Teacher preparation programs and calculator pedagogy
by

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ABSTRACT

The National Council of Teachers of Mathematics wrote a position paper in 1987 in which they called for changes in instructional methods including using technology in the classroom. Almost three decades later, research of calculator usage in general has revealed that the main factor restricting student calculator use was the teacher. Either, teachers were not adequately trained in the technology or the teachers feared that the use of the calculator would increase mathematical illiteracy. This study determined what institutions with certified teacher preparation programs were requiring graduates to complete the necessary courses to rectify this situation. Data for this heuristic case study was obtained from six middle level and six secondary level teacher certification institutions. All 12 institutions were certified by the Council for the Accreditation of Educator Preparation. Six of the 12 institutions (three each of the middle level and secondary level) were also certified by the National Council of Teachers of Mathematics.

During this study, two main questions guided the research: What do mathematics teacher educators believe about the use of calculators in the classroom? and How do mathematics teacher educators use methods courses to prepare pre-service teachers to use calculators to develop sound pedagogy? The answers were found through a qualitative case study which made use of telephone interviews for much of the information. Due to the stipulation of using only institutions in *Praxis®* states, no institutions from my home state of Texas could be used. This same

stipulation meant that most of the institutions in the study were beyond my reach except through telephone interviews.

Regarding the first question of “What do mathematics teacher educators believe about the use of calculators in the classroom?” the findings drawn from the information provided by teacher educators who participated in this study was that in general, teacher educators believed that the students’ use of calculators is unavoidable; however, the educating of a pre-service teacher to use calculators efficiently for pedagogical purposes has issues that need to be addressed.

Regarding the second question of the study of “How do mathematics teacher educators use methods courses to prepare pre-service teachers to use calculators to develop sound pedagogy?”, the findings drawn from the information provided by teacher educators who participated in this study was that pre-service teachers had little opportunity to develop pedagogical skills with calculators.

The process standards listed by National Council of Teachers of Mathematics include problem solving, reasoning, communications, connections, and representations. In each case, calculators can be used to enhance students’ understanding of mathematics. For example, to solve real world problems, students must be able to use the representations they are furnished to determine a reasonable solution and communicate that solution across many subjects. Calculators can facilitate students seeing multiple representations of the same information, which benefits their overall understanding of a concept.

The National Council of Teachers of Mathematics should re-examine the *Principles and Standards of School Mathematics* and other documents to ensure that they appropriately reflect 21st century learners' needs. Furthermore, it would be prudent for National Council of Teachers of Mathematics to support the use of age appropriate calculators and provide more specific guidelines for implementation of technologies such as calculators for each grade level.

Based upon the findings of this study, the National Council of Teachers of Mathematics and the Council for the Accreditation of Teacher Preparation in granting certification of teaching programs, should also have a process in place to ensure that certified institutions adequately address the preparation of pre-service teachers in regard to teaching technologies such as calculators. Examining syllabi for mathematics methods classes would be an important first step.

Teacher preparation institutions and programs, no matter whether traditional in nature or those alternative in nature, would benefit by being cognizant of the National Council of Teachers of Mathematics principles and standards and work to ensure mathematics educators center methods coursework on these principles and standards. Furthermore, teacher preparation institutions and programs should support education departments and mathematics departments working in tandem to prepare pre-service mathematics teachers to face the challenges of preparing the next generation of students to be successful in a world that is becoming more competitive globally.

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CHAPTER I

INTRODUCTION

The National Council of Teachers of Mathematics (NCTM) wrote a position paper (NCTM, 1987) almost three decades ago in which they called for changes in instructional methods including using technology in the classroom (NCTM, 1989). Two years later, NCTM published a position statement on the use of calculators urging school districts to promote calculator usage at all ages (1991). Early research of calculator usage in general revealed that the main factor restricting student calculator use was the teacher (Schmidt & Callahan, 1992). Either, teachers were not adequately trained in the technology (Burke, 2001) or the teachers feared that the use of the calculator would increase mathematical illiteracy (Pomerantz, 1997).

The Conference Board of the Mathematical Sciences (CBMS) is an organization comprised of 17 professional mathematical societies. In 2012, CBMS published a report concerning the courses which mathematics teachers should be required to complete in order to receive certification. One key finding of the report was that pre-service mathematics teachers were not required to take coursework which examined mathematics from a teacher's perspective (CBMS, 2012, p. 17). However, the opportunity for pre-service teachers to practice from a teacher's perspective has been noted as invaluable (Brown et al., 2007). By logical extension, most pre-service teachers have probably not examined the use of calculators as a teaching pedagogy from the perspective of a teacher, although they most likely have used calculators at some point in time during their years of schooling.

Background of the Problem

Attitudes of educators towards the calculator as an instructional tool has been slow to change. For example, Milou (1999) noted "although the college board has allowed students to use graphing calculators on the SAT, classroom teachers remain unsure or unwilling to allow students to use graphing calculators on all of their exams" (p. 136). Mason (2010) found that many educators do not allow students to use the calculators simply because they have not been allowed to use it on the state test or because of teacher insecurities in using the device (Burke, 2001).

Researchers have shown that calculators should be an integral part of instruction in the mathematics classroom and that mathematics educators strongly support this stance (Dion et al., 2001; Ellington, 2003; Pomerantz, 1997). For example, Ellington (2012) performed a meta-analysis of research on calculators where control groups were compared to treatment groups. The meta-analysis results prompted Ellington (2012) to suggest the following recommendations with respect to calculator use: (a) calculators should be used at all grade levels and (b) calculator usage should increase as student grade level increases.

Even though NCTM believes that calculators should be used in all levels of learning (NCTM, 2000), teacher preparation programs have unintentionally inhibited the use of calculators in the mathematics classroom (NCATE, 2010). In a study of 19 newly credentialed teachers, Gainsburg found (2012) “that an additional methods course or more student teaching would have been helpful” (p. 370) while in pre-service classrooms to form positive perceptions of calculators as an instructional tool.

The teachers believed that “extra ‘hands-on’ teaching practice offered by extended or methods-course-concurrent student teaching would have built their confidence about using” such technology (Gainsburg, 2012, p. 370).

Why Calculators?

The earliest archaeological evidence of a Greek abacus was found in the 5th Century BCE (Ifrah, 2001). Many people believe that this was the forerunner of today’s calculator, however, one important element was missing. There was no zero.

In the 3rd Century BCE, Babylonian scholars became the first to use the zero (Ifrah, 2001). Unbeknownst to these Babylonian mathematicians, this one unit allowing for the place value system would permit the invention of mechanized methods to add and subtract numbers (Ifrah, 2001). In the 2nd Century BCE, Plutarch, a Greek biographer, described a sand abacus (Ifrah, 2001). Later, this same type of abacus was found in the remains of the Christian population in the mediaeval West. This abacus did calculations using either “Roman numerals or Greek alphabetic numerals” (Ifrah, 2001, p. 17).

After this time, the progression of the abacus was not known for certain, however, the present form of the abacus was introduced into China about 1200 AD. The abacus appeared in Korea about 1400 AD and then in Japan about 1600 AD (Aspray, 1990).

John Napier invented a system of ten ‘bones’ or wooden rods called “Napier’s Bones” in 1617 (Ifrah, 2001). The use of Napier’s Bones facilitated multiplication of two or more digits. Subsequently many inventions became based on the idea of

Napier's Bones. In 1623, Wilhelm Schickard constructed his "calculating clock" which could execute all four of the basic arithmetical operations and operated on the same principles as Napier's Bones (Ifrah, 2001). In 1642, Blaise Pascal, the great French mathematician constructed his "Pascaline" which could carry automatically (Ifrah, 2001).

Prior to the start of the nineteenth century, calculating machines were not widely marketable due to the fact that they were designed for commercial and international banking sectors (Ifrah, 2001). The first major advance for a widely used "calculator" was Charles-Xavier Thomas' invention of the *Arithmometer* in 1822, which became the first calculator to be commercialized on a large scale (Ifrah, 2001). This calculator spurred many other inventions which ultimately lead to the adding machine and typewriter (Ifrah, 2001). The term calculate came from the abacus which was made of pebbles or calculi (plural for calculus) (calculus, n.d.). So if you were using an abacus you were calculating (calculate, n.d.). This definition may differ from what students consider to be accomplishing when they think of calculating.

The calculator of today, became possible because of two inventions. One was the integrated circuit in 1958 by Jack Kilby of Texas Instruments and the other was the liquid crystal displays (LCD) in the 1970's (Ifrah, 2001). Texas Instruments first applied for a patent in 1967 of its *Miniature Electronic Calculator*, however, the patent was not granted until 1972 (Ifrah, 2001). This patent office delay allowed Universal Data Machine to launch the first commercial four-operation pocket calculator on April 14, 1971 (Ifrah, 2001). This calculator weighed in at 2.5 ounces and cost $150 (Ifrah, 2001).

This single invention prompted one of the great debates of all times – whether to give a student a calculator or not and at what age? From 1976 to 1980, calculator research flourished. In 1986, Hembree and Dessart compiled a meta-analysis of these studies. This meta-analysis concluded that for grades kindergarten through 12, with the exception of grade 4, the use of calculators improved the student's basic skills (Hembree & Dessart, 1986). Hembree and Dessart (1986) also found that students using calculators had higher achievement on tests and exhibited a better attitude toward mathematics as a whole.

In 2003, Ellington conducted another meta-analysis using calculator research studies published from January 1983 to March 2002. This new meta-analysis had the same results as the previous meta-analysis, even though the research studies were done almost 25 years apart (Ellington, 2003). Students were found to have better basic skills and higher efficacy when a calculator was involved in the learning process (Ellington, 2003).

In a survey administered to more than 800 elementary, middle, and high school teachers, the teacher was found to have been one of the most important factors when considering calculator use by students in the classroom (Brown et al., 2007). Furthermore, in a research study compiling interview data from 52 newly credentialed mathematics teachers, these teachers believed that pre-service teachers must have the opportunity to learn to teach with calculators in order for students to be successful (Gainsburg, 2012).

In summary, with the invention of the calculator came many possibilities in the education of our children. This invention also caused a rift between those who think students should use a calculator and those who think that calculators would cause students to become mathematically illiterate. The calculator has also focused the spotlight on the professional development of in-service teachers and the preparation of pre-service teachers. This study was done to further clarify how pre-service mathematics teachers are taught to use calculators in their classrooms.

Definition of Terms

Mathematics course: for this study, a mathematics course is any course offered by the institution containing mathematical practice or theory; such as: calculus, linear algebra, geometry, and statistics.

Mathematics methods course: for this study, a mathematics methods course is any course required to obtain a teaching certification and includes best practices of mathematical pedagogy. During a mathematics methods course, "participants explore diversity and equity, mathematics standards and curriculum, and technology integration as critical components of planning for and implementing mathematics instruction and assessment" (University of Phoenix, 2016, para. 1).

State standards: the standards adopted by each state as the basis for the curriculum in that state.

Council for the Accreditation of Educator Preparation (CAEP): the organization charged with certifying that U.S. teacher educator programs meet stringent requirements (CAEP, 2015d).

Principles and Standards for School Mathematics **(PSSM):** published by the National Council of Teacher of Mathematics whose objective is to provide "a vision for school mathematics" (NCTM, 2000, p. 3).

National Council for Accreditation of Teacher Education (NCATE): As of July 1, 2013 NCATE and the Teacher Education Accreditation Council (TEAC) became known as the Council for the Accreditation of Educator Preparation (NCATE, 2014).

PRAXIS® Mathematics Exam**:** An exam that measures specific mathematical content and pedagogical knowledge for beginning teaching practice. "*The Praxis Series*® is grounded in current research, including a comprehensive analysis of the most important tasks and skills required of beginning teachers" (ETS, 2015c, para. 1). This content area test of knowledge was used to determine the states selected for this study.

Problem Statement

NCTM standards have explicitly stated "Appropriate calculators should be available to all students at all times" (NCTM, 1989, p. 7). NCTM has provided teachers with examples of how a calculator should be used to enhance the learning of students (NCTM, 1989). One of NCTM's recommendations has been that "calculators must be accepted at the K-4 level as valuable tools for learning mathematics" (NCTM, 1989, p. 19). NCTM has encouraged the increased use of calculators as students become older and are required to perform more and more tedious computations

(NCTM, 2000). NCTM's Technology Principle stated, "electronic technologies – calculators and computers – are essential tools for teaching, learning, and doing mathematics" (NCTM, 2000, p. 24).

This leads one to ask why calculators have not been used in all levels of mathematics classrooms (Burke, 2001). Where does the fault lie? Is it with the schools for not furnishing the calculators, with teachers for not using the calculators, or that teacher preparation programs have not properly prepared the teachers to use the calculators in a classroom environment?

Purpose of the Study

The purpose of this qualitative case study was to investigate university mathematics education programs and the methods they employed to prepare pre-service mathematics teachers in their use of calculators in the classroom. Preparing pre-service teachers to effectively use calculators in their classrooms ensures that today's students are better prepared to perform in the 21st century (Bell, 2001). The research questions guiding this study were:

- What do mathematics teacher educators believe about the use of calculators in the classroom?
- How do mathematics teacher educators use methods courses to prepare pre-service teachers to use calculators to develop sound pedagogy?

Significance of the Study

Teacher preparation programs could use the findings of this study to evaluate their mathematics education coursework and programs. Studies have shown that educators have a tendency to teach using methods similar to those employed by their own teachers (Gainsburg, 2012; Hardy, 2008). This study could allow teacher preparation faculty to reflect on best practices in the preparation of mathematics teachers.

This study might be of interest to pre-service teachers searching for universities at which to complete their teaching certificate requirements in mathematics. Since NCTM and state standards include the implementation of calculators in the classroom as best practices (NCTM, 2000), pre-service teachers should be prepared when they achieve certification to fulfill those requirements. NCTM, along with CAEP (Council for Accreditation of Educator Preparation), has developed a rigorous system to certify teacher education programs employing NCTM standards in pre-service teacher education (CAEP, 2015d). By exploring which certified institutions are actually upholding these high ideals, pre-service mathematics teachers will be better prepared to choose their institution wisely and should be better prepared to teach once they have completed the program of study.

