while Anna and Lane were at the high level on the IPAE index. For instance, Gina said:

But when we got into the applications, we used the calculators a lot. I like to do a lot of real-world situations that are modeled by trig functions and then have them write the trig function and then check their answer with the graph. This is something we spent a lot of time on.

**Teachers’ instructional views about using graphing calculators.** Anna and Ella, who had a high level IPAE index, said graphing calculators with CAS changed their approach to the course. Anna used spreadsheet features of the TI-Nspires a great deal in her classes. She also used the TI-Nspire mostly to draw scatterplots and do regressions. In addition, Ella used TI-89s to go back and forth among equations, graphs, and tables. She said:

It totally changes how you approach your teaching of it, because with the graphing calculators, you can actually go back and forth between equation, table, graph. I mean, you see those connections so much easier than if you’re having to do all of this by hand. I never taught without graphing calculators. That’s the way I learned, without graphing calculators.

In contrast, Brad, Isla, and John stated their approach of the course was not different because of the presence of graphing calculator technology. Brad used the advantages of curriculum materials, and emphasized things symbolically. Isla, comfortable with TI-84s, planned to start to teach how to use TI-89s first and to focus more on CAS activities. She reported it was overwhelming to learn both the book and graphing calculator during the school year. Duke and John, who were at the high level on the IPAE index, noted they had skipped
some areas, such as finding roots, which were not needed in precalculus according to their state objectives.

Some teachers commented on the advantage of focusing on the concepts. For instance, Duke said, “The good thing about the graphing calculator is no number crunching, let’s get to the concept.” Carl reported using technology and understanding mathematics were both skills he wanted to teach his students. Gina and Hugo, who had a medium level on the IPAE index, taught the course by using the advantages of graphing calculators to show additional techniques, such as explaining both algebraically and graphically. Gina said:

Well, I think it helps me present material in more than one way, which is helpful for the students. So if they can show it algebraically then show it graphically, solving equations so they can see visually “Oh, there’s two solutions there” and that kind of thing. So I try whenever possible to present the idea of more than one way of technology.”

Teachers’ use of graphing calculators based on topics. Teachers generally talked about statistics, trigonometric functions, and polynomials as the topics for which their students mostly used graphing calculators. Anna, Gina, Hugo, and John used graphing calculators mostly in statistics topics. Duke, Gina, and John also used graphing calculators in trigonometric functions. In addition, Anna reported polynomials were more interesting with TI-Nspires but did not indicate why. Brad wanted to see more CAS activities in polynomial topics. Gina reported polynomials were possible topics to use CAS. Table 14 documents the chapters in which teachers indicated both students and teachers used graphing calculators based on their responses on the chapter evaluation forms.

Teachers’ use of graphing calculators in assessment processes. Teachers generally talked about the tests their students took during the course as well as upcoming standardized tests
(ACT and SAT). Table 15 reports Anna, Carl, Duke, Gina, and Lane used no calculator tests or questions as a part of their testing process, either as an entire no-calculator test or a test on which some portion did not allow calculators. Three of these teachers (Anna, Duke and Lane) were at the high level on the initial perceived attitude and experience index. Gina, who was at the medium level on the IPAE index said:

Table 14. *Graphing Calculator Usage on Chapters by Students and Teachers.*

<table>
<thead>
<tr>
<th>Content</th>
<th>Functions</th>
<th>Statistics</th>
<th>Trigonometry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chapters</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>8</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>T</td>
<td>S</td>
<td>T</td>
<td>S</td>
</tr>
<tr>
<td>Anna</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brad</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Carl</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duke</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ella</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Fifi</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gina</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hugo</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Isla</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>John</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Lane</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* T= teachers, S= students; shaded boxes indicate graphing calculator was used for that chapter by either teacher or student depending on the column heading; X=Teacher did not teach 50% of the chapter. Data are based on responses to chapter evaluation forms.

Table 15. *Teachers’ Perspectives about Using Graphing Calculators on Assessments.*

<table>
<thead>
<tr>
<th>Teacher</th>
<th>In Class Tests</th>
<th>External Exams (ACT, SAT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anna</td>
<td>No-calculator tests</td>
<td>CAS not on ACT</td>
</tr>
<tr>
<td>Brad</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carl</td>
<td>No-calculator tests</td>
<td>TI-89s are allowed on SAT</td>
</tr>
<tr>
<td>Duke</td>
<td>Half test no-calculator</td>
<td></td>
</tr>
<tr>
<td>Ella</td>
<td></td>
<td>TI-84s are allowed on ACT</td>
</tr>
<tr>
<td>Fifi</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gina</td>
<td>No-calculator as a part of tests</td>
<td></td>
</tr>
<tr>
<td>Hugo</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Isla</td>
<td></td>
<td></td>
</tr>
<tr>
<td>John</td>
<td></td>
<td>TI-84s are allowed on ACT and SAT</td>
</tr>
<tr>
<td>Lane</td>
<td>No-calculator as a part of tests</td>
<td>No graphing calculators on the exam</td>
</tr>
</tbody>
</table>

* Shaded rows indicate teachers did not make any comments about assessment during the interview.
We have a part of the test usually without the calculator, so if I want to know if they’ve memorized a formula or something, I put it on that part. And I don’t care what they know on the calculator. They’ve programmed some part (inaudible), but I’m testing some other stuff in another way. So, to me that pretty much takes care of all the problems if I clear, reset the memory at the end of the week and go on.

However, Ella and John mentioned the benefits of using graphing calculators without CAS for ACT exams. For instance, Ella said:

I’ll let them use the 84s if they prefer, and that goes back to the fact that, they’re regular precalculus kids, so they’ll be taking the ACT, they’ll be taking college algebra, none of those allow use of the 89, so they need to know how to use an 84.

Anna’s students complained about the allowed graphing calculators (TI-84) because the TI-84 filled up only one screen rather than the multiple screens they were used to on the Nspire. Carl was amazed that TI-89s were allowed on the SAT. Interestingly, Lane said no graphing calculators (with or without CAS) were allowed on the external exam taken by his students.

Six teachers (Anna, Brad, Duke, Ella, Hugo, and John) taught in states where students typically or sometimes were required to take the ACT rather than the SAT for graduation or college admission. At the time the evaluation study was conducted, the ACT did not permit the use of the TI-89 because of the CAS capability but the SAT did.

**Teacher support to use graphing calculators more effectively.** Duke, Gina, and Isla addressed the learning curve related to the use of graphing calculators with CAS they received from UCSMP. For example, Gina said:

And the learning curve, just for me to learn ClassPad because it’s not, doesn’t operate like TI’s at all. I started downloading the manual, to have something to study. The
learning curve for me to learn how to use it and instruct the kids in it and then for them
did not seem like [a good use of time]. And these kids who are going on are going to be
taking AP Stats next year, they would really need to be comfortable and well-versed in
the TI-83, -84. I didn’t think I would be doing them a service and taking the time to …

Brad, Carl, Duke, Fifi, Gina, Isla, and Lane talked about their need to have a manual
showing the steps for using graphing calculators with CAS they received from UCSMP. Five of
these teachers had a medium level on the IPAE index. Sample comments are as follows:

I wish the Nspire had a … I know it’s online in pdf form, but I would like a paper, a real
manual for that. And the reason being is it’s still quicker to search visually through paper
than it is electronically through a document for something. At least for me, maybe
because I’m old. (Brad)

Well, starting with the TI-89s it would have been nice to have a detailed handbook. I
know there were some things posted online and that helps some, but reading through that
I didn’t get everything I needed, and I just had to play around with it until I figured out
some things. So a detailed handbook would be helpful because that is the predominant
technology to be used with the CAS. As a supplement would be nice for the teacher and
maybe the student. (Duke)

Fifi, Isla, and John reported that there was a need for time and in-service training like workshops
to help those using UCSMP graphing calculators with CAS to learn how they worked. Sample
comments are as follows:

I would say for me I am new to the topic, new to the course, so if I am going to use a
calculator without any background, without any workshop, you know, it would be harder
for me to use that calculator, the CAS something. (Fifi)
Well, not relative to the technology really, maybe playing around with it. If I knew in the summer what, like if I had the calculator a couple months ahead of time to play with, and knew how it was going to be used throughout the book, that probably would’ve been helpful. I think my frustrations are a function of the study as opposed to the book, you know, it’s just that you guys were getting it off the ground as we were starting school and the time when I had to work on it this summer, it wasn’t available, and then I got it when we moved into this building, the week before, on August the 15th, and everything we owned was piled in that room, so trying to get out of that mess, get your room set up, get started, learn a book, learn a calculator, was a little bit overwhelming. (Isla)

**Importance of using graphing calculators.** On the end-of-year teacher questionnaire, teachers were asked about their views related to the importance of helping their students use a graphing calculator as a tool for learning mathematics. Their responses to these questions are related to the theme, “teachers’ use of graphing calculators,” from the interview and so are reported here. Table 16 documents teachers’ responses to those questions on the end-of-year questionnaire. Anna, Duke, Ella, and John, who had a high level on the IPAE index, considered helping students learn to use a graphing calculator as a tool as of highest importance. In total, nine teachers reported graphing calculators were quite or highly important in their teaching (median = 3).

Additionally, teachers were asked how important it was for them to help their students learn to use a symbolic manipulator as a tool for learning mathematics. Teachers’ perspectives about the importance of symbolic manipulators were quite a bit lower than their perspectives about the importance of graphing calculators (median = 2). Interestingly, none of the eleven
teachers thought helping their students learn to use a symbolic manipulator as a tool was of highest importance.

**Suggestions for use of graphing calculators in the textbook.** Teachers’ technology use can also be affected by the suggestions included in the textbook. Therefore, teachers’ responses to questions about suggestions for the use of graphing calculators in the textbook were analyzed.