NCTM and CAEP should also benefit from the findings of this study. These two entities certify teacher preparation programs as to the quality of education the students receive in a given program of study (CAEP, 2015b); however, the results of this study may impact the perceptions of these accreditation programs with regard to successful teacher preparation programs. For example, the findings from this study could alter the method by which institutions receive certification from NCTM, especially if they do not address significant principles, such as technology, which is strongly supported by NCTM.

K-12 students could also benefit from the findings of this study. The ultimate consumer for a mathematics teacher is their students. This study explored the methods by which mathematics teachers are being prepared to meet the students' needs as far as calculator usage is concerned. In order to educate students properly, teachers must be prepared to teach using technology that, in many cases, they were not taught with (Chamblee, Slough, & Wunsch, 2008; Kastberg & Leatham, 2005; Mason, 2010: Rowland, Turner, & Thwaites, 2014). Changing how teachers are trained to use technologies such as calculators will impact student learning.

CHAPTER 2

LITERATURE REVIEW

Acquiring information concerning calculators in education compelled me to investigate the subject further. When I began this endeavor I was unaware some teacher preparation programs were not certified by NCATE or CAEP. I was also unacquainted with the background of the NCTM opinion statements and the controversies concerning developments that led to the printing of the *Principle and Standards for School Mathematics* (PSSM). As I researched this information, it became increasingly clear that I would have to explain, at least to some degree, the historical background concerning the use of calculators in public schools. The literature review synthesizes this information.

Council for the Accreditation of Educator Preparation

The Council for the Accreditation of Educator Preparation (CAEP) was formed on July 1, 2013 with the consolidation of The National Council for Accreditation of Teacher Education and the Teacher Education Accreditation Council (NCATE, 2014). Their mission is stated as "CAEP advances excellent educator preparation through evidence-based accreditation that assures quality and supports continuous improvement to strengthen P-12 student learning" (CAEP, 2015c, para.2).

The goals listed for CAEP include:

1. To raise the bar in educator preparation
2. To promote continuous improvement
3. To advance research and innovation

4. To increase accreditation's value
5. To be a model accrediting body
6. To be a model learning organization (CAEP, 2015c, para. 3).

Although, CAEP became an organization in 2013, its standards could not be fully implemented until 2016 (CAEP, 2015a). Thus, this study has been undertaken during a period of transition.

National Council of Teachers of Mathematics

In 1892, the Commission on the Reorganization of Secondary Education appointed a special committee, headed by William Heard Kilpatrick, to evaluate the condition of mathematics in American schools (Donoghue, 2003). The Committee of Ten, as the committee was named, was the first major public attempt at creating a standardized mathematics curriculum (Bullock, 2013). The Committee of Ten report, released in 1920, listed five details to be examined further. Among other things, this list contained ideas that specific mathematic topics be defined for each student and that, above all, the individual needs of the student should determine the mathematics classes required to graduate. The list also included using the students' own ideas and interest to determine which classes the student would need (Donoghue, 2003).

Even before it was officially published, the Committee of Ten report was rejected as being ludicrous because the committee contained no mathematicians, only educators (Donoghue, 2003). In "an effort initiated by the Men's Mathematics Club of Chicago" (Donoghue, 2003, p. 187) a meeting was arranged during the National Education Association conference in 1919 (Donoghue, 2003) to discuss the impending report of the Committee of Ten. During this meeting, "127 mathematics teachers from twenty states formed the National Council of Teachers of Mathematics" (Donoghue, 2003, p. 187). C. M. Austin, the first president of NCTM, in his inaugural address stated, "So-called educational reformers have tinkered with the courses, and they, not knowing the subject and its values, in many cases have thrown out mathematics altogether or made it entirely elective" (Bullock, 2013, p. 77). He went on to add that these committees "have generously called in high school teachers to help, but the fact is that it remained for the college people to initiate the work... NCTM was formed to help remedy the situation" (Bullock, 2013, p. 77). Austin also stated the primary reason for establishing the council was:

> First, it will at all times keep the values and interests of mathematics before the educational world. Instead of continual criticism at educational meetings, we intend to present constructive programs, be friends of mathematics. We prefer that curriculum studies and reforms and adjustments come from the teachers of mathematics rather than from the educational reformers. (Donoghue, 2003, p. 187)

NCTM became a single voice and consolidated the mathematics education communities' resources into a "national voice for the profession" (Donoghue, 2003, p. 187). In its mission statement, NCTM positioned itself as "the public voice of mathematics education, supporting teachers to ensure equitable mathematics learning of the highest quality for all students through vision, leadership, professional development, and research" (NCTM, 2015c, para.1). NCTM was founded as an organization to provide resources *for* teachers rather than being an organization *of* teachers.

"New Math" was the major mathematics reform movement initiated after Russia's success with *Sputnik* (Bullock, 2013). The New Math reform failed, in part, some say, because it was a response to a manufactured crisis that caused a real crisis in mathematics education (Bullock, 2013). Others theorized that this reform attempt failed because "its goals were simply too ambitious to allow any opportunity for success" (Bullock, 2013, p. 83). The "Back to Basics" movement followed as the response to the failure of New Math "to equip students with basic consumer computational skills" (Bullock, 2013, p. 83).

The next milestone of the 1980's was *A Nation at Risk* published by The National Commission of Excellence on Education (Bullock, 2013). Like *Sputnik*, this report positioned mathematics education reform at the center of conversation. *A Nation at Risk* led to the *Priorities in School Mathematics* (PRISM) research study, published in 1981 by NCTM (Bullock, 2013). PRISM laid the foundation for all of the activities of NCTM in the 1980's and "functioned as a barometer for predicting which curriculum changes might be readily adopted and which ones might meet with resistance" (Bullock, 2013, p.87).

The recommendations as to the direction of mathematics education in the 1980's, which were initiated by PRISM, occurred at a "time of national economic crisis and further moves by the NCTM to return control of the mathematics education conversation to mathematics teachers" (Bullock, 2013, p. 87). These recommendations were published by NCTM as *An Agenda for Action:*

Recommendations for School Mathematics of the 1980's (Bullock, 2013). The preface of *An Agenda for Action* (NCTM, 1980) stated

> The National Council of Teachers of Mathematics, as an organization of professional educators, has a special obligation to present its responsible and knowledgeable viewpoint of the directions mathematics programs should be taking in the 1980's. These recommendations represent both realism and responsibility. They are realistic in their attention to hard data.... The recommendations are responsible to the profession and to the public since they represent a very broad base of belief about objectives and priorities.... These recommendations are not the end of our efforts but a beginning. They represent an agenda for a decade of action, and we call on all interested persons and groups to join us in a massive cooperative effort toward better mathematics education for all our youth. (pp. i-ii)

Recommendation 3 of *An Agenda for Action* stated, "Mathematics programs must take full advantage of the power of calculators and computers at all grade levels" (NCTM, 1980, p. 8). Shirley A. Hill was the president of NCTM and Edgar L. Edwards, Jr. was on the board of directors which signed the preface of the *Agenda for Action*. During an interview in 2002, Dr. Hill, when asked about her views of calculators, stated,

> Use the tool when it's sensible to use the tool. Don't fail to use a tool that's valuable in instances where it is valuable. Children using calculators are also learning computation. You can use a calculator to help kids to learn how to think through [a problem] ... and understand them better. (Roberts, 2002a, p. 38)

Mr. Edwards stated during his interview "Well, this has been a real headache in trying to get calculators into the classroom. The calculator is a device that can be used to help students learn and do mathematics" (Roberts, 2002b, pp. 31-32).

An Agenda for Action laid the foundation for the *Curriculum and Evaluation Standards for School Mathematics* (NCTM, 1989), *Professional Standards for Teaching Mathematics* (NCTM, 1991), and *Assessment Standards for School*

Mathematics (NCTM, 1995) which were published in response to a lack of any standardized curriculum being used. The NCTM leadership believed that they did not have the right to criticize any other curriculum unless they were willing to put forth a curriculum to replace the previous attempts.

The writing team for *Curriculum and Evaluation Standards for School Mathematics* (CESSM) were charged with creating “a coherent vision of what it means to be mathematically literate both in a world that relies on calculators and computers to carry out mathematical procedures and in a world where mathematics is rapidly growing” (NCTM, 1989, p. 1). In the CESSM, NCTM encouraged the use of calculators across all age groups and grade levels (NCTM, 1989) and even went so far as to offer a diagram of how a teacher should know when calculator use was appropriate (See Figure 2.1).

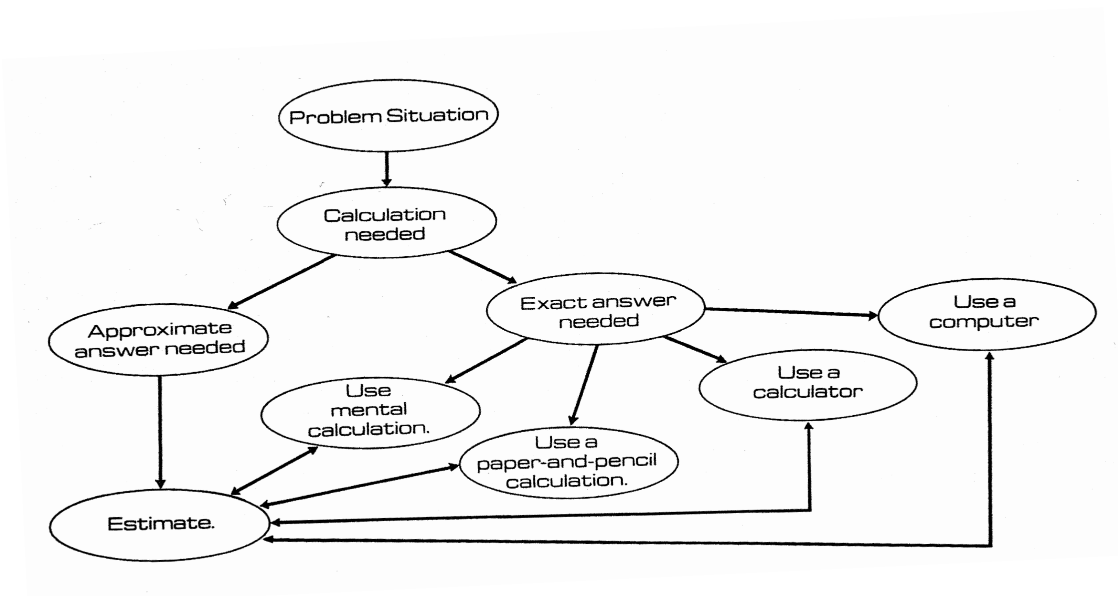


Figure 2.1. Diagram for deciding calculator use in numerical problems (NCTM, 1998, p. 9). Reprinted with permission from *Curriculum and Evaluation Standards for School Mathematics*, copyright 1989, by the National Council of Teachers of Mathematics. All rights reserved.

Figure 2.1 demonstrates that in a problem situation which requires calculation, the student must first decide if an approximate answer is needed or an exact answer is needed. If an exact answer is needed, then one of the methods used to obtain that answer would be a calculator. Using mental calculations and paper and pencil calculations are also listed as being appropriate when an exact answer is needed. The figure likewise shows that an estimate can be found before using a calculator to find the answer, no matter which method is used or whether an exact answer is needed or not.

According to the CESSM, “Students should be able to decide when they need to calculate and whether they require an exact or approximate answer. They should be able to select and use the most appropriate tool” (NCTM, 1989, p. 8). The CESSM provided many examples of how calculators should be used. For instance, CESSM offered the following guideline: “Some calculations, if not too complex, should be solved by following paper and pencil algorithms. For more complex calculations, the calculator should be used (column addition, long division)” (NCTM, 1989, p. 8).

The *Professional Standards for Teaching Mathematics* (PSTM) declared that mathematics teaching needed “elementary and secondary teachers who are more proficient in using, and helping students use, technology and other tools to pursue mathematical investigations” (NCTM, 1991, p. 1). These professional standards also stated that pre-service teachers were seldom shown how the topics that they studied in college relates to the mathematics they would be teaching in elementary and secondary schools (NCTM, 1991). The PSTM called for the use of technology in the doing, teaching, and learning of mathematics as a responsibility of the mathematics educational community (NCTM, 1991).

Principles to Actions Ensuring Mathematical Success for All was published in 2014 and what had been the guiding principles became essential elements (NCTM, 2014). *Principles to Actions* “addresses the essential elements of teaching and learning, access and equity, curriculum, tools and technology, assessment, and professionalism” (NCTM, 2014, p. vii). The document’s primary purpose was to bridge the gap between the “development and adoption of” standards “and the enactment of practices, policies, programs, and actions required for widespread and successful implementation” of those standards (NCTM, 2014, p. 4). The developers of the *Principles to Actions* document declared that “calculators are a commonly used technology in mathematics classrooms, ranging from those incorporating basic operations in the lower grades to more advanced calculators in the upper grades (NCTM, 2014, p. 78).

NCTM, along with CAEP, also recognizes specific teacher education programs. The guidelines for recognition are available on the NCTM.org website. These guidelines were revamped in 2012; therefore, for the programs in this study, 2003 guidelines were used as many of the programs have not undergone recertification under the new guidelines. In 2003, CAEP was still known as NCATE. To achieve National Recognition as an NCTM accredited program all of the following requirements had to be met.

- The CAEP requirement for an 80% pass rate on state licensure test(s) is met.

    - 2 academic years of completer data are required if there are 10 or more completers in the most current academic year.
    - 3 academic years of completer data are required if there are fewer than 10 completers in the most current academic year but more than 10 completers in the past 3 academic years.
    - Not applicable toward recognition decision if there are fewer than 10 completers in the past 3 academic years.
- At least 80% of all indicators are met and at least one indicator of each standard is met.
- Data from two administrations of each assessment are included in the report. (NCTM, 2015b, para. 5-6)

Standard 6 of the NCATE/NCTM Program Standards (2003) stated, "Candidates embrace technology as an essential tool for teaching and learning mathematics" (NCTM, 2003, p. 2). This standard was identical for both the middle level and secondary level mathematics and only contained one indicator. Therefore, to satisfy the NCATE/NCTM requirement that "80% of all indicators and at least one indicator of each standard" (NCTM, 2015b, para. 5) be met would mean that this requirement must always be met to receive the national recognition.

In 2012, NCATE became CAEP and the NCTM CAEP standards were revamped to reflect the following changes, which only concerned the percentage of elements required to be met for national certification:

- More than 50% of the elements (essential and required additional) of each standard are met at the acceptable or target level.
- Three assessments (#1, #2, and #6) that collectively demonstrate an 80% alignment to each domain of the *NCTM CAEP Mathematics Content for Secondary (or Middle Grades or Elementary Mathematics Specialist*) are required to support Standard 1 - Content Knowledge.
- Two assessments are required to support all other standards (NCTM, 2015b, para. 2).

The NCTM CAEP standards also were overhauled so that instead of listing a standard for the use of calculators, as was done in 2003, the use of calculators was placed in Standards 3, 4, and 5, as well as being used in all topics listed in the secondary addendum in addition to the middle school addendum (NCTM, 2012). For example, standard 4 was mathematical learning environment and contains the following directive for pre-service teacher candidates, "apply mathematical content and pedagogical knowledge to select instructional tools such as ... mathematics-specific technologies and make sound decisions about when such tools enhance teaching and learning" (NCTM, 2012, p. 3).

The use of calculators was used in all topics listed in the secondary addendum in addition to the middle school addendum (NCTM, 2012). Since the use of calculators was provided for in each topic from Number and Quantity to Discrete Mathematics, once again it was not possible to receive national recognition from NCTM if the teacher preparation program did not teach how calculators could be used in the classroom.

As of fall 2015, NCTM had certified 108 schools in *Praxis®* states at a given level for preparing pre-service mathematics teachers (CAEP, 2015b). Table 2.1 indicates the wide variety of schools which were eligible for this study. Those with grade level "not stated" could be any grade level from 5th to 12th grade. Therefore, none of the institutions listed as grade level "not stated" were contacted because this research study was focused on Middle Level and Secondary certified institutions. The intention was to contact a variety of institutions in order to have a representative sampling of the different types.

Table 2.1

Types of NCTM Certified Institutions and the Level of Certification

Grade Level	Public	Private	Christian	Black	Women's	Online	Totals
4th - 8th	1	0	0	0	0	0	1
5th - 8th	1	0	0	0	0	0	1
5th - 9th	2	0	1	0	0	1	4
5th - 12th	5	0	1	0	0	1	7
6th - 8th	1	0	0	0	0	0	1
6th - 12th	4	0	0	0	0	0	4
7th - 12th	27	2	3	2	0	0	34
9th - 12th	2	1	2	0	1	0	6
5th - Adult	2	0	1	0	0	0	3
Algebra I	1	0	0	0	0	0	1
Not Stated	16	8	8	1	0	0	33
Secondary	6	2	5	0	0	0	13
Totals	68	13	21	3	1	2	108

Conference Board of Mathematical Sciences

The Conference Board of Mathematical Sciences (CBMS) was founded in 1960 but can trace its beginnings as far back as 1942. The CBMS was originally comprised of seven member societies and has increased to its present number of 17 member societies (CBMS, n.d.). These societies all

> have as one of their primary objectives the increase or diffusion of knowledge in one or more of the mathematical sciences. Its purpose is to promote understanding and cooperation among these national organizations so that they work together and support each other in their efforts to promote research, improve education, and expand the uses of mathematics. (CBMS, n.d., para. 1)

CBMS primarily engages in short term projects such as “The Mathematical Education of Teachers II” (2012) which was the latest publication in the *Mathematics Education Series* published by CBMS.

CBMS engages in a “Statistical Abstract of Undergraduate Programs in the Mathematical Sciences in the United States” once every five years (Blair, Kirkman, & Maxwell, 2013). The latest survey results released in 2010 contained detailed studies of undergraduate mathematics departments as well as a special topic of mathematical education programs (Blair et al., 2013). This survey revealed that of the four-year institutions who had a certification program, only 8% of those institutions had classes which were team taught by mathematics professors and education professors, although 97% of U.S. universities have both a mathematics and education departments (Blair et al., 2013).

The 2010 survey completed by CBMS also reported the resulting percentage of mathematics departments at four-year institutions offering courses to secondary pre-service teachers (Blair et al., 2013) as shown in Table 2.2.

Table 2.2

College Courses offered to Secondary Teachers

Course Name	Percentage
Advanced Calculus/Analysis	2%
Modern Algebra	4%
Number Theory	3%
Geometry	19%
Discrete Mathematics	6%
Statistics	5%
History of Mathematics	20%

Note: Adapted from Blair et al., 2013, p. 54.

CBMS also reported that their survey findings showed that 73% of four-year university College Algebra courses and 72% percent of Elementary Statistics courses allowed the use of calculators; although, how often and for what the calculators were used was not asked (Blair et al., 2013).

Praxis®

The Praxis Series® of tests were created by Educational Testing Services (ETS) to allow states a “standardized mechanism to assess whether prospective teachers have demonstrated knowledge believed to be important for safe and effective entry-level practice” (ETS, 2015b, p. 8). The *Praxis®* tests are adopted by different states as one indicator that a teacher has required the “academic skills, subject area knowledge, and pedagogical knowledge” (ETS, 2015b, p. 7) to become a proficient teacher. These assessments “offer states the opportunity to understand if their test takers are meeting the expectations of the profession” (ETS, 2015b, p. 7). Since these tests are identical from state to state, they are comparable and offer interstate mobility and eligibility (ETS, 2015b). For this reason, only states which use the *Praxis®* tests are considered for this study.

Praxis® tests are developed using the *Standards for Educational and Psychological Testing* which has strict guidelines that must be adhered to. Furthermore, each test is prepared to assess the test taker’s knowledge that either may not be readily available, too difficult or expensive to obtain, or may not be found accurately from other sources (ETS, 2015b). Each tests undergoes a strict nine-step development process which include the National Advisory Committees of ETS as well as outside experts (ETS, 2015b).

Praxis® CORE academic skills tests are administered in 27 states, middle school mathematics tests in 29 states, and 34 states use the mathematics content knowledge test (ETS, 2015d). Four states require no testing to teach mathematics at any level and eleven states administer their own tests for certification (ETS, 2015a).

At the time this study began and after some of the interviewees had already been chosen, Indiana changed from a *Praxis®* state to certifying teachers based upon a state exam that was prepared by Indiana. The new testing guidelines became official as of September 1, 2015. Since I would be questioning the mathematics educators based on what they had been teaching and doing, I felt that this would not affect the outcome of my study and chose to continue using Indiana as planned.

Common Core State Standards for Mathematics

The Common Core State Standards for Mathematics (CCSSM) "is a set of high-quality academic standards in mathematics and English language arts. These learning goals outline what a student should know and be able to do at the end of each grade" (CCSSI, 2016a, para. 2). These standards provide consistent learning goals across the 42 states and District of Columbia, which have adopted them.

The CCSSM listed "use appropriate tools" (CCSSI, 2016b, para.7) and provided an example of such tools when stating "mathematically proficient high school students analyze graphs of functions and solutions generated using a graphing calculator' (CCSSI, 2016b, para. 7). According to Lynch-Davis (2015) "calculators have an important role in supporting and advancing elementary mathematics learning" (para.4).

NCTM described the CCSSM as providing "guidance and direction, and helps to focus and clarify common outcomes" (NCTM, 2014, p. 4). CCSSM "does not describe or prescribe the essential conditions required to ensure mathematical success for all students" (NCTM, 2014, p. 14). "The primary purpose of *Principles to Actions* is to fill this gap between the development and adoption of CCSSM and other standards and the enactment of practices, policies, programs, and actions required for their widespread and successful implementation" (NCTM, 2014, p. 4).

Theoretical Framework

In his essay, “The Classroom Teacher” (1924), Dewey stated “the central problem is how to use all of our existing resources in developing the classroom teacher” (p. 156). Dewey (1924) added “the principle of learning by experience, if it is a good principle for pupils, is a good principle for teachers” (p. 157). Dewey’s philosophy is applicable when educating pre-service teachers in using calculators in their classrooms to teach students.

The theoretical framework used for this study came from the essays of Lee Shulman. Shulman (2004) contended that preparation of teachers should be not only the education department’s focus, but should also involve the particular discipline. "We must teach foundations in such a way that is bound up with the content of instruction. It does not make sense to separate the content from the pedagogy now any more than it did for Dewey in 1896" (Shulman, 1990, p. 309). Shulman (2004) also believed the “transfer of training is the most important single concept in any educationally relevant theory of learning” (p. 77). Research by Shulman and others (e.g., Guskey, 1986; Maeda, Newton, Alexander, & Senk, 2014; Tondeur, van Braak, Sang, Voogt, Fisser, & Ottenbreit-Leftwich, 2012) have repeatedly shown that for teachers to be successful with calculators, the pre-service teachers must have an opportunity to practice using the calculator in a classroom situation.

Conceptual Framework

The conceptual framework used for this study was derived from the *Principles and Standards for School Mathematics* (PSSM) (NCTM, 2000). In 1980 NCTM published *An Agenda for Action* which provided the recommendation that the calculator was to be “integrated and required” (p. 9) in the mathematics curriculum. Two decades later NCTM called “for a common foundation of mathematics to be learned by all students” (NCTM, 2000, p. 5). NCTM’s Technology Principle stated “electronic technologies – calculators and computers – are essential tools for teaching, learning, and doing mathematics” (NCTM, 2000, p. 24) and that “the effective use of technology in the mathematics classroom depends on the teacher” (p. 25).

Review of Literature Concerning Calculators in the Classroom

The Conference Board of the Mathematical Sciences (CBMS) (2012) suggested that calculators, as well as other technology, needed to be learned as a teaching tool – not just for calculating. The authors of this report also indicated that pre-service teachers be required to take coursework in which the tools of teaching – calculators and other technology – be presented in the same manner in which that teacher would use them in the classroom (CBMS, 2012). In a study of mathematics teachers, Simmt (1997) found that these teachers used calculators as an extension of the way they always used to teach the course – only used to observe graphs and transformations. One of the conclusions of Simmt’s (1997) study was that teaching the way the class has always been taught could be changed if teachers felt more comfortable using calculators.

After conducting five years of experiments concerning teacher professional development using technology, which have been published in at least 12 different articles, Mishra and Koelher (2006) determined part “of the problem, we argue, has been a tendency to only look at the technology and not how it is used. Merely introducing technology to the educational process is not enough" (p. 1018). Their theory was that unless the teacher has technological pedagogical knowledge, a portion of their education was absent and their teaching was lacking (Mishra & Koelher, 2006). Koelher, Mishra, and Cane (2013) expounding on Lee Shulman's framework by setting forth the importance of being taught how to teach with technology and being given an opportunity to actually teach with technology.

In 2005, NCTM published a Joint Report with the Association of State Supervisors of Mathematics (ASSM) called *Standards & Curriculum: A View from the Nation* which compared the mathematics curriculum from state to state and found that calculator use was not mentioned or "noted weakly" (Lott & Nishimura, 2005, p. 50). By this time many studies (e.g. Banks, 2011; Roberts, 2002: Willoughby, 1983) had documented that calculators and other technologies were gaining popularity as instructional tools and were used on national assessments such as the ACT. One wonders why there was this continuing lack of emphasis to include calculators in curriculum standards documents.

Hardy (2008) investigated nine pre-service secondary mathematics teachers taking a methods course, taught by him, for teaching secondary mathematics. During this course, participants were given ample opportunity to build knowledge from their own experiences including building lessons incorporating the use of calculators and other technology. Hardy (2008) found "teachers and teacher candidates have also criticized teacher educators for espousing teaching with technology but failing to integrate it into their own pedagogy" (p. 4468). Brown et al. (2007) found that more than 800 pre-service mathematics teachers felt the need for methods courses integrating the use of calculators in their teaching. By integrating calculators in to their own teaching, teacher educators could show how "a professional is capable not only of practicing and understanding his or her craft, but of communicating the reasons for professional decisions and actions to others" (Shulman, 1986, p. 13).

In summary, professional organizations have recommended calculators be used by students. Accrediting organizations have proposed that pre-service teachers not only be taught how to use calculators to instruct students but that these pre-service teachers be allowed time to practice using calculators to teach (CBMS, 2012; NCTM, 2000). One recommendation has been that more methodology courses providing activities for using a calculator by the pre-service teachers should be required during initial training (Brown et al., 2007).

The Impact on Students

As was noted earlier, the ultimate consumers for a mathematics teacher are the students. NCTM has very carefully outlined six principles which lay the “foundation of mathematics to be learned by all students” (NCTM, 2000, p. 5). These six principles are: “equity, curriculum, teaching, learning, assessment, and technology” (NCTM, 2000, p. 11). These principles ensure that all students can learn and understand mathematics and use mathematics to meet the standards which NCTM has put forth (NCTM, 2000). NCTM listed problem solving, reasoning, communication, representation, and connections among the process standards (NCTM, 2000), in addition to the principle of technology.

Problem Solving: Problem solving ensures that the student is able to use the facts, concepts, and procedures they have acquired. Middle school years are a time for making mathematics fun and applicable to the real world by choosing problems carefully. “Students acquire an appreciation for, and develop an understanding of, mathematical ideas if they have frequent encounters with interesting, challenging problems” (NCTM, 2000, p. 211). Calculators can be used for the students to build independence when solving problems (Campbell & Stewart, 1993). Calculators also foster enthusiasm and confidence while allowing for more persistence by the student (Campbell & Stewart, 1993). For example, the teacher could hand out a sheet, which was prepared in advance, giving the instructions of how to build a house with one window. After having built the house with one window on the calculator by plotting points and connecting them with lines, the students would have to add another window, or a door, or maybe even a chimney to the house. By using their calculators to perform enjoyable, real-world activities, the teacher has used the students’ enthusiasm to complete the problem to help build their confidence in solving problems.