Table 16. *Teachers' Perspectives about the Importance of Graphing Calculators in their Teaching.*

<table>
<thead>
<tr>
<th>Importance</th>
<th>Anna</th>
<th>Brad</th>
<th>Carl</th>
<th>Duke</th>
<th>Ella</th>
<th>Fifi</th>
<th>Gina</th>
<th>Hugo</th>
<th>Isla</th>
<th>John</th>
<th>Lane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Importance of graphing calculators</td>
<td>H</td>
<td>S</td>
<td>Q</td>
<td>H</td>
<td>H</td>
<td>Q</td>
<td>Q</td>
<td>Q</td>
<td>Q</td>
<td>H</td>
<td>S</td>
</tr>
<tr>
<td>Importance of symbolic manipulator</td>
<td>Q</td>
<td>S</td>
<td>Q</td>
<td>Q</td>
<td>L</td>
<td>Q</td>
<td>L</td>
<td>L</td>
<td>S</td>
<td>L</td>
<td>S</td>
</tr>
</tbody>
</table>

*L=Of little importance, S=Somewhat important, Q=Quite important, H=Of highest importance

Their responses to these questions are related to the theme, “teachers’ use of graphing calculators,” from the interview and so are reported here. Table 17 displays teachers’ perspectives about the suggestions included in the textbook. Although Anna and Isla disagreed that the textbook provided good suggestions for the use of calculators, the other teachers agreed or strongly agreed the textbook provided good suggestions for the use of calculators.

In terms of suggestions for the use of graphing features of a calculator in the textbook, only Isla was neutral about suggestions for the use of graphing features. The other teachers agreed or strongly agreed the textbook provided good suggestions for the use of graphing features of a calculator. In terms of suggestions for the use of table features, only Anna thought the textbook did not provide good suggestions. Seven teachers (Brad, Carl, Duke, Ella, Fifi, Gina, and Isla) reported the textbook provided good suggestions for the use of table features. All except Fifi provided their perspectives about suggestions for the use of computer algebra systems in the textbook. Anna and Isla disagreed the textbook provided good suggestions, but six
Table 17. Teachers’ Perspectives about Calculators Suggestions Included in the Textbook.*

<table>
<thead>
<tr>
<th>Suggestions</th>
<th>Anna</th>
<th>Brad</th>
<th>Carl</th>
<th>Duke</th>
<th>Ella</th>
<th>Fifi</th>
<th>Hugo</th>
<th>Isla</th>
<th>John</th>
<th>Lane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use of calculators</td>
<td>D</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>SA</td>
<td>A</td>
<td>A</td>
<td>D</td>
<td>A</td>
</tr>
<tr>
<td>Graphing features</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>SA</td>
<td>A</td>
<td>A</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Table features</td>
<td>D</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Computer algebra system features</td>
<td>D</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>NA</td>
<td>N</td>
<td>A</td>
<td>D</td>
<td>N</td>
</tr>
</tbody>
</table>

*SA=Strongly agree, A=Agree, N=No opinion, D=Disagree, SD=Strongly disagree, NA=No answer

Teachers (Brad, Carl, Duke, Ella, Hugo, and Lane) agreed the textbook provided good suggestions for the use of computer algebra systems.

Table 18 summarizes the findings in the theme “Teachers’ Use of Graphing Calculators.”

Teachers’ Opinions about Students’ Use of Graphing Calculators

Table 19 indicates how teachers reported students used calculators in the FST class and is presented here because of its relation with the theme “teachers’ opinions about students’ use of graphing calculators.” All the participant teachers’ students used calculators for checking answers, doing computations, solving problems, graphing equations, making tables, and finding equations to model data. Only four teachers (Anna, Brad, Hugo, and Isla) had students use calculators to work with a spreadsheet. Interestingly, three of these four teachers (Brad, Hugo, and Isla) were at the medium level in terms of the IPAE index. Except for Fifi, all teachers had students use calculators to analyze data. Students in Anna’s, Brad’s, Carl’s, Duke’s, and Ella’s classes used calculators to simplify algebraic expressions. Anna’s, Carl’s, Duke’s, Ella’s, and Hugo’s students used other features of CAS, but those features were not specified. Anna, Duke, and Ella had a high level on the IPAE index. Anna also had students use calculators for “projects, using sliders for dynamic graph changes,” and Hugo had students use calculators to find exact trigonometric values.
<table>
<thead>
<tr>
<th>Support</th>
<th>Assessment</th>
<th>Topics</th>
<th>Instructional views</th>
<th>Purposes</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>manual showing the steps</td>
<td>no-calculator tests &amp; CAS not on ACT</td>
<td>statistics &amp; polynomials</td>
<td>spreadsheet features</td>
<td>explore &amp; do problem</td>
<td>daily</td>
</tr>
<tr>
<td>manual showing the steps</td>
<td>polynomials</td>
<td>emphasized symbolic ways</td>
<td>explore &amp; check</td>
<td></td>
<td></td>
</tr>
<tr>
<td>manual showing the steps</td>
<td>no-calculator tests &amp; TI-89s are allowed on SAT</td>
<td>trig functions</td>
<td>skipped some areas, such as finding roots &amp; get to the concept</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TI-84s are allowed on ACT</td>
<td></td>
<td></td>
<td>equations, graphs &amp; tables</td>
<td></td>
<td>daily</td>
</tr>
<tr>
<td>manual showing the steps &amp; in-service training</td>
<td>no-calculator as a part of tests</td>
<td>statistics &amp; trig functions &amp; polynomials</td>
<td>additional ways (algebraically and graphically)</td>
<td>check &amp; do problem</td>
<td>Gaily</td>
</tr>
<tr>
<td>manual showing the steps</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>manual showing the steps &amp; time</td>
<td>TI-84s are allowed on ACT and SAT</td>
<td>trig functions</td>
<td>skipped some areas, such as finding roots</td>
<td></td>
<td></td>
</tr>
<tr>
<td>manual showing the steps</td>
<td>no-calculator as a part of tests &amp; no graphing calculators on the exam</td>
<td></td>
<td></td>
<td>explore &amp; check</td>
<td></td>
</tr>
</tbody>
</table>

Table 18. Teachers' Use of Graphing Calculators.

Anna  Brad  Carl  Duke  Ella  Fifi  Gina  Hugo  Isla  John  Lane
Table 19. *Features of Graphing Calculators Teachers Reported Students Using.*

<table>
<thead>
<tr>
<th>Use</th>
<th>Anna</th>
<th>Brad</th>
<th>Carl</th>
<th>Duke</th>
<th>Ella</th>
<th>Fifi</th>
<th>Gina</th>
<th>Hugo</th>
<th>Isla</th>
<th>John</th>
<th>Lane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Checking answers</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Doing computations</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Solving problems</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Graphing equations</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Working with spreadsheet</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Making tables</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Analyzing data</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Finding equations to model data</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Simplifying algebraic expressions</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Other features of CAS</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
</tbody>
</table>

*Y=Yes, N=No

**Students’ reactions to using graphing calculators.** Teachers reported that their students in general liked the graphing calculators. Anna, Brad, Duke, Gina, Hugo, Isla, John, and Lane noted their students liked the graphing calculators. Specifically, Anna’s students got excited and liked mathematics with the TI-Nspire. Her students signed up for the next mathematics course that planned to use the same graphing calculator technology. Hugo said:

I think they’ve really liked it. There were a few small things I noticed, talking about how if there’s just small things where it’s “Oh wow, that’s so much easier now,” where I think they do understand the fundamentals but seeing this simpler way that might make it, so when we were talking about solving equations and they had never considered the idea of graphing an equation and finding where it crosses the axis and that’s your answer to it.

Many students in Duke’s, Gina’s, Isla’s, and Lane’s classes had difficulties or did not like the calculator at first. Although Gina did not use ClassPads at all, which were more sophisticated than she was used to, other teachers (Duke, Isla, and Lane) used the TI-89s received from UCSMP. Those teachers’ students also had a hard time at first using the new types of graphing calculators with CAS. For example, Duke said:
The first week they were not happy with the TI-89, because it was different and too hard but like I said, a lot of them want to keep it because it will solve the equations for them, and the 84 won’t do that, and it will give exact values for trig, and their 84 won’t do that. They realize their 89 will do some things that their 84 won’t. They like it.

Gina stated it was hard to even get students to bring their graphing calculators to class but eventually students were amazed with the graphing features of graphing calculators. After they used and learned more capabilities, they started to like graphing calculators. However, Carl and Ella explained their students did not like graphing calculators with CAS (TI-89s) at all.

**Effects of using graphing calculators on students’ learning.** Teachers’ perspectives on how helpful calculators were for students’ learning were also measured on the end-of-the-year questionnaire (see Table 20). Teachers’ responses are reported here because of the relation with the sub-theme “effects of using graphing calculators on students’ learning.” Carl and Ella indicated calculators were not very helpful for their students’ learning. Carl commented, “just gave answers, no understanding.” Four teachers (Brad, Duke, Isla, and Lane) reported those calculators were somewhat helpful for students’ learning, Anna, Fifi, Gina, and Hugo stated calculators were very helpful. Interestingly, three of those four teachers (Fifi, Gina, and Hugo) had a medium level on the IPAE index. Therefore, using graphing calculators and understanding the helpfulness of calculators for students’ learning may enhance teachers’ perspectives on using graphing calculators when they have a lower IPAE index level.