Reasoning: Reasoning is another standard of NCTM’s which all students should have ample opportunity to display (NCTM, 2000). Teachers can foster mathematical reasoning by carefully selecting problems requiring deductive and inductive reasoning (NCTM, 2000). In mathematics, inductive reasoning is used to make a guess at a property; however, deductive reasoning is used to prove that the property holds true for all cases (Underwood, 2000). An example of deductive reasoning is “When the wind blows in West Texas the sky is brown. The wind is blowing in West Texas today. Today the sky is brown.” In deductive reasoning, the first statement is the hypothesis statement, and if it is true, as well as the following statement being true, then the conclusion will be true (Bradford, 2015). However, in the example provided, the first statement is not always true; therefore, the conclusion is faulty. Inductive reasoning takes specific examples to reach general conclusions, such as “My math teacher is skinny. My last math teacher was skinny. All math teachers are skinny.” Inductive reasoning uses observations and patterns to discern a pattern. Even if the first two statements are true, with inductive reasoning, the conclusion can be false (Bradford, 2015).

Communication: When teaching reasoning, or allowing students to display their reasoning skills, it is important that the students communicate why and how they worked the problem the way they did (NCTM, 2000). Communication is another standard for mathematics students of all levels (NCTM, 2000). Being able to communicate the how, why, or what of a problem are just as important as being able to problem solve and reason through the problem. Communication has many forms. The solution to a problem could be conveyed by verbal explanation, written explanation, modeling it with manipulatives, presentations such as PowerPoints and SmartBoards® as well as using calculators to model the solution. According to the Mathematical Association of America (MAA) (2016) communicating to learn mathematics is just as important as learning to communicate mathematics. When communicating mathematics, the purpose is not for the student to prove that they understand how to do the mathematics but to explain how to work the problem so that others understand the mathematics (MAA, 2016). Being able to solve any given problem does no good if you are unable to communicate the process you used to solve the problem as well as the solution to the problem.

Representation: Representation is another standard given by NCTM for students to learn (NCTM, 2000). Graphing was a topic that was not in the textbooks for high school Algebra over 100 years ago (Nyberg, 1924; Stone & Millis, 1906). Today, students must not only graph but also represent the problems by using tables, graphs, verbal descriptions, or algebraic symbols. Figure 2.3 shows a graphical representation and a tabular representation. The symbolic description is y = 2x + 1 and a verbal description could be "You are building two chimneys with a block on top of one of the chimneys. How many blocks does it take to build the chimneys?"

x	Math	y
0	2(0) + 1	1
1	2(1) + 1	3
2	2(2) + 1	5
3	2(3) + 1	7
4	2(4) + 1	9
5	2(5) + 1	11
n	2n + 1	

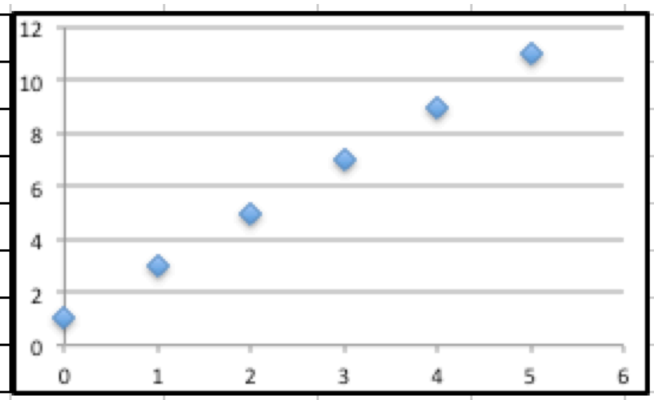


Figure 2.2. Graphical representation and the associated data.

NCTM (2000) believes that representation is central to the study of mathematics and suggests that students:

- "Create and use representations to organize, record, and communicate mathematical ideas
- Select, apply, and translate among mathematical representations to solve problems
- Use representations to model and interpret physical, social, and mathematical phenomena" (p. 280)

Students must be able to understand how the different representations are connected to each other and which representation will best answer their problem (NCTM, 2000). The graphing calculator is an effective tool for allowing students to practice these different representations (Kastberg & Leatham, 2005). Figure 2.3 is a screen shot of the TI-Inspire which is being used to enable students to "represent relationships among quantities using visual models, tables, graphs, and words; and define, evaluate, and compare functions" (Texas Instruments, 2014, p. 2).

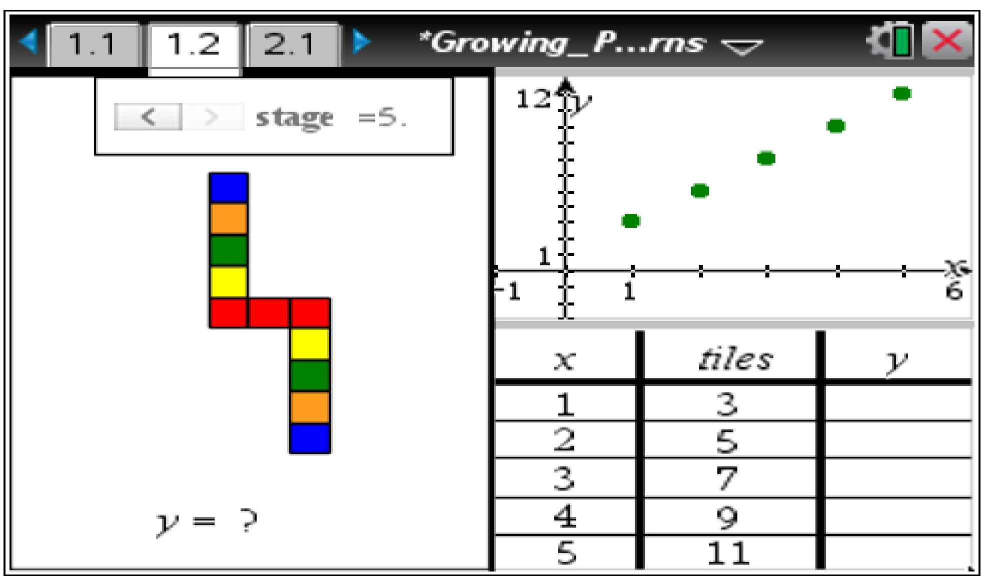


Figure 2.3. An example of using the TI-Inspire to teach multiple representations of functions. Courtesy of Texas Instruments.

Preparing for a lesson and knowing how to use the calculator to teach the lesson requires previous knowledge of not only the content but the many features of the calculator itself. When pre-service teachers are not exposed to modeling of this type of problem, they are unprepared to adequately teach students how to use the calculator. As a result, students will not be adequately prepared to face today's challenges, whether that is passing a state exam, passing the SAT, or working on technological advances (Bahr, Monroe, & Eggett, 2014).

Connections: This process standard includes connecting mathematical ideas as well as connecting mathematics to context outside of mathematics (NCTM, 2000). For example, a student in wood shop might use the Pythagorean theorem he/she learned in mathematics class to calculate the length of a board needed to complete the rafter between the ceiling joist and the ridge plate. Or perhaps the physics student is using their mathematical knowledge of using the diameter or radius to find the circumference to calculate rotations per minute of a gear. Building these connections between content areas allows the students' of today to be better prepared to face a future of technological advances of which we can only dream.

Each pre-service teacher must be adequately prepared to implement the PSSM in teaching mathematics. However, if the pre-service teacher has not been exposed to teaching with a calculator – not just using a calculator – then that pre-service teacher will revert back to using identical methods that were employed when they were students (Simmt, 1997; Walen, Williams, & Garner, 2003). Walen et al.'s study included 66 pre-service mathematics teachers and discovered the pre-service mathematics teachers had never used the tool for teaching – "only as a tool for doing mathematics" (Walen et al., 2003, p. 459). Simmt (1997) observed six high school mathematics teachers, who only used calculators to facilitate graphing in lessons the teachers had previously taught but not to "encourage conjecture and prove or refute ideas" (p. 275). Researchers have concluded that teachers revert back to methods they were taught with until the teacher can be shown the benefits of calculator use (Simmt, 1997; Walen et al., 2003).

Calculators in the Classroom

Many research studies have been completed concerning calculators and students. A few of these studies have been included in this section as examples of the type of research done and some of the important findings.

High School Students in Calculus: In a study done by Santos, Aguero, Borbon, and Paez (2003), 24 students were given the task of solving the following problem:

> The distance between two poles is 10 m as shown in the figure [2.4]. The length of each pole is 3 and 5 meters respectively. To support the poles, a cable from the top of each pole will be tied to a point on the ground between the two poles. Where should that point be located in order to use the minimum length of cable? (p. 121).

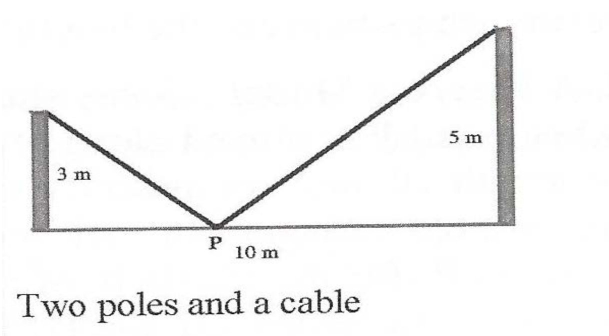


Figure 2.4 Diagram of problem (Santos et al., 2003, p. 121).

Students were allowed to work in groups or individually and utilized many different models to solve the problem: discrete model using a visual approach, symbolic model using graphical representations of problems, and dynamic model using a reproduction of the problem where P could actually be moved (Santos et al., 2003). While solving this problem, the students realized what a "powerful tool" the calculator could be in exploring "relationships that did not appear in paper and pencil approaches" (Santos et al., 2003, p. 126).

High School Algebra I Students: Heller, Curtis, Jaffe, and Verboncoeur (2005) completed a study of 458 Algebra I students from Oregon and Kansas. Teachers were asked to complete a comprehensive questionnaire including how they used calculators in the classroom, how much time the students spent with calculators, how they learned to use calculators for instruction, and other questions regarding specific topics and whether a calculator was used to teach those topics (Heller et al., 2005). The results of the Heller et al. (2005) study were:

- the more the graphing calculator was used in the classroom during instruction, the higher the students scored on the end of course exam, and
- students with teachers who participated in trainings and workshops on teaching with the graphing calculator scored significantly higher than those students whose teachers were self taught.

This particular study was conducted to provide additional information a prior study (Heller & Paulukonis, 2000) of Algebra I students' success on end of course exams when calculators were used during instruction (Heller et al., 2005). The findings of Heller et al. (2005) reinforced the findings of the Heller and Paulukonis (2000) study.

Middle School Students: Edwards and Ozgun-Koca (2009) conducted a study on 54 middle school students using calculators. Almost 90% of the students liked doing mathematics with a handheld calculator and 72% of the students agreed that the calculator helped them understand the mathematics lesson (Edwards & Ozgun-Koca, 2009). This study also revealed that students were more eager to learn and more motivated when using calculators (Edwards & Ozgun-Koca, 2009).

Elementary Students: Polly (2008) conducted a longitudinal research study involving 13,812 first grade students and 3,753 teachers. The results of this study indicated, when instructional practices such as writing algebraic expressions and explaining strategies were coupled with calculator use, student achievement was greater than with just the instructional practices alone (Polly, 2008). This additional increase in student achievement when calculators were used was due to the students being able to devote more time to conceptual understanding (Polly, 2008). This findings of this particular study indicated that calculators, not just graphing calculators, were beneficial to students (Polly, 2008).

In summary, it is clear that research supports pre-service teachers having an opportunity to practice teaching with a calculator (CBMS, 2012) because of the positive impact for the student. Furthermore, NCTM has mandated that all students will be taught using calculators (NCTM, 2000). Since the end result of preparing pre-service teachers is ultimately the students' ability to survive in a world full of technology, these teachers should be prepared to give the students every advantage to which they are entitled. However a critical question still needs to be addressed, how then do we prepare teachers to use calculators as pedagogical tools?

CHAPTER 3

METHODOLOGY

Planning this qualitative case study began with wondering why calculators are so difficult to teach with. As I continued to plan this study, I realized that I, nor anyone I was acquainted with, had an opportunity to learn how to teach using a calculator.   This led me to review how educators learn to teach with calculators, which became my topic. I began believing that I would perform a quantitative study, however, I soon realized that a qualitative case study would better answer my questions. As in most qualitative studies, the methods changed as the purpose changed. In this chapter, I have elaborated on the how's and why's of the current study.

According to Merriam (2009), "A case study is an in-depth description and analysis of a bounded system" (p. 40). Merriam went on to add "the bounded system, or case, might be selected because it is an instance of some process, issue, or concern" (p. 41). A qualitative case study best represented my study because it involved a bounded study in which I examined how colleges were preparing pre-service teachers with respect to calculator use (Merriam, 2009). I choose only institutions that prepared bachelor degree pre-service middle level and secondary mathematics teachers. Elementary pre-service teachers were not included in my study because NCTM does not recognize this certification. My research was a heuristic case study since it was an "in-depth description and analysis of a bounded system" (Merriam, 2009, p. 23) and served to "illuminate the reader's understanding of the phenomenon under study" (Merriam, 2009, p. 44). In other words, I chose to complete a heuristic case study to enlighten the reader, as well as myself, concerning a phenomenon which occurs often – a teacher, fresh out of college, unable to teach using a calculator appropriately.

Choosing Participants

I used purposive sampling, as defined by Erlandson, Harris, Skipper, and Allen (1993) because my participants were chosen based on several restrictions which ensured my study was bounded (Merriam, 2009). First, each participant taught a mathematics methodology class, which was required by their institution to obtain either middle level or secondary mathematics certification and required of undergraduate students in pursuit of their first degree. Second, each participant was employed by a teacher preparation program certified by CAEP to ensure the quality of the program. Third, each participant was employed by a teacher preparation program requiring the prospective teacher to pass the *Praxis*® Mathematics Content Exam in order to receive certification in that state.

I chose only CAEP certified schools since CAEP is the certifying agency for educator programs. NCTM certified schools were chosen because of their stance on calculator use at all grade levels and the certification that certain programs receive from NCTM saying that those programs maintain that standard. A total of 12 participants were involved in the study.

Along with the above stipulations, three of these participants were from teacher preparation programs which were both CAEP and NCTM certified at the middle level and another three were from teacher preparation programs which were CAEP and NCTM certified at the secondary level. I also selected three participants from teacher preparation programs which were CAEP certified but not NCTM certified at the middle level and the final three participants were from teacher preparation programs which were CAEP certified but not NCTM certified at the secondary level. I intended to compare the data collected from participants at the CAEP and NCTM certified institutions to the data collected from participants at CAEP and non-NCTM certified institutions.