Teachers reported both positive and negative effects of using graphing calculators in terms of students’ learning. Anna, Duke, and Fifi reported graphing calculators positively affected students’ learning because they were able to find the answers for problems. Therefore,
Table 20. *Teachers' Perspectives about the Helpfulness of Graphing Calculators in Terms of their Students’ Learning.*

<table>
<thead>
<tr>
<th>Teachers</th>
<th>Anna</th>
<th>Brad</th>
<th>Carl</th>
<th>Duke</th>
<th>Ella</th>
<th>Fifi</th>
<th>Gina</th>
<th>Hugo</th>
<th>Isla</th>
<th>John</th>
<th>Lane</th>
</tr>
</thead>
<tbody>
<tr>
<td>How helpful are calculators for students’ learning</td>
<td>V</td>
<td>S</td>
<td>N</td>
<td>S</td>
<td>N</td>
<td>V</td>
<td>V</td>
<td>V</td>
<td>S</td>
<td>NA</td>
<td>S</td>
</tr>
</tbody>
</table>

*V=Very helpful, S=Somewhat helpful, N=Not very helpful, NA=No answer

teachers were able to include better questions, and students were able to talk more about the essence of the problems. Duke said:

In a positive way, we are able to get past, we don’t spend a lot of time doing calculations; we spend a lot of time talking about the essence of the problem and the concepts of the problem. The technology helps us get to those concepts a lot quicker, I wouldn’t go back, I wouldn’t trade it. There will be struggle at times with some algebra I skills.

Hugo commented using graphing calculators brought not only graphing but also deeper understanding, which was truer learning. Fifi and Gina noted the visualization opportunities of graphing calculators were better for students. Gina said:

I think it helps them immensely being able to see visually solutions to trig equations for example. I think, if we talk about the CAS. If we don’t do much with patterns, and I would like to do more with that, and I think that’s where the CAS is really being helpful, like that pattern we did yesterday. Something like that that’s simple to show. More complex things, we really need the CAS.

Fifi also talked about teaching mathematics with graphing calculators for certain things instead of by hand:

I do like it. I think it saves us time. If I wanted to show a graph and I had to do it by hand, they’d get one graph in. Now I can pop off a half dozen of them in five minutes and they
can compare and contrast the different things. It allows them to explore, to check their work. If they get an answer and think it’s right they can go back and see where it fits on the graph.

In contrast, Carl and Fifi also stated negative effects of graphing calculators for students’ learning. Carl said meanings were missing because students did not interpret their answers when they used graphing calculators. Fifi also said, “I would say the students don’t know what to think anymore; they reply more on the graphing calculator and the technology. So, the aspect of figuring it out by themselves without a calculator, for them they can’t do it.”

**Effects of graphing calculators on students’ skills.** The most common topic talked about by teachers in terms of the topics students could not do well as regards the use of graphing calculators was students’ arithmetic skills. Anna, Carl, Duke, Ella, Fifi, Gina, John, and Lane indicated their students’ arithmetic skills were affected negatively because they had access to the graphing calculators. Interestingly, Anna, Duke, Ella, John, and Lane had a high level on the IPA£ index. Specifically, they pointed out adding, multiplying, and converting fractions to decimals were the skills affected most negatively because of the usage of graphing calculators. Ella said: “Our arithmetic skills, our fifth-grade math skills are below par. Simple things like adding fractions and when you get common denominators. Converting back and forth between fractions, decimals. Those definitely need improvement.” However, only Isla mentioned her students could “add signed numbers better” because of the use of graphing calculators.

Two teachers (Hugo and John) stated their students’ graphing skills were affected positively by graphing calculators. John said “The type of problems I think, graphing. Graphing is a big one. Graphing by hand is a skill that I don’t think they have. We use the calculator that gives them that skill.” Hugo and John also commented their students could solve equations better
with graphing calculators. Anna and Ella commented their students could solve problems better because they had access to graphing calculators. Anna said:

I think they can attack a problem better and just attacking a problem, not being afraid to attack a problem. Cause they’ll play. They will literally play with everything that they’ve got in their hands. I keep telling them “You have the most powerful calculator in the world. Don’t ever tell me you didn’t attack a problem.” And they’re really good about that. They will try something and I think that’s a part of UCSMP as well. UCSMP is helping, from that point of view. I think that’s probably the main thing and I’m getting them to like the mathematics, certainly makes polynomials more interesting.”

Brad, Duke, Fifi, and Isla indicated their students could analyze data better by using graphing calculators with CAS. Duke said:

Well, I do think they can do way better. They can actually start to deal with data and think about the ideas in it. And, they just analyze the data or in modeling, that if they didn’t have the technology we wouldn’t even be talking about it. I mean, the computation would be too involved, and there would be too much of a cognitive load before they ever got to the pay-off. And it just wouldn’t be a high school topic. So anything that has to do with analyzing data and modeling, it’s something that they can get an idea about, and they can start thinking about and gaining some understanding of, but if they had to do it on their own with paper and pencil, it wouldn’t even be in the curriculum. And they wouldn’t have an idea. And they need to have those ideas because when they get to college, all the stuff, analyzing data is everywhere. Any discipline that’s trying to do anything that imitates science.
**Students’ dependency on the graphing calculators.** Teachers’ usage of graphing calculators may cause students to depend on them. Teacher interviews documented that students’ dependency on the graphing calculators was a big issue in terms of using graphing calculators. Therefore, I generated this sub-theme, defining teachers’ ideas about students’ dependency on graphing calculators in the course and their daily life. Anna, Ella, Fifi, John, and Lane stated their students relied on the graphing calculators too much. All those five teachers, except Fifi, were at the high level in terms of their IPAЕ index. For instance, Anna, who reported her students used graphing calculators and CAS daily, said:

> Uh, yeah. I think they’re relying on it more than ever and I’m not too sure how big of a negative that is, how grave a negative. But there is more reliance cause they’re using it more. That’s just kind of a natural flow.

John, whose students also used graphing calculators daily said:

> Negatively [in terms of technology influence], by it gives them too much of a crutch sometimes, they are depending on the calculator doing their thinking. So when they are working with the calculator, they rely too much on the calculator run and feel the calculator can do anything but it can’t think for them so you have to set them straight.

Ella and Fifi emphasized graphing calculators made life easier and students had access to graphing calculators everywhere in their daily life. Table 21 summarizes findings in the theme “teachers’ opinions about students’ use of graphing calculators.”

**Teachers’ Issues with Graphing Calculator Technology**

Teachers faced some difficulties when they used graphing calculators and addressed those issues during the interviews. The most common issue was the liability issue of the graphing calculators sent by UCSMP to loan to students. Teachers were responsible for those loaned
Anna, Carl, Fifi, Gina, Isla, and John reported keeping graphing calculators in good condition was difficult for their students. Anna said, “There are some issues because of the brand new calculators [the Nspires] and the prototypes that probably won’t repeat themselves and it is they break down, things don’t work, they eat batteries, they get lost.” Carl said: “I’m Table 21. Teachers’ Opinions about Students’ Use of Graphing Calculators.

<table>
<thead>
<tr>
<th>Teachers</th>
<th>Anna</th>
<th>Brad</th>
<th>Carl</th>
<th>Duke</th>
<th>Ella</th>
<th>Fifi</th>
<th>Gina</th>
<th>Hugo</th>
<th>Isla</th>
<th>John</th>
<th>Lane</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reactions</strong></td>
<td>Like</td>
<td>Like</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Learning</strong></td>
<td>Able to find the answers for problems &amp; Visualization &amp; Do not know what to think anymore</td>
<td>No interpretation</td>
<td>Able to find the answers for problems &amp; Visualization</td>
<td></td>
<td>Able to find the answers for problems &amp; Visualization</td>
<td></td>
<td>Able to find the answers for problems &amp; Visualization</td>
<td></td>
<td>Able to find the answers for problems &amp; Visualization</td>
<td></td>
<td>Able to find the answers for problems &amp; Visualization</td>
</tr>
<tr>
<td><strong>Skills</strong></td>
<td>Arithmetic skills negatively &amp; Problem solving positively</td>
<td>Data analyzing positively</td>
<td>Arithmetic skills negatively &amp; Problem solving positively</td>
<td>Data analyzing positively</td>
<td>Arithmetic skills negatively &amp; Data analyzing positively</td>
<td>Data analyzing positively</td>
<td>Arithmetic skills negatively &amp; Data analyzing positively</td>
<td>Data analyzing positively</td>
<td>Arithmetic skills negatively &amp; Graphing &amp; solving equations positively</td>
<td>Data analyzing positively</td>
<td>Arithmetic skills negatively</td>
</tr>
</tbody>
</table>

88
going to be fighting kids to pay. I’m hearing the word is that I’m going to be paying the bill for
calculators.” Those teachers worried about the cost of graphing calculators and who was
responsible to pay the cost for missing calculators. In addition, that issue might be a reason for
teachers to avoid loaning the graphing calculators with CAS provided by UCSMP because the
teachers (Fifi, Gina, and John) who mentioned liability issues did not loan the graphing
calculators with CAS.

Another issue was related to cheating or using features that minimized the mathematics.
Gina brought up cheating as an issue that graphing calculators conveyed:

Well, we always have the issue of cheating and test security of course. What I do is I
reset the memories on calculators after a test they have taken if they use their calculator.

Some teachers do it before, too.

Anna stated the “solve” command could be an issue because with that feature students could
solve some problems just by clicking the button:

But what was the first method in every single class? The solve command. Every single
class, the first group went straight to the solve command. So, you know, I can’t blame
them. Some of that manipulative skill I think has fallen. I don’t really mind it so much.

They know that they can solve it.

John found his students used graphing calculators even for simple calculations.

A third issue was not being familiar with the type of graphing calculators loaned from
UCSMP. Especially, the combination of graphing calculator technology usage with a new book
was challenging for some teachers (Isla and John). John said: “It’s difficult when you’re using a
new book and new technology if you are not familiar with the technology to do both. I would be
selfish and say I’d rather have other things I do.” Table 22 summarizes findings in the theme “teachers’ issues with graphing calculator technology.

Table 22. Teachers’ Issues with Graphing Calculator Technology.

<table>
<thead>
<tr>
<th>Teachers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anna</td>
</tr>
<tr>
<td>Brad</td>
</tr>
<tr>
<td>Carl</td>
</tr>
<tr>
<td>Duke</td>
</tr>
<tr>
<td>Ella</td>
</tr>
<tr>
<td>Fifi</td>
</tr>
<tr>
<td>Gina</td>
</tr>
<tr>
<td>Hugo</td>
</tr>
<tr>
<td>Isla</td>
</tr>
<tr>
<td>John</td>
</tr>
<tr>
<td>Lane</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liability &amp; Minimized mathematics</td>
</tr>
<tr>
<td>Liability &amp; Minimized mathematics</td>
</tr>
<tr>
<td>Liability</td>
</tr>
<tr>
<td>Liability &amp; Cheating</td>
</tr>
<tr>
<td>Liability &amp; Overwhelming</td>
</tr>
<tr>
<td>Liability &amp; Simple calculations &amp; Overwhelming</td>
</tr>
</tbody>
</table>

**Index of Teachers’ Use of Graphing Calculators**

Table 23 reports teachers’ index and levels of graphing calculator usage throughout the year. The minimum score was five and the maximum score was 52 in this index of teachers’ use of graphing calculators; scores were categorized into three levels by dividing the scale into thirds with five-20 considered low use, 21-36 considered medium use, and 37-52 considered high use. Gina, Isla, John, and Lane had a medium use of graphing calculators; the other seven teachers were high in terms of their use of graphing calculators.

Table 23. Index of Teachers’ Use of Graphing Calculator Level over Course of Year.*

<table>
<thead>
<tr>
<th>Teachers</th>
<th>Anna</th>
<th>Brad</th>
<th>Carl</th>
<th>Duke</th>
<th>Ella</th>
<th>Fifi</th>
<th>Gina</th>
<th>Hugo</th>
<th>Isla</th>
<th>John</th>
<th>Lane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use of graphing calculator</td>
<td>41</td>
<td>41</td>
<td>40</td>
<td>45</td>
<td>38</td>
<td>44</td>
<td>34</td>
<td>40</td>
<td>31</td>
<td>32</td>
<td>34</td>
</tr>
<tr>
<td>Teacher’s level</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>M</td>
<td>H</td>
<td>M</td>
<td>M</td>
<td>M</td>
</tr>
</tbody>
</table>

* Minimum score=5, Maximum score=52

Comparing teachers’ initial perceived attitude and experience index and teachers’ summary use of graphing calculators index shows six teachers’ use of graphing calculators during the year did not match with their initial perceived attitude and experience. Brad, Carl,
Fifi, and Hugo, who were at the medium level based on their initial perceived attitude and experience index, showed high use during the year. Interestingly, John and Lane, who showed medium use over the course of year based on the index, were at the high level on the initial perceived attitude and experience index.

**Summary**

In this chapter, I exhibited the results of teachers and classroom demographics and teachers’ initial perspectives on their attitude and experience index based on their responses on the beginning-of-year teacher questionnaire. In addition, I also presented the teachers’ perspectives on using graphing calculators during the course based on the end-of-year teacher questionnaire, teacher interviews and chapter evaluations. I also compared their initial perceived attitude and experience index and their use of graphing calculators index.
CHAPTER FIVE: DISCUSSION, IMPLICATIONS, AND LIMITATIONS

In this study, I used both qualitative and quantitative approaches to investigate perspectives on eleven UCSMP teachers who taught an FST course regarding the use of graphing calculators. Specifically, I answered the following research questions:

1. In what ways do eleven teachers use graphing calculators in an 11th-grade Functions, Statistics, and Trigonometry course?

2. What are eleven teachers’ perspectives on student learning when students use graphing calculators in an 11th-grade Functions, Statistics, and Trigonometry course?

3. What are eleven teachers’ perspectives on their teaching an 11th-grade Functions, Statistics, and Trigonometry course using graphing calculators?

To respond to the research questions, I used data gathered through different data collection tools. Teachers completed beginning-of-the-year teacher questionnaires and end-of-the-year teacher questionnaires, as well as chapter evaluation forms for every chapter they taught. Their responses to those items were analyzed in terms of the research questions. Dr. Denisse Thompson, Director of Evaluation, interviewed teachers about the UCSMP curriculum to gain information about the class, to understand how UCSMP (specifically FST) was working in that class and school, and to investigate teachers’ views on their lessons and their use of graphing calculators. I analyzed the interviews using thematic analysis. In this chapter, I discuss my results in comparison with other studies, present implications based on my findings, and give suggestions for future research. I also state the limitations of the study.
Summary of Findings

Teachers’ interview responses resulted in the creation of several sub-themes. Although not all teachers made comments in all themes, Table 24 indicates sub-themes mentioned by at least half of the teachers who were at the medium or high level on their IPAE index. Thus, teachers at both the medium and high index levels reported their students liked graphing calculators used in their classes over the school year within the sub-theme “students’ reactions to using graphing calculators.”

Teachers who were at the medium level based on the IPAE index typically mentioned the liability issues for their students for the loaned graphing calculators from UCSMP. Teachers at that level also indicated their students were impacted positively in analyzing data because of the graphing calculators. However, those teachers also reported they needed a manual for the graphing calculators with CAS loaned from UCSMP and wanted a manual showing how the new graphing calculators work with step-by-step instructions.

Teachers at the high level based on the IPAE index reported they used no calculator tests or questions as a part of their testing process, either as an entire no-calculator test or a test on which some portion did not allow calculators. In addition, they generally discussed issues related to those types of graphing calculators being allowed on external exams, such as the ACT or SAT. Teachers at the high IPAE index level had concerns about their students’ dependency on graphing calculators. In addition, all teachers who were at the high index level commented their students’ arithmetic skills were affected negatively by the presence of graphing calculators.

Discussion

The results from teachers’ responses to the interviews showed some agreement with the literature in terms of teachers’ use of graphing calculators for exploration purposes. Teachers’
Table 24. Overall Thematic Analysis Results Based on Teachers’ IPAЕ Index.

<table>
<thead>
<tr>
<th>Sub-themes from teachers’ responses</th>
<th>Teachers’ level based on IPAЕ index</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Medium ($n = 6$)</td>
</tr>
<tr>
<td></td>
<td>High ($n = 5$)</td>
</tr>
<tr>
<td>Issues of using graphing calculators$^a$</td>
<td></td>
</tr>
<tr>
<td>Using graphing calculators in assessments</td>
<td></td>
</tr>
<tr>
<td>Teacher support needed in terms of graphing calculator technology$^b$</td>
<td></td>
</tr>
<tr>
<td>Students’ reactions to using graphing calculators</td>
<td></td>
</tr>
<tr>
<td>Effects of graphing calculators on students’ arithmetic skills$^c$</td>
<td></td>
</tr>
<tr>
<td>Effects of graphing calculators on students’ analyzing data skills$^d$</td>
<td></td>
</tr>
<tr>
<td>Students’ dependency on the graphing calculators</td>
<td></td>
</tr>
</tbody>
</table>

Shaded areas indicate at least half of the teachers mentioned the sub-theme. $^a$Liability was the issue here. $^b$A manual showing how to use the graphing calculator step-by-step. $^c$Negative effects occur on students’ arithmetic skills. $^d$Positive effects occur on students’ analyzing data skills.

Responses showed agreement with ideas instructional and communication technology provide “dynamic and visual tools to explore mathematics in shared space” (Computer Algebra Systems in the Mathematics Curriculum, 2008, p. 7) and “engages students with interactive explorations” (Roschelle & Singleton, 2008, p. 954).

Some teachers’ comments about the use of multiple representations were consistent with research that indicates graphing calculators enable students to examine “the related meanings of a concept through the display of multiple representations” (Roschelle & Singleton, 2008, p. 954). In addition, teachers’ comments about the advantages of using graphing calculators to lessen number crunching so the focus of teaching can be on concepts and conceptual understanding are similar to the work of Kendal et al. (2004) and Huntley et al. (2000), who found teachers could cope with calculation problems in instruction by using graphing calculators. Similar to teachers in the study by Hégedus and Kaput (2004), teachers in my study perceived graphing calculators as being able to help students have better understanding of the concepts.

Teachers’ views were consistent with those by Leng (2011) in terms of their perspectives on using graphing calculators because of the visual opportunities they bring. Similarly, teachers’ usage of graphing calculators for checking purposes agrees with roles identified by Doerr and
Zangor (2000) and with the result of “giving students more responsibility for checking their work and justifying their solutions” by Roschelle and Singleton (2008, p. 954).

Teachers’ responses were also similar to those by Ertmer et al. (1999) as students got excited and motivated when they used graphing calculators. For instance, teachers and students found polynomials were more interesting with graphing calculators even though a specific reason was not stated. However, some teachers in the study indicated concerns about student learning with graphing calculators in terms of missing meanings of the concepts, which is not an issue frequently encountered in the literature.

Teachers in the study typically commented the textbook suggested good examples for using graphing calculators, particularly graphing, table, and computer algebra system features. However, Anna, who was at the high level on the index of teachers’ use of graphing calculators over the course of year, disagreed the textbook suggestions were good for usage of graphing calculators, table, and computer algebra system features. That teacher used graphing calculators at a high level over the year, perhaps because of her high initial perceived attitude and experience level index. Anna also remarked the graphing calculator activities included in the textbook should have more exploration for students, similar to a recommendation by Almekhlafi and Almeqdadi (2010). Therefore, Huntley et al.’s (2000) idea that absence of supported curriculum materials may hinder the usage of graphing calculators was not supported by this teacher.

Teachers also indicated their need for professional development programs to be able to use the graphing calculator more effectively in their lessons. This was similar to Almekhlafi and Almeqdadi’s (2010) suggestion about planned periodic professional development for more effective technology integration.
Brinkerhoff (2006), ChanLin et al. (2006), and Lumb et al. (2001) pointed out lack of time for teachers to prepare as an institutional and administrative barrier. Similarly, some teachers in this study stated they needed time to prepare and play to figure out the features of the CAS-capable graphing calculators loaned by UCSMP.