Locating Participants

From the CAEP website, I obtained a list of teacher preparation programs which were certified by CAEP and those which were certified by CAEP and NCTM. Table 3.1 presents the inclusion criteria used to identify institutions for this study. The process of going through the criteria list was repeated until a sufficient number of faculty members for each type of preparation program were located.

Table 3.1

Inclusion Criteria for Institutions

Question	Yes	No
Is the teacher preparation program in a state which requires *Praxis*® content exam for certification?	Next question	Do not include in research
Is the teacher preparation program certified by CAEP?	Next question	Do not include in research
Is the teacher preparation program for those receiving undergraduate degrees?	Next question	Do not include in research
Is the teacher preparation program certified by NCTM?	Next question	Possibly will be used as non-NCTM certified school
Is the teacher preparation program certified for middle school?	Use this program to find a professor	See if program prepares teachers for secondary
Is the teacher preparation program certified for secondary?	Use a random number generator to select program for study.	Do not include in research

Once I located the institutions which met the CAEP and NCTM certification, as well as being in a state where the *Praxis*® Mathematics Exam was required, I used the various institutions' websites to obtain information regarding course requirements and instructor information. An email (see Appendix C) was sent to all prospective participants from the selected institutions explaining my research, requesting their assistance, and requesting an appropriate time to call them for an interview. However, this method of emailing the participants and waiting on them to schedule an interview did not provide enough initial participants. At the end of three months, I only had five total participants. The IRB was amended to allow me to call participants and ask for their assistance once I had emailed them and secured their agreement to participate. The format for the semi structured phone call interviews can be found in Appendix D.

Data Sources

The data sources for this study included interviews, course syllabi, institutional websites containing online course catalogues, textbooks, the NCTM Standards, and my researcher's reflexive journal. Table 3.2 lists the research questions as well as the specific data sources that provided the information required to answer each question. Following the table, each data source has been discussed in further detail.

Table 3.2

Data Sources to Answer Research Questions

Research Question	Data Sources
What do mathematics teacher educators believe about the use of calculators in the classroom?	Course syllabus Interviews Course textbooks Reflexive Journal
How do mathematics teacher educators use methods courses to prepare pre-service teachers to use calculators to develop sound pedagogy?	Online catalogues Interviews Course syllabus Course textbooks Reflexive Journal

Online University Catalogues: The initial source of data for this study were online university catalogues to determine which courses were required for pre-service teachers and for learning outcomes. This data source provided "a context for understanding" the coursework required to complete teacher certification (Erlandson et al., 1993, p. 101). Additionally, this information was used in order to locate the interviewees. I contacted the individuals to see if they taught mathematics courses for pre-service teachers or were mathematics teacher education faculty members.

Interviews: Seidman (1998) stated, “At the root of in-depth interviewing is an interest in understanding the experience of other people and the meaning they make of that experience” (p. 3). In this study, I used interviewing as one of my data sources. Telephone interviews were employed since the cost of traveling to all of the participating states was prohibitive. Fontana and Frey (2000) believed using one type of interviewing over another was the same as the quantitative/qualitative debate of past generations. Miller (1995) concluded that interviews done by telephone were “not better or worse” than those conducted face to face (p.37). Others have concluded it is “worthwhile to consider telephone interviews as a way to enhance qualitative research” (Sturges & Hanrahan, 2004, p. 116).

Interviews were conducted via a telephone call once an email had been sent describing my research in detail. Each interview was conducted after asking whether there were any questions and assuring the interviewee that the interview could be stopped at any time. Using a semi-structured interview format (see Appendix A) as a starting point, I conducted each participant’s call via telephone speaker and recorded the interview with a digital recorder. During each interview, a “Do Not Disturb” sign was placed on my office door.

These technology-enabled conversations were subsequently transcribed as soon as possible after the interview. A transcript of the conversation was emailed to each participant for his or her approval which allowed for member checking (Lincoln

& Guba, 1985). Member checking was used to "provide evidence of credibility – the trustworthiness criterion analogous to internal validity in conventional studies" (Lincoln & Guba, 1985, p. 374). The only correction that was made to the transcripts was when I misspelled the name of one of the previous classes that the participant had taught.

Course Syllabus: Once these courses were selected and a contact with a faculty member was established, I then requested a course syllabus for these particular classes during the interview to further help me understand the coursework (Erlandson et al., 1993). These syllabi were used to ascertain any assignments involving calculators, whether or not any NCTM publications were required, and which calculator, if any, were required for the course. The syllabi were also used to lead me to the course textbook and resources such as NCTM's *Principles to Actions.*

Couse textbooks: The textbooks provided information concerning how calculators were mentioned in the book and potentially used in the mathematics methods class. Any assignments from the book could help facilitate understanding of the professors' beliefs concerning calculators and their use in the classroom (Erlandson et al., 1993).

Researcher's Reflexive Journal: Another data source was the reflexive journal I kept during this study. Lincoln and Guba (1985) suggested that a reflexive journal was a daily record "about self and method" (p. 327). I used the reflexive journal to keep a record of my thoughts and feelings, as it pertained to this study. For instance, I made entries while compiling the literature review, following interviews, while transcribing interviews, following the transcription of interviews, while analyzing the interview transcripts, and so forth. By looking back on this journal as I was analyzing the data and writing the paper, I was constantly reminded of the basis of my decisions and the processes which occurred during the course of this study (Lincoln & Guba, 1985).

Data Analysis

According to Erlandson et al. (1993), analysis of data begins the first day of data gathering. Interviews were digitally recorded, transcribed, and then analyzed using the constant comparative method during readings of the transcripts and the documents. As I read the transcripts, I compared them to previous incidents and coded them appropriately (Glaser & Strauss, 1967). “The purpose of the constant comparative method of joint coding and analysis is to generate theory more systematically than is allowed by using explicit coding and analytic procedures” (Glaser & Strauss, 1967, p. 102). After I gathered the data from the interviews and the documents, I continued the process of analyzing that data which I had started the first day of this study. Strauss and Corbin (1998) feel that “the purpose of analysis is to build theory” therefore as I analyzed my data, I constantly kept this thought in mind (p. 88).

First, after reading each data source through three times, the interviews and syllabi collected were coded by hand for any themes or trends. Second, selected portions of the interviews and syllabi were entered into a spreadsheet to expedite viewing of the data and sorting. Data was then uploaded into Dedoose, a web application for analysis of qualitative and/or mixed methods data (Dedoose, n.d.). "Using a computer-assisted qualitative data analysis program can take qualitative data analysis much further than is possible compared to conducting the analysis manually" (Leech & Onwuegbzie, 2011, p. 71).

Each data file in Dedoose was then tagged with descriptors to identify demographic information of each participant. These descriptors included pseudonyms, years taught, title and position, name of course, and other information. Once tagging was completed, I further unitized the data by disaggregating it into smaller pieces of information (Erlandson, et al., 1993). These "excerpts" (as they are known in Dedoose) are short phrases or words which "will, sooner or later, serve as the basis for defining categories" (Lincoln & Guba, 1983, p. 344). The unitized data was assigned different codes which were eventually narrowed down to 35 different codes.

Leech and Onwuegbuzie (2011) listed seven types of analysis including constant comparison, keywords in context, and word count. These authors believe that by using computer software to analyze the data, multiple types of analysis can be performed to aid the emergence of underlying theories and relationships (Leech & Onwuegbuzie, 2011). By using multiple types of analysis, Leech and Onwuegbuzie (2011) assert that analysis triangulation is accomplished which improves the trustworthiness of the study.

Following the constant comparative method of coding, I used the word count feature in Dedoose to obtain the number of times which certain words, such as "tool" and “appropriate,” were used during the interviews by the participant. Codes were also counted using classical content analysis so that the codes that were most often used became apparent (Leech & Onwuegbuzie, 2011). Once all of the data were coded and sorted, I compared the coded data and the literature review in order to obtain the overall meaning of the data.

In the final analysis step, the coded, unitized, and categorized data were analyzed for themes, which were ultimately considered with the two research questions in mind. Thirteen different themes emerged which ultimately were reflected in the two research questions, for example, “I don’t use one in class” was combined with “I don’t need one in class” to become “I don’t teach with a calculator”.

Trustworthiness

For a qualitative study to be considered rigorous, the trustworthiness of the study must be shown. Trustworthiness is comparative to internal validity for a quantitative study (Lincoln & Guba, 1985). Lincoln and Guba (1985) listed four methods which should be used to ensure trustworthiness: credibility, transferability, dependability, and confirmability. To establish trustworthiness, four requirements must be met: “truth value, applicability, consistency, and neutrality” (Lincoln & Guba, 1985, p. 290).

Credibility: Credibility was shown by triangulation of three or more data sources (Lincoln & Guba, 1985). Triangulation was achieved by “the use of multiple and different sources, methods, investigators, and theories” (Lincoln & Guba, 1985, p. 305). By comparing the interview transcripts, the course catalogues, course syllabi, and my reflexive journal notes, triangulation was achieved during the analysis phase as well as throughout my study.

Lincoln and Guba (1985) also listed member checks as another method of establishing credibility. Once I completed the interviews and transcribed them, I emailed the transcript to each participant for their approval. By providing them with those transcripts, the individual had the opportunity to approve or deny what I understood had been said during the interview.

Dependability: The second way in which trustworthiness can be achieved is by dependability. This can be established by developing an audit trail. For this study my reflexive journal was used to satisfy this requirement (Lincoln & Guba, 1985). "The reflexive journal, a kind of diary in which the investigator on a daily basis, or as needed, records a variety of information about self and method" (Lincoln & Guba, 1985, p. 327). My thoughts concerning what I was told during the process of preparing for this study, what I was told during the interviews, and how I perceived what I have been told were recorded in this journal to assist with my data analysis.

Following the interview, pseudonyms were assigned to identify the professor and to further enhance the audit trail. To further assist in the audit trail, each line of the transcribed interview was numbered so that each quote could be referred to by the type of certification the institution has, the grade level at which the institution is certified, the interview order followed by a dash, and then the line of the transcript the quote is contained. For instance, NCTM ML2-42 would mean that this institution was CAEP and NCTM certified for the middle level, this was the second completed interview, and the quoted material can be found on line 42. CAEP SEC3-24 would mean that this was a CAEP certified institution but not NCTM for the secondary level, this was the third completed interview, and the quote could be found in line 24 of the transcript. For the syllabi, an S will follow the interview number, so that, NCTM SEC4S-36 would be a CAEP and NCTM certified secondary institution, from the fourth interview conducted, and the quoted material was from line 36 of the syllabus. If a statement from my reflexive journal is cited the reference will be RJ12.2.15-32, which means the reflexive journal entry from December 2, 2015 line 32 was quoted. When quoting any material from the data sources, a pseudonym will be referred to along with the data explained above. Each pseudonym was assigned at the time of transcription and a detailed list of participants along with pseudonyms, number of years at the institution, as well as other demographic data have been listed in the findings in chapter IV.

Confirmability: Confirmability can be established in several ways, however, triangulation, keeping a reflexive journal, and an audit trail (Lincoln & Guba, 1985) were the main components used to address confirmability. By maintaining a detailed audit trail, I am ensuring that my research cannot only be confirmed but can also be duplicated.

The audit trail began with my list of criteria for inclusion found in Table 3.1. This trail continued from the CAEP website to the NCTM website and then on to the institutional websites. Once possible participants were located by finding the courses posted as required by the instructors or the professor for each class, then an email describing my research was sent to the individual. Some participants answered my email request for an interview while others had to be reminded by calling and asking for an interview. At that time all participants were asked for a syllabus to the course described; all but two participants sent a syllabus. I used triangulation to double check interview data with actual course assignments.

I also used my reflexive journal to make any notes about the interview I particularly wanted to remember. For instance, the tone of the participant's voice as the questions were asked or whether or not s/he hesitated when asked certain questions. I also used the reflexive journal to record any thoughts or processes that I considered along the way (Lincoln & Guba, 1985).

Transferability: The fourth way in which trustworthiness can be established is by transferability through using purposive sampling (Lincoln & Guba, 1985). As stated earlier, my sampling was purposeful. I have also used thick description – whereby the readers can determine if the context and the sampling could match his or her own research and whether the study might be replicated (Lincoln & Guba, 1985).

My steps to address trustworthiness ensure that my study can be replicated with accuracy. The main limitation to my study was in the number of participants. Originally, I wanted a total of 20 participants, five from each of the four categories in my study. However, although numerous attempts for requests to participate in the study were sent, this number was not achieved. A compromise of 12 participants or three from each category was accepted. Since most participants answered the questions in the same manner, I believe that a consensus can be drawn from the 12 interviews and other data.

In summary, my study has trustworthiness because of credibility, dependability, confirmability, and transferability (Lincoln & Guba, 1985). I have established credibility with triangulation and member checking, dependability with an audit trail, confirmability with triangulation and reflexive journal, and transferability with purposive sampling and thick description (Lincoln & Guba, 1985). All of these qualities ensure that my research study was valid and can be replicated.

Researcher Bias

Having taught mathematics at the high school level for 19 years, I bring certain biases to this study. One of the biases is due to me having worked with first year teachers, newly certified to teach, who had absolutely no idea how to use calculators to instruct students. Another bias, which happened personally was taking mathematics courses at the college level and the professors not modeling calculator use. In fact, most of my college professors did not allow calculators for any mathematics class. That was 20 years ago and I was hoping to find that things had changed. I entered this research with the assumption that I would find college professors were not adequately preparing pre-service mathematics teachers to use calculators effectively as an instructor and perhaps the reason was they had no idea how to incorporate them into their own courses.

I was emergency certified, which means I was hired with the understanding that I would complete all necessary steps required for teacher certification except student teaching within three years. Since I was emergency certified, I was immediately thrust in to a classroom full of students expecting me to know what I was doing. I found out that being able to use a calculator as a problem-solving tool and being able to use a calculator as a teaching tool were two totally different things. For instance, when you use a calculator to solve a problem, the wrong key can get pressed and you just correct it. However, when you are demonstrating to 25 14-year-olds how to solve a problem and you tell them the wrong key stroke, then your mistake just became amplified 25 times. After 19 years of seeing new teachers begin teaching, I also found that pre-service teachers have not been provided time to learn to teach or even practice teaching with calculators either in mathematics courses or mathematics education methods courses.