Some teachers encountered the issue of different types of graphing calculators allowed on external exams (ACT and SAT) than the ones they used in class. Interestingly, teachers in my study did not mention the size of graphing calculator screens as a drawback. However, Kendal et al. (2004) stated graphing calculator screens are too small for students to see each other’s work. In addition, teachers did not state the length of their instructional time as a drawback to integrating graphing calculators in their teaching. However, Leng (2011), and Lee and McDougall (2010) emphasized this issue in their studies.

The literature typically includes quantitative studies to compare students’ achievement by those who used graphing calculators and those who did not use graphing calculators in their mathematics courses. Many of these studies compared students’ achievement at the levels of Algebra I and II. Some studies have examined teachers’ beliefs or perspectives on using graphing calculators in high school mathematics courses, and some of these studies have measured teachers’ perspectives on using graphing calculators with questionnaires or surveys. However, few studies have investigated teachers’ perspectives on using graphing calculators with a detailed analysis using qualitative or mixed methods. Furthermore, many of the studies are about teachers’ perspectives on using graphing calculators in Algebra I and II courses. Additionally, the number of participants in those studies was small, typically from one to six. Only a limited number of studies with participants who taught a precalculus course in high school have been conducted to examine teachers’ perspectives on using graphing calculators.
Therefore, this study adds to the literature by using a large number of teachers (11) who taught a precalculus course and studying their perspectives on using graphing calculators, with or without CAS.

**Implications**

First, the findings of the present study may inform teacher educators about the need for teacher development programs for teachers in terms of using graphing calculators. They might create professional development programs for teachers who are supposed to use technology in their instruction, especially when they are supposed to use a new technology with which they are not familiar. They might consider using the IPAE index to measure teachers’ first perspectives on using graphing calculators, with or without CAS. Teacher educators can then suggest different types of professional development programs for teachers. For instance, teacher educators might create professional development programs for teachers who are not at the high IPAE level index, including detailed workshops about unfamiliar features of graphing calculators. It might be beneficial for these teachers to see step-by-step procedures to use graphing calculators appropriately. In other words, teachers should understand thoroughly the features of the technology and how it works. Then, there might be additional workshops about how teachers can use this technology efficiently, including with actual classroom examples showing how they can apply this technology for the topics they teach.

Professional developers might also give teachers suggestions about the frequency of using graphing calculators and solutions for possible ways to help students become less dependent on the graphing calculator. For instance, workshops might incorporate different types of activities, suggesting situations in which graphing calculators might be used and other situations where they might not be allowed. In other words, there might be appropriate sample
activities for conceptual understanding with graphing calculators, activities to apply either with or without calculator usage, and activities for procedural understanding without graphing calculators. Furthermore, teachers can take advantage of comparing these types of activities and understand the essence of using graphing calculators. Additionally, teacher educators might consider presenting different roles of graphing calculators, such as “computational, transformational, data collection and analysis, visualization, checking” (Doerr & Zangor, 2000) with appropriate activities. Thus, teachers might have a chance to incorporate graphing calculators for purposes other than computation.

Teacher educators can also consider the results of this study in terms of assessment processes. Teachers who were at the high level based on the IPAE index showed they used either an entire no-calculator test or a test on which some portion did not allow calculators. However, teachers who were at the medium level based on the IPAE index did not mention the assessment process. Therefore, after the teachers experience how to use graphing calculators and integrate them in their lesson, it might be beneficial to discuss how to apply their understanding of using graphing calculators in their assessment process. Teachers who do not have a firm understanding of using graphing calculators for assessment might take additional workshops where teachers can create both tests with graphing calculators and no-calculator tests and discuss issues for the nature of mathematics when technology might be limited.

Furthermore, with graphing calculators it might also be possible for students to give answers to questions without thinking. Teacher educators can include workshops illustrating activities to improve students’ conceptual understanding. Thus, teachers can become proficient and knowledgeable about using graphing calculators more effectively in their lessons.

Textbook developers might benefit from teachers’ comments about more exploration
activities with graphing calculators, especially with CAS. In other words, curriculum developers might design activities, including integration of CAS features and exploration for students. In addition, curriculum developers might consider external exams which do not allow certain types of graphing calculators. Therefore, they might include different types of graphing calculators for different types of questions based on the goals of the activities. Furthermore, they might consider creating two-chapter tests. The first chapter might be for more explorations and conceptual understanding of core concepts with open-ended questions allowing the use of more developed graphing calculators with CAS, such as the TI-Nspire. The second chapter might be for exams with the type of graphing calculators allowed in these exams (TI-83, TI-84). In this way, both teachers and students have opportunities to use different types of graphing calculators for different purposes.

**Suggestions for Further Research**

This study aimed to examine teachers’ perspectives on using graphing calculators in a high school precalculus course. Therefore, data in this study were collected only from the teachers. If I conducted the study again, I would consider making some changes in the study. It would be useful to collect similar data from students to compare students’ opinions with teachers’ opinions about using graphing calculators. It would give another lens to investigate and understand the usage of graphing calculators in advanced mathematics courses. Although some student perspectives were collected as part of the evaluation study of FST, such data were not available as part of this dissertation study. In the literature, the administrators’ perspective is also mentioned as a possible effect on teachers’ use of graphing calculators. Therefore, it would be useful to interview school administrators to investigate how their perspectives on using graphing calculators in precalculus courses affect teachers’ use of graphing calculators.
In addition, the data were based on teachers’ responses and opinions reported on the questionnaires, chapter evaluation forms, and interviews. Classroom observations might bring more information to understand teachers’ perspectives on using graphing calculators and how they apply their perspectives to their teaching. A framework including the purposes for which graphing calculators are used, how frequently students use graphing calculators, and how students interact with graphing calculators might be useful information to provide a detailed understanding of graphing calculator usage in precalculus courses.

The results showed some teachers’ initial perspectives and experience level as measured by the IPAЕ index and their use of graphing calculators index throughout the year were not at the same level. For further research, it might be useful to understand the possible reasons for these differences by interviewing teachers both at the beginning of the school year and at the end of the school year. Furthermore, it is possible to gain more understanding of how teachers experienced teaching the course with graphing calculators by asking more detailed interview questions, such as (1) For what purposes did you use graphing calculators mostly?, (2) How did you use graphing calculators for the topics of functions, trigonometry, and statistics, and why?, (3) What roles of graphing calculators did you use for functions, trigonometry, and statistics topics?, (4) Why did you prefer to use graphing calculators?, (5) How did you use multiple representations for functions, trigonometry, and statistics topics, and what were some of the advantages?, (6) Should your students solve problems with graphing calculators or by paper and pencil? Why?, (7) Is it possible to save time by using graphing calculators or do you need more class time to use graphing calculators appropriately? Why?, (8) In what ways did your thoughts about using graphing calculators change during the course?, (9) What type of problems do you and your students use graphing calculators to solve?
Furthermore, teachers’ perspectives on using graphing calculators with CAS can be examined with more detailed questions and these perspectives can be compared with their perspectives on using graphing calculators without CAS. For instance, researchers might investigate which CAS features teachers used most often, for which topics teachers use CAS features frequently, how they allow their students to use those features in assessment, and what kinds of CAS features are helpful in the assessment process. Therefore, it might be possible to determine if there are any differences in perspectives between teachers who use graphing calculators with CAS and those who use graphing calculators without CAS.

Additionally, further research can investigate how teachers’ initial perceived attitude and experience (IPAE) index affect students’ achievement during the FST course. This can be examined by comparing student achievement from teachers at the medium and high level based on their IPAE index. Then, students’ achievement can be examined based on teachers’ perspectives on using graphing calculators over the year.

Another possible area for further research is teachers’ initial perspectives (before the course) and final perspectives (after the course) of using graphing calculators and comparing those results with their students’ initial perspectives and final perspectives on using graphing calculators. It might be good to see the impact of teachers’ perspectives on students’ perspectives on using graphing calculators.

**Limitations of the Study**

This study had some limitations. First, I used existing data from an evaluation study conducted for the UCSMP. The nature of the data had a broad sense about the FST course and also graphing calculator use. For instance, all the data collection items I used for this study were created to gain information from teachers about the FST course as a whole, with limited but not
extensive data collected about their graphing calculator usage. However, if I had interviewed the teachers for the purpose of only investigating their perspectives on graphing calculator usage, I might have asked different questions or focused in more detail on issues about graphing calculator usage. Therefore, it might have been possible to produce more themes and sub-themes as well as a deeper understanding of teachers’ perspectives about using graphing calculators in high school precalculus courses. In addition, I could have ensured I obtained responses about all issues of interest from all teachers.

The data were collected in the 2007-2008 school year. However, UCSMP textbooks are still used in mathematics classrooms and the issues related to graphing calculators have not changed much during these years. Although I did not personally collect the data, I have informally analyzed similar data for another course and am familiar with the structure of the data.

Another limitation of this study might be the data collection method. Teachers bring their perspectives on using graphing calculators in the beginning- and end-of-year teacher questionnaires, teacher interviews, and chapter evaluation forms. I analyzed the data based on teachers’ responses to those instruments. Although there was triangulation among the data collection tools, using more data collection instruments might have helped to gain a deeper understanding of teachers’ perspectives on using graphing calculators.

I analyzed teacher interviews based on thematic analysis, during which I paid equal attention to each teacher. However, researcher subjectivity is one of the main characteristics of qualitative studies. My personal background, experience, teaching perspective, and subconscious personal and professional biases related to using graphing calculator technology might have influenced my view of the data. According to Tappan and Brown (1992), hermeneutic
considerations “indicate that the same text can be read [and interpreted] in a number of different ways” (p. 186). Therefore, a different researcher might reach a different conclusion from what I drew in this study.