Limitations

The primary limitation to my study was the number of participants. I originally wanted to interview 20 participants, five from each group. However, I had difficulty finding 12 participants that were willing to be interviewed even after sending out additional requests. Another limitation to my study was that I only interviewed the participants one time. In some cases, once was enough, but there were a couple of the participants whom I tried to reach with follow up questions once I had reviewed their syllabus, but they failed to respond to the request. My intention was to question the participants further about their use of calculators in that some required a lesson to be planned using a calculator, but I wondered if the pre-service teacher's were ever required to actually present the lesson. If the lesson was presented, I would liked to have known what the pre-service teacher learned from that experience and how would they use what they learned in their future classrooms to help students be more successful. However, that type of information would have been best obtained from the pre-service teachers, not the participating teacher educators.

This chapter described how the data was obtained and categorized as well as how the validity of my research was established. I described which data sources were used and how each one was used. I also described how the data was analyzed and how my audit trail was styled. The practice for dealing with quotes from participants was also explained. Listing researcher biases and any limitations to this study completed the chapter.

CHAPTER 4

FINDINGS

The findings of this study have been used to answer the two research questions, which were:

- What do mathematics teacher educators believe about the use of calculators in the classroom?
- How do mathematics teacher educators use methods courses to prepare pre-service teachers to use calculators to develop sound pedagogy?

Conducting interviews and comparing comments from interviews with the syllabus for the course used to prepare the pre-service mathematics teacher were used to answer to each of these questions.

Participant Descriptions

Context is important in qualitative studies. In order to aid the reader in understanding the participants' responses, I have provided demographical information concerning the 12 instructors and faculty members who agreed to participate in the study (see Table 4.1). This information was compiled from the participants' responses to interview questions one through five (see Appendix A). Four male and eight female higher education faculty participated in my study. Eight of the interviewees had earned a doctoral degree with the remaining four holding a master's degree. Of the eight doctoral degrees, the specialization ranged from pure mathematics to curriculum and instruction with an emphasis in mathematics education. The average number of years of experience in teaching pre-service mathematics teachers for all 12 participants was 13.25 years, with a range of 2 years to 32 years.

Table 4.1

Demographics of Participants

	Mid Level NCTM	Mid Level Non-NCTM	Secondary NCTM	Secondary Non-NCTM	Total
Gender:					
Male	1	2	1	0	4
Female	2	1	2	3	8
Average No. of Yrs. Teaching Pre-Service Teachers	8.3 years	12 years	14.7 years	18 years	13.25
Methods Taught by Department:					
Education	1	1	3	3	8
Mathematics	2	2	0	0	4
Highest Degree Held:					
Master's	1	1	0	2	4
Doctorate	2	2	3	1	8

For this study, eight of the participants indicated the mathematics methods classes were taught in the education department with the other four participants stating these courses were taught in the mathematics department. None of the mathematics methods courses were team taught between the two departments. To further describe the participants, following is a list of pseudonyms and more specific data based upon the type of certification (NCTM or Non-NCTM) and the grade level of pre-service teacher they prepare.

- NCTM Certified for Middle Level:

  - Linda has taught at the same public university for the last two and a half years however, she has been teaching classes which prepare mathematics teachers for the last 6 years. Linda has also taught College Algebra and Intermediate Algebra as well as Secondary Mathematics Methods. She has a Ph.D. in curriculum and instruction with an emphasis in mathematics education.
  - Joshua has taught classes which prepare mathematics teachers at the same public institution for 5 years. Joshua has only taught elementary and middle level mathematics methods. He has a Ph.D. in educational inquiry, measurement, and evaluation with a specialization in mathematics education.
  - Catherine has taught classes which prepare mathematics teachers for the last 10 years, all at the same online university. She also mentors pedagogy courses, history, writing, and general education mathematics classes. She has a master's in teaching and a master's in mathematics.
- CAEP Certified but Non-NCTM for Middle Level:
  - Richardo has taught classes which prepare pre-service teachers for the past 7 years at the same public university. Richardo also has taught calculus and algebra. He has Ph.D. in mathematics.
  - DeeDee has taught at the same Christian university for the last 25 years and has taught pre-service mathematics teacher for 24 years. DeeDee has taught Calculus 1, 2, 3, College Geometry, Linear Algebra,

Abstract Algebra, and Sense and Logic. She has a Ph.D. in pure mathematics.

  - Bryson has taught for the last two years at the same Christian university and has taught pre-service mathematics teachers for both of those years. Bryson has taught teaching secondary methods and secondary school issues. He has a master's degree in history and was a Nationally Board Certified teacher.

- NCTM Certified for Secondary Level:
  - JoJo has taught pre-service mathematics teachers for 32 years at the same Christian institution. JoJo has taught calculus as well as mathematics methods for secondary mathematics students. She has a master's degree in natural science.
  - Rueben has taught at the university level for 10 years and pre-service mathematics teachers for 5 years at a Christian institution. Rueben has taught Foundations of Algebra, College Algebra, Elementary Statistics, Trigonometry, Calculus, mathematics for elementary teachers, geometry for middle school teachers, and secondary methods for mathematics. He has a Ph.D. in education with a minor in mathematics.
  - Martha has only been at her current public university teaching pre-service mathematics teachers for two years but has taught for 20 years. Martha teaches a sequence of three courses for elementary and middle

level teachers and mathematics methods for secondary teachers. She has a Ph.D. in mathematics education.

- CAEP Certified but Non-NCTM for Secondary Level:
    - Laura has taught for pre-service mathematics teachers at the same public institution for 6 years. Laura has taught Elementary Science Methods, Elementary Mathematics Methods, Secondary Science Methods, Secondary Mathematics Methods, Mathematics for Elementary Teachers, Euclidean Geometry, and Differentiating Instruction. She has a master's degree in secondary education.
    - Rea has taught at the college level for 25 years and pre-service mathematics teachers for 20 years at the same private college. Rea has taught secondary mathematics education and secondary classroom environment. She has a master's degree in secondary mathematics education.
    - Jill has taught the last 20 years at the same Christian institution where she teaches pre-service mathematics teachers. Jill teaches methods and materials in the education department. She has a Ph.D. in curriculum and instruction.

Findings Related to Second Research Question

My second research question, "How do mathematics teacher educators use methods courses to prepare pre-service teachers to use calculators to develop sound pedagogy?" was best answered in the questions and answers outlined in Table 4.2.

Table 4.2

Answers to Selected Interview Questions

	Mid Level NCTM	Mid Level Non-NCTM	Secondary NCTM	Secondary Non-NCTM	Totals
Describe how you use calculators in your mathematics methods classroom.					
- I do not use it to teach with	2	3	3	2	10
- To support instructional objectives	1	0	0	1	2
How did you learn to use a calculator to teach with?					
- Workshops	0	0	1	0	1
- Self-taught	0	0	1	1	2
- College course	1	0	0	0	1
- Did not answer	2	3	1	2	8
Describe how students use calculators in your mathematics methods classroom.					
- CBR Lab	0	1	0	0	1
- Debate appropriate uses	2	0	0	0	2
- Present a lesson	0	0	2	0	2
- They do not use it	1	2	1	3	7
For what topics or concepts do you feel calculators are inappropriate?					
- Computation/perform operations	3	3	3	3	12

The answers have been divided between middle level NCTM certified institutions and non-NCTM institutions, as well as secondary level NCTM certified institutions and non-NCTM institutions.

To summarize Table 4.2, 10 of the 12 participants said that they did not use the calculator to teach students. The other two participants allowed the pre-service teachers to use calculators in their class to support the instructional objectives of the day. When the participants were asked how they learned to use the calculator as an instructional tool, eight of the 12 did not actually answer the question. The remaining four participants learned to use the calculator as an instructional tool as follows: two were self taught, one learned in workshops which he attended, and one learned in a technology course during his graduate work.

Seven of the 12 participants reported they did not use the calculator in the mathematics methods classes which they taught to prepare pre-service teachers. Of the five that did use the calculator in their methods classes, one participant required the pre-service teachers in the mathematics methods class to prepare a lesson and another participant reported requiring one of the pre-service teachers to prepare and present a calculator focused lesson to the rest of the class. A third participant had a lab where the pre-service teachers were allowed to interact with a CBR and TI calculator so that they could understand how the CBR could be used in graphing; however, the pre-service teachers were not required to prepare a lesson using that information. The final two participants discussed appropriate uses for the calculators' in the mathematics classroom.

All 12 of the participants had the same response when asked what topics were inappropriate for children to use calculators. All 12 participants thought that calculators were inappropriate for calculations and performing computations. These findings will be discussed in the following sections.

Calculator Use by Instructors in Class: There were only two different answers given to the question of how the instructor used the calculators in class. The first was demonstrated by Martha (pseudonym), who said she taught with calculators "more in the math class than in the methods class" (NCTM SEC9-55). All but two of the instructors said they did not teach mathematics methods with the calculator. The two professors who said they taught with a calculator did so "to support the instructional objective" (NCTM ML2-61) of the day.

As to how the participants learned to use calculator during instruction, some of the participants avoided answering the question. Eight of the 12 participants had replies similar to DeeDee who stated, "The students can use them [calculators] but I don't teach with it" (CAEP ML1-57), which really did not answer the question of how she learned to use calculators during instruction. Richardo indicated he used calculators "very rarely" (CAEP ML11-46), which also did not directly answer the question. The remaining four answers varied from being self taught (NCTM SEC7; CAEP SEC6) to workshops (NCTM SEC5) to a course in college which "focused on technology use" (NCTM ML2-48).

Pre-Service Teacher Use of Calculators: The answers were a little more varied on how the pre-service teachers used the calculators in the methods class, however, seven of the 12 said that they required no lesson involving the calculator and only two of the remaining five said that they required the pre-service teachers to prepare a lesson using the calculator. Most of the answers were similar to Linda's who stated,

> Because mine is a methods course, I focus more on the appropriate use of technology. We don't use calculator for computation but ... to help pre-service teachers to know when it is appropriate – when appropriate opportunities are for their kids to use it. (NCTM SEC3-58)

Roberto mentioned "a lab where they use the CBR (Calculator Based Ranger) with the TI (Texas Instruments) calculators to learn how to use the CBR" (CAEP ML11-49). The last two participants agreed in principle with Joshua who said

> I give them some reading, Van de Walle's most current text and they do some reading in NCTM's *Principles to Action* and then I have them construct arguments for ways in which technology can be used as a tool for learning and ways in which technology can be used inappropriately to do the thinking for the students (NCTM ML2-66).

However, other participants' responses were that the pre-service teacher could use calculators for computational purposes, but no lesson plans were required to be developed and submitted (NCTM SEC7, NCTM SEC9, and NCTM ML3).

Findings Related to First Research Question

The first research question, "What do mathematics teacher educators believe about the use of calculators in the classroom?" appeared to be best answered by the participant's responses to the last three questions of the interview protocol concerning their philosophy with regard to calculator use, appropriate uses of the calculator, and NCTM's calculator policy statement.

NCTM Principles: A question pertaining to NCTM Technology Principles was posed to the participants. “In a position statement in July of 2011, concerning the use of calculators, NCTM stated, ‘the proper implementation of the Technology Principle depends on teachers’ creating approaches to classroom instruction that appropriately integrate the use of technology into lessons focused on learning mathematics.’ What is your impression of this?”

Nearly all participants stated the importance of the principle but were quick to qualify the statement. For instance, Laura said, “I agree with NCTM on this. I feel that a tool – any tool – can be beneficial in the classroom as long as it is being used to help children understand the math in appropriately structured ways” (CAEP SEC6-108). DeeDee believed that “[technology] shouldn’t be ignored, that’s for sure, but I want [the children] to know the theory behind what they are doing” (CAEP ML1-93). When asked if he believed in what NCTM had to say about technology, Joshua stated, “Yes [I believe in technology], but you have to consider it alongside the instructional objectives” (NCTM ML2-87). Martha replied, “I am a firm believer in this [the use of technology]. My students read those technology statements and I require my students to join NCTM” (NCTM SEC9-98). Linda only said, “I agree with that” (NCTM ML3-96) but then later said, “In elementary, it is not appropriate for teaching computation” (NCTM ML3-100). Richardo answered, “I think pre-service teachers need time practicing teaching period” (CAEP ML11-75). In general, all of the participants agreed with the statement; however, each one of them were quick to add a qualifying statement.

Appropriate Uses of Calculators: The next to the last question asked, "For what topics or concepts do you feel calculators are appropriate?" Some of the participants began answering this question by listing graphing and statistics as the only appropriate uses for a calculator (NCTM SEC5; NCTM ML3; NCTM SEC9). However, all of the participants, at some point, listed what they considered to be inappropriate use of calculators. All 12 participants answered identically for inappropriate uses – calculations or performing operations. Rueben's statement was echoed time and time again, "I don't believe [calculators] are useful when we are trying to get kids to learn basic facts" (NCTM SEC5-139). Some were a little more direct with their answers, "I would promote the fact that if someone is going to be an elementary teacher, they need to make sure the students know how to do things without the calculator first" (CAEP ML1-100). All participants felt that children should know how to perform the calculations without their calculator and then half agreed that the children could use the calculator to check their answers (CAEP SEC6; NCTM SEC7; NCTM SEC9; NCTM ML3; CAEP ML1; NCTM ML2).

Calculator Philosophy: The final question asked to the participating teacher educators was "What is your philosophy of calculator use?" The participants had many different answers although they comprised one of three main ideas: used as a tool, used to check answers, and used for anything but computations. Some, like DeeDee, thought, "it's just a tool and it's not part of the curriculum as far as I'm concerned" (CAEP ML1-118). While JoJo believed, "It's a nice tool when used appropriately and when used with discretion. I'm a firm believer in using a calculator to check your answer, but it should never be the primary or sole [resource]" (NCTM SEC7-111) for working a problem. Reuben said concerning his philosophy of calculator use:

> We need to teach kids to be proficient with the calculator because in real life, very few of them are going to do things where they don't use some type of calculator. For us to do that, our teachers have to be well trained to use the calculator (NCTM SEC5-166).

The final example of the answer to the philosophy of calculator use was best summed up by Richardo when he said, "So if the goal of a lesson or instructional unit is to focus on computation, then I don't feel that the calculator is best to be used" (CAEP ML11-84).

An unanticipated finding from the data was a philosophy implied from pre-service teachers and mathematics content teachers. This philosophy was shown when Rueben stated, "I have a lot of students that are kind of anti-calculator" (NCTM SEC5-93). Once he made this statement, I then asked him "Why do you think they are anti-calculator?" (NCTM SEC5-97) and he replied "I think that comes from a lot of faculty in the math department. There are several math professors that don't allow [the pre-service teachers] to use calculators at all" (NCMT SEC5-98). Linda also echoed this sentiment when asked, "What is your impression of using calculators in math class?" (NCTM ML3-74). Her reply was "They don't allow them in some of the classes where I teach" (NCTM ML3-76).

Other Interview Questions

There were five questions posed in the interview process whose answers were difficult to analyze. One question had no common answers, one question had all of the same answers, and three questions had generally the same answers. In all five cases, I did not believe that the participants' response to these questions affected the outcomes of this study.

As to whether pre-service teachers took content courses in separate classes from mathematics majors or engineer majors, the answer was no – in all cases. As to other instances of technology the participants believed were beneficial in mathematics class, the answers varied greatly from mentioning Excel spreadsheets to Desmos (an online graphing program) to iPads to Cabri, Jr., (a geometry application for TI-83 and TI-84) to SPSS (statistics software) to Mathematica (a computer algebra program). Two of the other questions dealt with the first time the participant remembered using a calculator and what they remembered about using a calculator in school. All participants said they either vaguely remembered using a calculator or they stated that it was too long ago and could not recall using a calculator.

When asked their impression of calculator use in mathematics classes for graduate students, for undergraduate students, and for their own child, answers seemed to be common for each of the three but not across the three. For instance, all participants felt that undergraduate students should be allowed to use calculators but not graduate students since their learning was mostly theoretical in nature. When participants were asked about their own children, most of them had older or very young children and would not answer a question dealing with a hypothetical situation.

Terminology

The word “tool” was used 25 times by six different participants during their interviews when referring to the calculator. Tool has been defined as “a device or implement, especially one held in the hand, used to carry out a particular function” (“tool,” n.d.). However, the participants’ various uses of the calculator in this study indicated the calculator was being used in preparing pre-service teachers in a variety of ways: to check an answer already acquired with paper and pencil, to work problems that are too tedious to do with paper and pencil, to show graphs, to work with CBR’s, and to do anything but computations.

The word “appropriate” or some form of “appropriate” (such as appropriately) was used 33 times by seven different participants during the interview process. Appropriate has been defined as “suitable or fitting for a particular purpose” (“appropriate,” n.d.). To use a calculator appropriately would depend on what purpose you wanted to use it for and if that particular calculator was suitable for that purpose. In general there are three main types: (a) a basic four function calculator which is appropriate for elementary students or household needs; (b) a scientific calculator which is “an electronic device for performing calculations; now especially a calculator with advanced mathematical functions, typically one which is programmable and has trigonometric, logarithmic, and exponential functions” (scientific calculator, 2016); and (c) a graphing calculator which can perform graphical representation in addition to all of the same calculations as scientific calculators. For example, a scientific calculator would be appropriate for solving problems involving trigonometric functions; however, it would not be appropriate for graphing a function. A graphing calculator, however, would be appropriate for both solving problems involving trigonometric functions and graphing a function.

Course Syllabi

Syllabi were received from 10 of the 12 participants. An examination of the syllabi uncovered only four of the 10 syllabi mentioned that students were required to have a calculator. Two participants listed graphing calculators (NCTM SEC9S-22; NCTM ML4S-130) and one participant specifically listed a scientific calculator (CAEP ML1S-37) as course requirements. None of the other participants' syllabi listed a calculator as being a requirement; however, one participant did have an assignment referring to introducing the TI-92 calculator (NCTM SEC7S).

DeeDee listed in her syllabus that "calculators may be used on homework, quizzes, and exams" (CAEP ML1S-98); however, she did not include an assignment using calculators to instruct students in her syllabus. Catherine wrote in her syllabus she wanted the pre-service teacher to:

> Learn enough about your chosen calculator that you can solve the following equation involving a third degree polynomial: $x^3-5x^2+x+6=0$. In your study notebook, explain how to get the solution to this problem with a graphing calculator (NCTM ML4-237).

In her syllabus, Martha had as the topic for a specific week "Technology (bring a calculator)" and lists assignments for that same day as "Read Text Ch. 5 p. 180-198" (NCTM SEC9S-215). Rueben's did not list calculators as a requirement for class; however, his syllabus did contain the information that each pre-service teacher would give two technology presentations, which may include “a graphing calculator” (NCTM SEC5S-125). JoJo had an “Introduction to the TI-92 Calculator” (NCTM SEC7S-176) as the topic for the seventh meeting of the course; however, she did not require a calculator for the secondary mathematics methods course. Not enough information was given in the syllabi to ascertain how the calculator was to be employed in the class.

Six of the 10 syllabi received from participants included references to NCTM. Three of those six syllabi noted the pre-service teacher was required to join NCTM (NCTM SEC9S; NCTM SEC5S; CAEP ML12S), two syllabi noted students had to acquire *Principles to Actions* in addition to a textbook (NCTM ML2S; CAEP ML11S), and one syllabus mentioned chapter 3 of the *NCTM Principles and Standards* in the course materials (CAEP SEC6S). Only one of the six syllabi listed an assignment focusing on NCTM. Martha’s syllabus included an assignment to “explore NCTM website – join, come prepared to share one resource” (NCTM SEC9S-167). Martha also had assignments such as “Read NCTM Position Paper: Procedural Fluency” (NCTM SEC9S- 176), “NCTM article review 1 (your choice)” (NCTM SEC9S-192), and “NCTM article review 2” (NCTM SEC9S-228). Except for Martha’s specific assignments, there were no further directions given as to how NCTM materials or the required membership would be utilized during the course.

Unanticipated Findings

There were two instances of unanticipated findings in this study. One occurred when participants were asked about other technologies used in their mathematics class. Four of the 12 participants provided very specific examples of other types of technology which they used themselves. Desmos, an online graphing program, was cited by Reuben for his use (NCTM SEC5); however, he did not require his students to have a calculator nor would he allow a calculator to be used in class by the pre-service mathematics teachers. Roberto mentioned “a lab where they use the CBR (Calculator Based Ranger) with the TI (Texas Instruments) calculators to learn how to use the CBR” (CAEP ML11-49); however, he also said that he did not use calculators in the classroom except “very rarely” (CAEP ML11-46).

In the syllabi obtained from the participants, those who mentioned calculators or NCTM did so in a very vague manner. Even those who listed calculators in their course activities failed to provide enough specifics so that one could determine the participants’ expectation toward using calculators in the lesson. Three participants listed joining NCTM as a course requirement although only one listed any type of assignment pertaining to that membership.

Chapter Summary

The analysis of the data from the interviews and course syllabi resulted in several important findings. First, the teacher educators participating in this study did not prepare pre-service teachers to use calculators to develop sound pedagogy during the methods course, which was a specific question asked in this study. This finding was demonstrated by analyzing the participants’ answers to the interview questions concerning how the instructor in methods courses used calculators and how the pre-service teachers used calculators during the course activities and was further supported by examining the participants' syllabi for the methods course. Only three syllabi mentioned assignments containing calculators.

The answer as to what the participating mathematics teacher educators believed about the use of calculators in the classroom was found in their answers to the last three questions of the interview protocol. These questions investigated the teacher educators' philosophies with regard to calculator use, what the teacher educator believed was appropriate use (or inappropriate use) of a calculator in a mathematics classroom, and the teacher educators' belief's toward NCTM's calculator policy statement. The answers to these three questions indicated that all of the teacher educators participating in this study believed that the NCTM calculator policy was a good thing, but the participants were also very quick to qualify their statements. The participating teacher educators' comments indicated more concern about the inappropriate use of using calculators for computation and performing operations rather than discussing the appropriate uses of a calculator as an instructional tool. Lastly, the participating teacher educators' collectively held a philosophy that the calculator should be used as a tool, or to check answers, or for anything other than computations and performing calculations.

CHAPTER 5

DISCUSSION

To begin this discussion, I think it is appropriate to reiterate the reasons for undertaking this research study. I taught high school mathematics, including Algebra 1 and 2, Geometry, Pre-Calculus, and AP Calculus, for 19 years. During these 19 years, I taught myself, with the aid of a workshop or two, to use the calculator as a pedagogical tool. Yes, that is correct – a teaching tool. As an emergency certified teacher, I believed it was important that I learn to use the calculator as a pedagogical tool. I attended workshops and worked with the calculator during my own time because I believed being able to use the calculator to teach with would be beneficial to my students. This was the basis of my perceptions of calculators and the foundation of any biases I have held on the topic.

Discussion Related to First Research Question

In response to the first research question of "What do mathematics teacher educators believe about the use of calculators in the classroom?", in general, the participants in this study believed that the students' use of them is unavoidable. During the analysis of the data, six of the participants in this study referred to the calculator as a tool. DeeDee, JoJo, Laura, Joshua, Richardo, and Rueben used the term tool during their interviews. In total, the calculator was referred to as tool 25 times. The phrases surrounding the use of "tool" indicated these teachers' working definition of tool was to check an answer already acquired by pencil and paper, or to solve tedious problems, or to show graphs, or to work with CBR's, or to do anything other than computations. Their definition or use of the term tool may not have been the same one as I have. My definition of tool was an object used to accomplish a task without which would be more difficult or impossible. A universal definition of the term tool is not easy to develop. For instance, a screwdriver can be used, as the name suggests, to drive screws in to wood. However, a screwdriver can also be used to pry two things apart. The calculator is no different than a screwdriver in that respect; there may be multiple meanings held by individuals regarding what the calculator can or should be used for in the classroom.

According to JoJo, the calculator was “a nice tool when used appropriately and when used with discretion. I’m a firm believer in using a calculator to check your answer” (NCTM SEC7-112). JoJo may not have believed in using a calculator as a teaching tool, as articulated in her statement, but she believed checking answers with the calculator was acceptable. However, according to NCTM (2003), “certified teacher preparation programs must embrace technology as an essential tool for teaching and learning mathematics” (p. 2). JoJo is a professional educator at an institution which is NCTM certified but as the teacher for “all of the math methods for secondary math students” (NCTM SEC7-26). JoJo was apparently unaware of NCTM’s view that the calculator was important to both “teaching and learning mathematics” as NCTM certification required that “Candidates embrace technology as an essential tool for teaching and learning mathematics” (NCTM, 2003, p. 2).

Joshua indicated he tried “to create task[s] where the use of a calculator is an absolutely appropriate tool” (NCTM ML2-137). Joshua taught middle school mathematics methods courses. He did not further elaborate on his use of the term "appropriate" directly, but did state,

> If my interest is teaching a standard where they are supposed to perform an operation, then I feel like I have to be a little more careful with technology use because a child can quickly learn to punch the numbers in to the calculator, generate an answer, and never have to think about the reasonableness of the answer or why that operation was appropriate within the given situation (NCTM ML2-99).

One can infer that an inappropriate use of the calculator would be to perform operations or computations. Others seemed to agree with Joshua's perspective.

DeeDee stated, "I would promote the fact that if someone is going to be an elementary teacher, they need to make sure the students know how to do things without the calculator first" (CAEP ML1-100). Rueben related during his interview that "with Common Core the calculators are not encouraged until later in school" (NCTM SEC5-157). He was trying to show the pre-service teachers how to find patterns in addition and multiplication without calculators. His perception of a calculator was that of a graphing tool or to work tedious problems. Dr. Hill, a past president of NCTM, always believed that "children using calculators are also learning computation" (Roberts, 2002a, p. 38). NCTM has long supported the use of calculators for all classrooms from Kindergarten to 12th grade (NCTM, 2000).

However, the most disturbing part of not allowing calculators until after elementary school grades has been that many students have lacked the confidence and enthusiasm for mathematics which could have been fostered at an early age (Campbell & Stewart, 1993). According to a study of 43 middle school students done by Edwards and Ozgun-Koca (2009), "89% of the students they surveyed like doing mathematics with Nspire® (a handheld calculator), 72% agreed that they understood the mathematics lesson better" (p. 3), and all students were more motivated and eager to learn when using calculators. One wonders if the 12 participants in this study were aware of such research findings and how they came to the conclusion of what was the appropriate use of calculators.

The 12 participants of this study had no or only vague memories of when they first saw a calculator in the classroom – either as a student or teacher. The same was true as to their first time to use a calculator. Some researchers might inappropriately infer from these responses that the event does not stand out in their minds, however many things escape our day-to-day notice, such as when we first learned to use seatbelts. However, findings from research studies indicate that if calculators were utilized to enhance mathematical learning, more students might appreciate and comprehend the importance of the calculator to their education (Campbell & Stewart, 1993; Edwards and Ozgun-Koca, 2009).

Discussion Related to Second Research Question

In seeking to answer the second study question of "How do mathematics teacher educators use methods courses to prepare pre-service teachers to use calculators to develop sound pedagogy?", there were several key points uncovered during the analysis of the interview data and course syllabi submitted by the participants. The simple answer was – the teacher educators participating in this study did not use calculators as pedagogical tools. This finding was supported by an analysis of their responses to interview questions and an examination of submitted course syllabi. However, NCTM's written documents *(Principle and Standards for School Mathematics* (NCTM, 2000), *Principles to Actions* (NCTM, 2014), *Calculator Use in Elementary Grades* (NCTM, 2015a*)*, CAEP guidelines (CAEP, 2015c), and CCSSM standards (CCSSI, 2016b) consider the use of calculators as an important pedagogical tool to aid students' mathematical understandings.

Teaching with calculators: In general, the participants in this study believed educating a pre-service teacher to use calculators effectively for pedagogical purposes was not important, contrary to the research of Shulman (2004) and others (e.g., Brown et al., 2007; Hardy, 2008). Shulman (2004) noted that the "transfer of training is the most important single concept in any educationally relevant theory of learning" (p. 77). Hardy (2008) found "teacher candidates criticized teacher educators for espousing teaching with technology but failing to integrate it into their own pedagogy" (p. 4468).