Another issue for the UCSMP project was the loaner graphing calculators. Schools were responsible for the graphing calculators received from UCSMP and teachers typically talked about the liability issues of the loaned calculators. This might be a negative issue for teachers, especially those who teach in low socio-economic areas. Project directors should consider that issue for use of graphing calculators with CAS in the future.
REFERENCES


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APPENDICES

Appendix A: Teacher Interview Protocol

Teacher Interview Protocol: 2007-2008

Teacher Name (Code) ______________________
School ______________________
Curriculum ______________________
Date ______________________
Interviewer ______________________

The purpose of this interview is
(1) to clarify and confirm information about the class that we have obtained thus far from you or from the district,
(2) to check to see how things are going,
(3) to answer any questions you may have about the study, or in the case of UCSMP teachers about the curriculum,
(4) to probe for additional insights related to the lessons or classes observed, and
(5) to probe for information about how features of the curriculum are being used.

I would like to audio-tape the interview if you don’t mind. Do you agree to be audio-taped?
1. a. Where does this class fit within the mathematics program at the school? That is, are there other courses that students at this grade level can take? (Probe for whether this class is at the high end, typical, at the low end, etc. Probe for what courses students had last year.)
   b. What courses might students take next year?
2. How were students assigned to this course? (Probe for random assignment, etc. If the teacher does not know, try to find out what individual at the school might know.)
3. What things would you most like students to learn from this course this year? (Probe for specific content if the teacher does not mention specific topics.)
4. How does the year seem to be going thus far? (Probe for any special issues, challenges, problems that have arisen.)
5. a. To what extent was the class period that I observed typical of your classes at this level this year? (If not typical, probe for differences.)
   b. (If the teacher has several sections of the same course) How does the class I observed compare to other sections of the same course that you teach? (Probe for whether the class is about the same, higher, or lower.)
   c. Describe your typical classroom structure in terms of how students work. (Probe for teacher directed lesson, students working in small groups, students working on activities, etc.)

6. I would like to discuss instructional practices related to the use of your curriculum materials.
   a. What are your expectations for students to read the text? (Depending on the response, 
      probe for how they handle reading, the reading level, the difficulty of reading, any other 
      issues related to reading, etc.)
   b. Discuss your expectations to have students write about mathematics. (Depending on 
      response, probe for the level of support for this activity that is in the text, frequency of writing 
      expectation, any other issues.)
   c. What are your expectations for homework? (Probe for amount of time, frequency, how 
      homework influences students’ grades, etc.)
   d. How do you determine which of the problems you assign for homework?
7. I would now like to discuss some specifics about the features of your curriculum materials.
   a. Describe how you use the end of chapter materials in your book. (e.g., SPUR Review, 
      Self Test, or equivalent)
   b. (For UCSMP Third Edition teachers) How have you used the activities embedded in the 
      curriculum materials? (Probe for student reactions, frequency of use, reasons for using or not 
      using, etc.)
   c. How have you used the Guided Examples? (Probe for student reactions, frequency of 
      use, reasons for using or not using, etc.)
8. We have asked you about the use of technology on the chapter evaluation/coverage forms as 
   its use relates to that chapter. (Ask this question depending on technology responses to the form, 
   possibly asking this question only of UCSMP Third Edition teachers.)
   a. What kind of technology is available to students in this class?
   b. (Depending on response to 8a) In what ways are you using the available technology?
   c. (Depending on the response to 8a) In a broad sense, how has the presence of calculator 
      technology influenced how you have approached the course? (Probe for influence on both 
      content taught and instructional strategies. Probe for differences due to graphing calculator 
      technology compared to scientific calculators.)
   d. What issues, if any, have arisen because of the presence of the technology?
   e. How have your students responded/reacted to the technology integration?
   f. To what extent has the use of technology influenced students' learning of mathematics? 
      (Probe for positive and negative influences for the types of technology available, including 
      graphing calculator, CAS, spreadsheets, geometric drawing tool, fraction calculator, etc.)
   g. What, if anything, can your students do well because they have the technology that they 
      would not be able to do without it?
   h. What, if anything, can your students not do well because they have had access to the 
      technology?
   i. (Perhaps to be asked only of UCSMP field-test teachers) What, if anything, have you 
      expected in terms of technology that is not present in the materials?
   j. (Perhaps to be asked only of UCSMP field-test teachers) What, if any, additional teacher 
      support would you have liked related to technology? (In particular, probe for issues related to 
      presence of graphing calculator technology.)
9. (For UCSMP FST or PDM Third Edition teachers who have taught from the Second Edition)
      expectations, prerequisite knowledge, etc.?
b. How would you compare the beginning of this year with UCSMP with the beginning of previous years?

10. What questions or comments do you have about the study we are conducting?

Thank you very much for your time.

Appendix B: University of Chicago School Mathematics Project

Mathematics Study 2007-2008

Functions, Statistics, and Trigonometry Teacher Questionnaire #1

Name ____________________________________________ Male___ Female___
School ______________________________________________
Email ________________________________________________
Phone number _______________________________________

1. Education
   Degree(s)          Major(s)                  Minor(s) (if any)
   ____________________       _________________ ______________     ___________________________
   ____________________       _________________ ______________     ___________________________
   ____________________       _________________ ______________     ___________________________

2. List your teaching certifications. (e.g., Mathematics 7-12)

3. Teaching experience
   Number of years teaching prior to this year
   Number of years teaching mathematics prior to this year
   Number of years teaching at present school prior to this year

4. a. Name of the course involved in this study
   b. Please check one of the following:
      ____ UCSMP Third Edition Teacher
      ____ UCSMP Second Edition Teacher
      ____ Other (Please specify the text you are using. ____________________________)
      If teaching from a non-UCSMP text, please attach a copy of the title page, the back of the title page containing the copyright information, and a Table of Contents.
   c. Number of years teaching this course prior to this year
   d. Number of years using a UCSMP text for this course prior to this year

5. How many minutes does this class meet each day?
   M _______ Tu _______ W _______ Th _______ F _______

6. Think about your plans for this mathematics class for the entire year. How important to you in your teaching are each of the following?

   Circle one: Of little importance, Somewhat important, Quite important, or Of highest importance.

   a. Increase students’ interest in mathematics
      Of little importance Somewhat important Quite important Of highest importance
   b. Help students learn mathematical concepts
      Of little importance Somewhat important Quite important Of highest importance
   c. Help students learn mathematical algorithms/procedures
      Of little importance Somewhat important Quite important Of highest importance

d. Help students learn to read mathematics  
   Of little importance  Somewhat important  Quite important  Of highest importance

e. Help students learn to read (non-textbook) mathematics-related materials  
   Of little importance  Somewhat important  Quite important  Of highest importance

f. Help students learn how to solve problems  
   Of little importance  Somewhat important  Quite important  Of highest importance

g. Help students learn to reason mathematically  
   Of little importance  Somewhat important  Quite important  Of highest importance

h. Help students learn how mathematics ideas connect with one another  
   Of little importance  Somewhat important  Quite important  Of highest importance

i. Prepare students for further study in mathematics  
   Of little importance  Somewhat important  Quite important  Of highest importance

j. Help students understand the logical structure of mathematics  
   Of little importance  Somewhat important  Quite important  Of highest importance

k. Help students learn to explain ideas in mathematics effectively  
   Of little importance  Somewhat important  Quite important  Of highest importance

l. Help students learn how mathematics ideas connect with one another  
   Of little importance  Somewhat important  Quite important  Of highest importance

m. Help students prepare for standardized tests  
   Of little importance  Somewhat important  Quite important  Of highest importance

n. Help students learn to use a graphing calculator as a tool for learning mathematics  
   Of little importance  Somewhat important  Quite important  Of highest importance

o. Help students learn to use a symbolic manipulator as a tool for learning mathematics  
   Of little importance  Somewhat important  Quite important  Of highest importance

p. Help students learn to use a computer as a tool for learning mathematics  
   Of little importance  Somewhat important  Quite important  Of highest importance

7. Think about your plans for this mathematics class for the entire year. About how often do you plan to do each of the following in your mathematics instruction?

   Circle one: Almost Never, Sometimes (once or twice a month), Often (once or twice a week), or Almost All Mathematics Lessons.

   a. Introduce content through formal presentations  
      Almost never  Sometimes  Often  Almost all

   b. Pose open-ended questions  
      Almost never  Sometimes  Often  Almost all

   c. Have students listen and take notes during presentations by the teacher  
      Almost never  Sometimes  Often  Almost all

   d. Engage the whole class in discussions  
      Almost never  Sometimes  Often  Almost all

   e. Require students to explain their reasoning when giving an answer  
      Almost never  Sometimes  Often  Almost all

   f. Have students work in small groups  
      Almost never  Sometimes  Often  Almost all

   g. Have students engage in mathematical activities using concrete materials  
      Almost never  Sometimes  Often  Almost all

   h. Have students use mathematical concepts to solve applied problems  
      Almost never  Sometimes  Often  Almost all

   i. Ask students to explain concepts to one another  
      Almost never  Sometimes  Often  Almost all

   j. Have students work on extended mathematics investigations or projects (e.g., assignments requiring more than a week)  
      Almost never  Sometimes  Often  Almost all

   k. Ask students to consider alternative methods for solutions  
      Almost never  Sometimes  Often  Almost all

   l. Ask students to use multiple representations (e.g., numerical, graphical, geometric, etc.)  
      Almost never  Sometimes  Often  Almost all
m. Help students see connections between mathematics and other disciplines
   Almost never  Sometimes  Often  Almost all
n. Assign mathematics homework
   Almost never  Sometimes  Often  Almost all
o. Have students write about mathematics
   Almost never  Sometimes  Often  Almost all
p. Ask students to justify or prove their conclusions
   Almost never  Sometimes  Often  Almost all
8. Think about your experiences with the following features of a graphing calculator or computer software. Describe your experience using the following scale. Circle one: Never used, Seldom used (some experience but not proficient), Use frequently (enough experience to be proficient)
   a. graphing features
      Never used  Seldom used  Use frequently
   b. table features
      Never used  Seldom used  Use frequently
   c. statistics features
      Never used  Seldom used  Use frequently
   d. equation modeling features
      Never used  Seldom used  Use frequently
   e. symbolic algebra features (e.g., computer algebra systems)
      Never used  Seldom used  Use frequently
   f. dynamic geometry (e.g., Geometer’s Sketchpad or comparable on a graphing calculator)
      Never used  Seldom used  Use frequently
   g. spreadsheet
      Never used  Seldom used  Use frequently
9. What do you expect to be your greatest challenge in teaching this class this year?
10. What else should we know about your participation in this study?

Appendix C: End-of-the-Year Teacher Questionnaire

Functions, Statistics, and Trigonometry Teacher End-of-Year Questionnaire

Name     __________________________________________ _________________
School     ________________________________________ ___________________

1. a. Name of the course involved in this study _______________________________________
b. What book did your students use in the classes in this study?
   ___ UCSMP Third Edition Functions, Statistics, and Trigonometry
   ___ UCSMP Second Edition Functions, Statistics, and Trigonometry

2. About what percent of class time each week did you devote to instruction in the following arrangements?
   a. whole class instruction
      _______
   b. small cooperative groups
      _______
   c. individual seatwork
      _______
   d. other
      (Please specify. ____________________________________________________________)

UCSMP Functions, Statistics, and Trigonometry. Chicago, IL: University of Chicago
School Mathematics Project. Used with permission.
3. About what percent of a typical lesson is devoted to the following activities?
   a. warm-up exercises/problems __________
   b. review of homework assignment __________
   c. introduction of new content __________
   d. attendance, classroom management __________
   e. other __________
   (Please specify. _________________________________________________________________)

4. a. What is the marking period structure for your school?
   _____ report cards every six weeks
   _____ report cards every nine weeks
   _____ other (Please specify. _____________________________)

b. In a given marking period, how many tests (30 minutes or longer) did you typically give, on average?
   __________

c. Did tests take the entire class period? _____ Yes _____ No

d. In a given marking period, how many quizzes did you typically give, on average? ______________

e. Did quizzes take the entire class period? _____ Yes _____ No

5. On the average, how many minutes of homework did you expect the typical student to do each day?
   _____ 0-15 minutes per day
   _____ 16-30 minutes per day
   _____ 31-45 minutes per day
   _____ 46-60 minutes per day
   _____ more than 60 minutes per day

6. What calculator technology was available for use by the majority of students during this mathematics class?
   (Check all that apply.)
   _____ calculators not available
   _____ a class set of scientific calculators
   _____ student-owned scientific calculators
   _____ class set of graphing calculators without computer algebra system capability
   _____ student-owned graphing calculators without computer algebra system capability
   _____ class set of graphing calculators with computer algebra system capability
   _____ student-owned graphing calculators with computer algebra system capability
   _____ the loaner calculators provided by UCSMP
   _____ other (Please specify. _____________________________________________________)

7. About how often did students use calculator technology during this mathematics class?
   _____ almost every day
   _____ 2-3 times per week
   _____ 2-3 times a month
   _____ less than once a month
   _____ almost never

8. For what did your students use calculator technology in this mathematics class? (Check all that apply.)
   _____ checking answers
   _____ doing computations
   _____ analyzing data
   _____ solving problems
   _____ finding equations to model data
   _____ graphing equations
   _____ simplifying algebraic expressions
   _____ working with a spreadsheet
   _____ other features of CAS
   _____ other (specify) ____________________________

9. If you had students use the computer algebra system capability on this calculator, if applicable, about how often did your students use the calculator for this purpose in your mathematics class?
   _____ almost every day
   _____ 2-3 times per week
   _____ 2-3 times a month
   _____ less than once a month
   _____ almost never

10. How helpful was this calculator for students learning mathematics in this mathematics class?
    ______ very helpful
    ______ somewhat helpful
    ______ not very helpful

11. How often did you expect students to read their mathematics textbook?
    _____ almost every day
    _____ 2-3 times per week
    _____ 2-3 times a month
    _____ less than once a month
    _____ almost never
12. How often did these things happen during this mathematics class?

<table>
<thead>
<tr>
<th></th>
<th>Daily</th>
<th>Frequently</th>
<th>Seldom</th>
<th>Never</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher read aloud in class</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Students read aloud in class</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Students read silently in class</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Students discussed the reading in class</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

13. How important do you think it is for students to read their mathematics text in order to understand mathematics?

<table>
<thead>
<tr>
<th></th>
<th>very important</th>
<th>somewhat important</th>
<th>not very important</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

14. How often did you expect students to write explanations to show what they were thinking when solving mathematics problems?

|                                | almost every day      | less than once a month | almost never |
|                                |                     |                         |              |
|                                |                     |                         |              |

15. How often did these things happen during this mathematics class when students solved problems?

<table>
<thead>
<tr>
<th></th>
<th>Daily</th>
<th>Frequently</th>
<th>Seldom</th>
<th>Never</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students wrote answers only</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Students wrote a few steps in their solutions</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Students wrote complete solutions</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Students explained or justified their work</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Students wrote proofs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Students wrote in journals</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Students did a project</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

16. How important do you think it is for students to write explanations to show what they were thinking when solving mathematics problems?

|                                | very important | somewhat important | not very important |
|                                |                |                    |                   |
|                                |                |                    |                   |

17. Think about your mathematics class this past year. How important to you in your teaching were each of the following? Circle one: Of little importance, Somewhat important, Quite important, or Of highest importance.

<table>
<thead>
<tr>
<th></th>
<th>Of little importance</th>
<th>Somewhat important</th>
<th>Quite important</th>
<th>Of highest importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase students’ interest in mathematics</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Help students learn mathematical concepts</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Help students learn mathematical algorithms/procedures</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Help students learn to read mathematics</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Help students learn to read (non-textbook) mathematics-related materials</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Help students learn how to solve problems</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Help students learn to reason mathematically</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Help students learn how mathematics ideas connect with one another</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prepare students for further study in mathematics</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Help students understand the logical structure of mathematics</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
k. Help students learn to explain ideas in mathematics effectively
   Of little importance Somewhat important Quite important Of highest importance

l. Help students learn to perform computations with speed and accuracy
   Of little importance Somewhat important Quite important Of highest importance

m. Help students prepare for standardized tests
   Of little importance Somewhat important Quite important Of highest importance

n. Help students learn to use a graphing calculator as a tool for learning mathematics
   Of little importance Somewhat important Quite important Of highest importance

o. Help students learn to use a symbolic manipulator as a tool for learning mathematics
   Of little importance Somewhat important Quite important Of highest importance

p. Help students learn to use a computer as a tool for learning mathematics
   Of little importance Somewhat important Quite important Of highest importance

18. Think about your mathematics class this past year. About how often did you do each of the following in your mathematics instruction?
   Circle one: Almost Never, Sometimes (once or twice a month), Often (once or twice a week), or Almost All
   Mathematics Lessons.
   a. Introduce content through formal presentations
      Almost never Sometimes Often Almost all
   b. Pose open-ended questions
      Almost never Sometimes Often Almost all
   c. Have students listen and take notes during presentations by the teacher
      Almost never Sometimes Often Almost all
   d. Engage the whole class in discussions
      Almost never Sometimes Often Almost all
   e. Require students to explain their reasoning when giving an answer
      Almost never Sometimes Often Almost all
   f. Have students work in small groups
      Almost never Sometimes Often Almost all
   g. Have students engage in mathematical activities using concrete materials
      Almost never Sometimes Often Almost all
   h. Have students use mathematical concepts to solve applied problems
      Almost never Sometimes Often Almost all
   i. Ask students to explain concepts to one another
      Almost never Sometimes Often Almost all
   j. Have students work on extended mathematics investigations or projects (e.g., assignments requiring more
      than a week)
      Almost never Sometimes Often Almost all
   k. Ask students to consider alternative methods for solutions
      Almost never Sometimes Often Almost all
   l. Ask students to use multiple representations (e.g., numerical, graphical, geometric)
      Almost never Sometimes Often Almost all
   m. Help students see connections between mathematics and other disciplines
      Almost never Sometimes Often Almost all
   n. Assign mathematics homework
      Almost never Sometimes Often Almost all
   o. Have students write about mathematics
      Almost never Sometimes Often Almost all
   p. Ask students to justify or prove their conclusions
      Almost never Sometimes Often Almost all

19. For each of the following, give your opinion about each of the statements related to the textbook you are using
   for this class. Strongly agree, Agree, No opinion, Disagree, Strongly disagree
   a. This textbook helps develop problem-solving skills.
      Strongly agree Agree No opinion Disagree Strongly disagree
   b. This textbook needs more exercises for practice of skills.
<table>
<thead>
<tr>
<th></th>
<th>Strongly agree</th>
<th>Agree</th>
<th>No opinion</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>c.</td>
<td>This textbook explains concepts clearly.</td>
<td>Strongly agree</td>
<td>Agree</td>
<td>No opinion</td>
<td>Disagree</td>
</tr>
<tr>
<td>d.</td>
<td>This textbook provides good suggestions for activities.</td>
<td>Strongly agree</td>
<td>Agree</td>
<td>No opinion</td>
<td>Disagree</td>
</tr>
<tr>
<td>e.</td>
<td>This textbook provides good suggestions for assignments.</td>
<td>Strongly agree</td>
<td>Agree</td>
<td>No opinion</td>
<td>Disagree</td>
</tr>
<tr>
<td>f.</td>
<td>This textbook needs more examples of the applications of mathematics.</td>
<td>Strongly agree</td>
<td>Agree</td>
<td>No opinion</td>
<td>Disagree</td>
</tr>
<tr>
<td>g.</td>
<td>This textbook provides good suggestions for the use of calculators.</td>
<td>Strongly agree</td>
<td>Agree</td>
<td>No opinion</td>
<td>Disagree</td>
</tr>
<tr>
<td>h.</td>
<td>This textbook provides good suggestions for the use of graphing features of a calculator.</td>
<td>Strongly agree</td>
<td>Agree</td>
<td>No opinion</td>
<td>Disagree</td>
</tr>
<tr>
<td>i.</td>
<td>This textbook provides good suggestions for the use of table features on a calculator.</td>
<td>Strongly agree</td>
<td>Agree</td>
<td>No opinion</td>
<td>Disagree</td>
</tr>
<tr>
<td>j.</td>
<td>This textbook provides good suggestions for the use of computer algebra systems.</td>
<td>Strongly agree</td>
<td>Agree</td>
<td>No opinion</td>
<td>Disagree</td>
</tr>
</tbody>
</table>

20. a. Are the students in this class required to take a state test this school year (such as tests to meet NCLB requirements)?
   - Yes (If yes, please answer 20b and 20c.)
   - No (If no, please answer 20d.)

   b. If yes, about how much time did you spend out of the textbook in review for this test?

   c. If yes, what influenced the amount of time you spent on review (e.g., district requirements, school requirements, your experience with the requirements for the test)?

   d. If no, why was review not necessary?

21. Below is some content that is covered in UCSMP *Functions, Statistics, and Trigonometry*. Check any that you think a typical teacher of this course would need some refresher work in before teaching for the first time.
   - using a graphing calculator
   - using computer algebra systems (CAS)
   - spreadsheets
   - statistical modeling
   - parametric equations
   - transformations
   - applications
   - sequences
   - trigonometry

22. What was your greatest challenge in teaching this class this year?

23. If you had the choice, would you teach from this text again next school year? Please explain why or why not.

24. Are there any special circumstances related to this class that we should know about that might help us understand the student achievement data?

THANK YOU!!!   THANK YOU!!!   THANK YOU!!!
Appendix D: Chapter Evaluation Form

University of Chicago School Mathematics Project

Functions, Statistics, and Trigonometry: Third Edition

Teacher ___________________________ School ___________________________

Date Chapter Began _______ Date Chapter Ended ________ No. Class Days (Including Tests) _______

1. Please complete the table below. In column A, circle the number of days you spent on each lesson. In columns B and C, rate the text and questions of each lesson using the following scale.
   1 = Disastrous; scrap entirely. (Reason?)  
   2 = Poor; needs major rewrite. (Suggestions?)  
   3 = OK; some big changes needed. (Suggestions?)  
   4 = Good; minor changes needed. (Suggestions?)  
   5 = Excellent; leave as is.

In columns D and E, respectively, list the specific questions you assigned in the lesson and comment on any parts of the lesson text or questions you think should be changed. Use the other side or an additional sheet of paper if you need more space.

<table>
<thead>
<tr>
<th>Lesson</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Circle the number of days you spent on the lesson</td>
<td>Rating</td>
<td>Questions</td>
<td>Questions Assigned</td>
</tr>
<tr>
<td>1-1</td>
<td></td>
<td>0</td>
<td>0.5</td>
<td>1</td>
<td>1.5</td>
</tr>
<tr>
<td>1-2</td>
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<td>1</td>
<td>1.5</td>
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<tr>
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<td>1.5</td>
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<td>1-9</td>
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<td>1</td>
<td>1.5</td>
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<tr>
<td>Self-Test</td>
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<td>0.5</td>
<td>1</td>
<td>1.5</td>
</tr>
<tr>
<td>SPUR Review</td>
<td></td>
<td>0</td>
<td>0.5</td>
<td>1</td>
<td>1.5</td>
</tr>
</tbody>
</table>

2. Overall rating of this chapter. (Use the same rating scale as at the top of the page.) __________

3. What comments do you have on the sequence, level of difficulty, or other specific aspects of the content of this chapter? __________

4. As we revise the student materials for this chapter,
   a. What should we definitely not change?
   b. What should we definitely change? What ideas do you have for changes that should be made?

5. As we revise the Teacher’s Notes for this chapter,
   a. What should we definitely not change?
   b. What should we definitely change? What ideas do you have for changes that should be made?

6. Did you use any UCSMP Second Edition materials during this chapter (Lesson Masters, Technology Masters, etc.)? Yes _____  No _____
   If yes, how and when?

7. While teaching this chapter, did you supplement the text with any materials other than those mentioned in Question 6? Yes _____  No _____
   If yes, which materials did you use and when?
   Why did you use these materials? (If possible, please enclose a copy of the materials you used.)

8. a. Did you as the teacher demonstrate or use a calculator with this chapter? Yes _____  No _____
   b. If yes, how did you use the calculator?
   c. What comments or suggestions do you have about the way calculator technology is incorporated into this chapter?


123
d. Did you download data sets from the UCSMP website? Yes _____ No _____
   If No, why not?
9. a. Did your students use a calculator with this chapter? Yes _____ No _____
   b. If yes, how did they use the calculator?
10. a. Did you as the teacher demonstrate or use a computer with this chapter? Yes _____ No _____
    b. If yes, how did you use the computer?
    c. What comments or suggestions do you have about the way computer technology is incorporated into this chapter?
11. a. Did your students use a computer with this chapter? Yes _____ No _____
    b. If yes, how did they use the computer?
12. a. Did you check out the loaner calculators to your students? Yes _____ No _____
    b. For this chapter, what technology access did students have other than the loaner calculators?
13. What challenges, if any, did you have with the technology in this chapter?
   a. How long did this chapter take to complete compared to Chapter 1 in the Second Edition?
   b. Please compare the extent to which the current chapter is more or less interesting than the comparable chapter in the Second Edition.
15. Did you use the test for this chapter that we provided in the Teacher’s Notes?
   Yes _____ No _____ If yes, what suggestions do you have for improvement?
   If no, what specific reasons influenced your decision not to use the test?
16. Other comments? Attach additional sheets as needed.
   Please return this form, along with a copy of the chapter test you administered to students if different from the provided Chapter Test.
Appendix E: Documents

Letter of Authorization

UCSMP

The University of Chicago School Mathematics Project
1225 East 60th Street, Chicago, IL 60637
(773) 702-1130 • FAX (773) 702-3114 • ucsmp@uchicago.edu

July 8, 2015

Mr. Ilyas Karadeniz, Graduate Student
University of South Florida

Dear Mr. Karadeniz:

Congratulations on completing your dissertation.

We are pleased to give you permission to include, in your printed dissertation, copies of the following instruments that were developed by UCSMP:

FST Chapter 1 evaluation form
FST Teacher Questionnaire beginning of the year
FST Teacher Interview Protocol
FST End of Year Questionnaire.

Best wishes for continued success in your work.

Sincerely,

Zalman Usiskin
Professor Emeritus of Education
Director, UCSMP

cc: Denisse R. Thompson
Ilyas Karadeniz,
USF Teaching and Learning
4202 E. Fowler Avenue, ALN 185 Tampa, FL 33620

RE: Expedited Approval for Initial Review
IRB#: Pro00020111
Title: Teachers’ Perceptions of Using Graphing Calculators with or without CAS in Precalculus

Study Approval Period: 1/5/2015 to 1/5/2016
Dear Ilyas Karadeniz:

On 1/5/2015, the Institutional Review Board (IRB) reviewed and APPROVED the above application and all documents outlined below.

Approved Item(s):
Protocol Document(s):
  ikaradeniz_proposal.docx

It was the determination of the IRB that your study qualified for expedited review which includes activities that (1) present no more than minimal risk to human subjects, and (2) involve only procedures listed in one or more of the categories outlined below. The IRB may review research through the expedited review procedure authorized by 45CFR46.110 and 21 CFR 56.110. The research proposed in this study is categorized under the following expedited review category:

(7) Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.

Your study qualifies for a waiver of the requirements for the informed consent process as outlined in the federal regulations at 45CFR46.116 (d) which states that an IRB may approve a consent procedure which does not include, or which alters, some or all of the elements of informed consent, or waive the requirements to obtain informed consent provided the IRB finds and documents that (1) the research involves no more than minimal risk to the subjects; (2) the waiver or alteration will not adversely affect the rights and welfare of the subjects; (3) the research could not practicably be carried out without the waiver or alteration; and (4) whenever
appropriate, the subjects will be provided with additional pertinent information after participation.

As the principal investigator of this study, it is your responsibility to conduct this study in accordance with IRB policies and procedures and as approved by the IRB. Any changes to the approved research must be submitted to the IRB for review and approval by an amendment.

We appreciate your dedication to the ethical conduct of human subject research at the University of South Florida and your continued commitment to human research protections. If you have any questions regarding this matter, please call 813-974-5638.

Sincerely,

Kristen Salomon, Ph.D., Vice Chairperson
USF Institutional Review Board
Office of Research & Innovation

IRB Certification

Certificate of Completion

Ilyas Karadeniz
Has Successfully Completed the Course in
CITI IRB Members
On
Tuesday, September 02, 2014
Reviewer’s Consent

I, Irem Akcakaya, have served as an auditor for the study “UCSMP Teachers’ Perspectives when Using Graphing Calculators in Advanced Mathematics” (IRB# 20111), by Ilyas Karadeniz. In these roles, I have worked with the researcher in coding and data analysis process.

Signature: 

Date: 06/15/2017
ABOUT THE AUTHOR

Ilyas Karadeniz was born in Konya, Turkey in August 1986. He began to learn English and Arabic as a foreign language in Turkey at age 14. He graduated from Konya Atatürk Anatolian Teacher Training High School in 2004. Then, he received his B.A. and M.A. degrees in Mathematics Teaching as an integrated program at the Balikesir University in 2009. He worked as a high school mathematics teacher in Konya Selcuklu Imam-Hatip High School for four months. He took an intensive English Language Education program at the University of Delaware before his doctoral program. In 2011, he started his doctoral studies in Curriculum Instruction with a concentration in Mathematics Education at the University of South Florida. During his courses, he was also an unpaid teaching assistant and classroom observer such as Teaching Mathematics in the Middle Grades, Teaching Senior High School Mathematics, and Intermediate Algebra. He is interested in research projects related to technology and mathematics. Specifically, his areas of interest are use of technology in mathematics education and teachers' perspectives.

Ilyas Karadeniz can be contacted at ilyaskaradeniz86@gmail.com