In contrast, participants in this study believed that using a calculator to teach with or having pre-service teachers use calculators to teach with was inconsequential. When the participants were asked how they learned to use the calculator as an instructional tool, eight of the 12 did not actually answer the question. Although no conclusion can be directly made, other researchers have noted the lack of demonstration of the use of the calculator as an instructional tool in methods or content courses (Brown et al, 2007; Burke, 2001; Gainsburg, 2012; Hardy, 2008). This practice appears to be repeating with the participants in this study. DeeDee stated, "I don't teach with it (a calculator)" (CAEP ML1-57) and Richardo explained that he used calculators "very rarely" during his methods classes (CAEP ML11-46).

Participants in this study also thought that the pre-service teachers did not need to prepare a lesson using calculators much less practice teaching with one. This was demonstrated in their interview responses and in the examination of submitted course syllabi. According to Linda, "Because mine is a methods course, I focus more on the appropriate uses" of calculators (NCTM SEC3-58). CBMS (2012) recommend that calculators needed to be learned as a teaching tool – not just for calculating. The examination of the participants' syllabi uncovered a lack of assignments pertaining to lesson plans using calculators or opportunities to practice teaching with a calculator.

Appropriate Uses of Calculators: The president of NCTM at the time the *Principles and Standards* were written was Dr. Shirley Hill. In an interview, Dr. Hill said, "Children using calculators are also learning computation. You can use a calculator to help kids to learn how to think through [problems]... and understand them better" (Roberts, 2002a, p. 38). However, the participants in this study appeared to disagree with Dr. Hill's viewpoint that calculators helped children learn computational skills. The participants expressed viewpoints similar to that expressed by Rueben who thought that calculators "are not useful when we are trying to get kids to learn basic facts" (NCTM SEC5-139).

The term "appropriate" was used 33 times by seven of the 12 participants when referring to using calculators. According to the participants in this study, a calculator should never be used for performing operations or computation as this was not an appropriate use of this technology. Students do need to develop computational fluency skills and they may better grasp why this skill is necessary when they have engaged in appropriately focused activities that facilitate mathematical understanding (Edwards & Ozgun-Koca, 2009). In the real world a variety of technological tools are often utilized which means that students could appropriately use a calculator to assist them with computations when solving a real-world problem. The bigger question to consider is who and/or what determines what is “appropriate” in regard to the use of a calculator in a mathematics lesson? Discussions involving “who”, “what” and “when” in regard use of calculators in the mathematics classroom could help pre-service educators wrestle with what would be appropriate uses of calculators and other technological tools.

Essential Uses of Calculators: NCTM certification of a teacher education program requires that “candidates embrace technology as an ‘essential’ tool for teaching and learning mathematics” (NCTM, 2003, p. 2). In *Principles to Actions*, NCTM lists “tools and technology” – in which they include calculators – as essential elements along with “teaching and learning, access and equity, curriculum, assessment, and professionalism” (NCTM, 2014, p. vii). NCTM views technology, including calculators, as “essential” while all the participants in this study were focused on the “appropriate” use of technology. Only one of the 12 participants thought that calculator use was “essential” (NCTM SEC9-103); however, he then clarified that the students need to “know how to use it appropriately” (NCTM SEC9-104). According to *Dictionary.com*, essential means “absolutely necessary;

indispensable" (essential, n.d.). An object could be considered appropriate, as are donuts, but not essential, as are vegetables. Or an object could be considered essential such as clothing but not always appropriate.

NCTM Technology Principle: In July of 2011, NCTM published a "Calculator Use in Elementary Grades" position paper which stated, "The proper implementation of the Technology Principle depends on teachers' creating approaches to classroom instruction that appropriately integrate the use of technology into lessons focused on learning mathematics" (NCTM, year, para. 6). In 2014, NCTM published *Principles to Actions* listing tools and technology (along with 5 other elements) as essential elements of a high quality mathematics education (NCTM, 2014). In July of 2015, NCTM published an updated version of the "Calculator Use in Elementary Grades" position paper in which "appropriate tools and technology, including calculators in the elementary grades, as essential elements in the classroom to aid students in making sense of mathematics and reasoning mathematically" (NCTM, 2015a, para. 6). NCTM's position has been consistent in the importance of the calculator as essential tools in the teaching and learning of mathematics.

All of the participants in this study agreed with the NCTM position statement concerning calculators; however, each one of them qualified their answer in some way. For instance, Laura thought the calculator was beneficial as long as it was being used in "appropriately structured ways" (CAEP SEC6-110). Linda was a little more direct in her statement of "in elementary, it [the calculator] is not appropriate for teaching computation" (NCTM ML3-96). Richardo answered, "pre-service teachers need time practicing teaching period" (CAEP ML11-75).

The NCTM (2011) position statement was written to clarify "the role of technology (calculators) in the teaching and learning of mathematics" (p. 1). As one of the six essential elements listed as being necessary to "high-quality mathematics education" (NCTM, 2014, p. 4), the Technology Principle should never be qualified – unless NCTM does so. What if, like the participants in this study, mathematics educators decided to qualify other Principles, such as the Curriculum Principle or the Equity Principle? The term principle, by definition means "a fundamental, primary, or general law or truth from which others are derived" (principle, n.d.).

Implications

Student learning should be the teacher's primary concern, which necessitates that he/she have developed strong pedagogical and content skills. Teacher educators and mathematics faculty strongly influence the development of these skills in pre-service teachers. As Walen et al. (2003) found in their research, mathematics educators "fall back on" (p. 460) teaching their students by replicating their own teachers' methods. If mathematics educators, either method or content, do not model effective use of a calculator for teaching and learning, the pre-service teachers will not be thoroughly trained in the use of calculators as a pedagogical tool. This lack of preparation with pedagogical best practices could potentially cause these pre-service teachers to use outdated methods when instructing 21st century students. Based on the comments in the interview, the mathematics education participants in this study did not focus on the pedagogical skills involved in teaching with calculators, as they were concerned with the appropriateness of calculator use by students.

For student problem solving: Campbell and Stewart (1993) noted that permitting students to use calculators for real world problem solving allowed students to enjoy and develop enthusiasm for mathematics. As Rueben stated,

> There's a lot of patterns that if you are working thru the problems, the student gets focused on how to get the solution and not the pattern that emerges. Whereas, with a calculator you can do a lot more problems quicker and you are able to look at that pattern then instead of the routine you've gone thru to get it (NCTM SEC5-128).

When students are allowed the opportunity to work with a calculator to solve a problem – any problem – then the student can focus their concentration on understanding instead of on calculating. According to the participants in this study, the use of calculators in such situations was not appropriate; however, according to NCTM the use of such technologies is essential. This type of conundrum must be openly addressed.

For student reasoning: Like any other skill, reasoning must be practiced. Calculators can help even very young students to learn this skill. Joshua was concerned that "a child can quickly learn to punch the numbers in to the calculator, generate an answer, and never have to think about the reasonableness of the answer" (NCTM ML2-101). However, a teacher's responsibility includes being sure the students question the reasonableness of the answers that the calculator generates.

For student communication: Should calculators be used to enhance communication skills? Calculators have become so advanced that their screens can be used to communicate mathematical concepts. For instance, the TI-84 contains an application which demonstrates why and how the area formulas of certain geometric figures are obtained. This application could be an exciting instructional tool for a fourth or fifth grade student trying to understand the formula used to find the area of a trapezoid.

For student connection: Connections are perhaps the hardest part of mathematics teaching in that teachers must connect the learning of mathematics students to history, English, science, and other subjects. Calculators can make these connections easier to accomplish. For instance, in science class a calculator can be used to find the line of best fit for a set of data obtained during an experiment. In history class the calculator could be used to make a histogram of the population of the U. S. from 1850-1950. In an English class a calculator could provide information about a pyramid using given dimensions which could then be used to compare and contrast different pyramids appearing in a story about ancient Egypt.

For student representation: Calculators are very beneficial for examining different representations of mathematical information. To solve real world problems, students must be able to use the information they are furnished to determine a reasonable solution. It makes sense for students to see representations in several ways. For example, information may be given in graph form and need to be converted to a list or an equation or maybe much data has been given and the student's dilemma is to decide which data was useful in solving the problem and which was just nonsense.

For pre-service teachers: If student understanding of mathematical concepts were the primary concern, then pre-service teachers would be required to not only practice teaching with calculators but would also be able to attend classes where appropriate models of calculator use in the mathematics classroom was the norm. There were three participants in this study, all who taught at NCTM certified institutions, that reported that the mathematics students at their institution were not allowed to use calculators in mathematics class (NCTM SEC5, NCTM ML3, NCTM SEC9). Rueben's comment was that his pre-service teachers had become "anti-calculator" (NCTM SEC5-93). How are pre-service teachers to learn effective pedagogy using calculators if they never see the tool appropriately modeled (Shulman, 2004) for and with them?

For students: Previous studies have found that the students felt better about themselves and enjoyed mathematics more when a calculator was utilized in mathematics class (Campbell & Stewart, 1993; Edwards & Ozgun-Koca, 2009; Ellington, 2003). Many of today's students perceive mathematics as an insurmountable challenge. Each year at the beginning of school, several students in my classroom would complain that they "hated math" and were not "good at it". Usually the statement "my mom or dad isn't any good at math either" followed this. Based on the findings of Edwards and Ozgun-Koca (2009), if using calculators can positively change the belief of these students regarding mathematics, why not give them a calculator? Albert Einstein's (n.d.) definition of insanity, "Doing the same thing over and over again and expecting different results," explains the importance of changing pedagogical methods to meet student needs.

Recommendations

The findings of this study have prompted three recommendations for NCTM and one recommendation for CAEP as certifying agencies, two recommendations for higher education institutions with teacher preparation programs, and four recommendations for faculty who educate pre-service mathematics teachers. The recommendations from this study's findings vary from updating certification requirements, improving syllabi assignments, to focusing on the pre-service teacher educator's classroom practices.

NCTM: NCTM should modernize the PSSM publication to appropriately reflect today's 21st century learners' needs. The information provided in the PSSM, written in 2000, is older than most of today's students. NCTM published the most recent position statement on technology for secondary grades in 2011. The findings of this study have exposed the need to continually update technology standards to reflect developments in technology and how to utilize that technology in solving real world problems as part of best pedagogical practices. Amara's law states, "We tend to overestimate the effect of a technology in the short run and underestimate the effect in the long run" (Amara, n.d.). Organizations such as NCTM should put into practice the regular examination of information on a specified schedule and especially after a major educational initiative, such as the development of Common Core standards (CCSSI, 2016a).

While NCTM has a position on the use of calculators at the elementary level (NCTM, 2015), the organization must attempt to do more in helping educators recognize that various calculators are appropriate depending on the age of the student and provide guidelines for implementation for each grade. For instance, the TI-73 is an appropriate calculator for younger middle grades students while the TI-Nspire can be used for secondary students and beyond. Other brands of calculators have corresponding models, which can also be utilized.

NCTM, by joining with CAEP, agreed to certify the teacher preparation programs at specific higher education institutions, which were granted the privilege of holding NCTM certification – a distinction that only 30% of all certified institutions hold (CAEP, 2015b). The findings of this study uncovered a potential disconnect between implementing NCTM standards and the actual practice of teacher educator programs. NCTM should maintain due diligence in avoiding a detachment between NCTM standards and actual practice, especially in regard to ensuring that all technologies are addressed in the preparation of pre-service teachers. Since technologies are ever evolving, this re-examination may need to occur more frequently than just when CAEP is recertifying a teacher preparation program.

CAEP: CAEP may have assumed NCTM accepted the responsibility of confirming that higher education institutions upheld the strict standards established by the two entities in regards to the preparation of mathematics teachers and the adherence to NCTM's standards. According to the findings in this study, CAEP needs to make sure they, as a certifying agency, remain vigilant in the implementation of their own standards, especially when recertifying a teacher preparation program.

Higher Education Institutions: Higher education institutions with teacher preparation programs which have been awarded NCTM certification, should continue to uphold the certifications they were granted. In fact, all teacher preparation programs should be cognizant of NCTM standards and assure mathematics educators center their coursework on these standards. Institutions should continue to maintain alignment to current standards in any education field.

Mathematics has been compared to learning a foreign language (Kenney et al., 2005). An institution would not award a Spanish teaching degree to a person who could not speak Spanish. So, why should an institution award a degree to a mathematics teacher who is not well trained in the best practices of teaching mathematics? Teacher preparation program faculty should be aware of the standards of each content area, updating syllabi and assignments accordingly.

Additionally, those institutions certifying teachers should also support the collaborative work of education departments and mathematics departments as they prepare pre-service mathematics teachers. There needs to be ongoing dialogues between the two departments about not only mathematical content, but the pedagogical skills needed to effectively teach such content. Too often teacher educator faculty and content faculty work in isolation from each other, with faculty only having a limited vision of what skills are needed to become effective teachers. The types of technologies used in PK-12 classrooms are often quite different than those used in teaching at the university level. There needs to be better communication between educators across the PK-16, no matter the content focus.

Pre-Service Teacher Educators: Educators of pre-service teachers should be cognizant of the latest teaching methods and prepare them to be the most successful teachers possible, no matter the content area. Those preparing these future teachers must be held to the highest standards. Advances in technology appear to be adopted much quicker at the PK-12 level. Mathematics methods teacher educators must be aware of new innovations and work with school districts, mentor teachers, and those who provide the content classes at the university level. By working closely with these colleagues, pre-service teachers should be better aware of the instructional tools and best pedagogical practices they will be using immediately upon stepping into their new role as a certified classroom teacher.

Pre-service mathematics methods teacher educators should provide more detail when lesson plans using calculators and teaching lessons with calculators are listed in the mathematics methods syllabi. According to CBMS (2012), mathematics teacher educators should model such lessons and also require pre-service teachers to develop, teach, and assess lessons that incorporate calculators and other technologies. For example, according to NCTM (2000), teachers are to foster the type of reasoning which would allow the students to question the reasonableness of their answer or why they used a particular operation in solving a problem. Having the opportunity to practice teaching with a calculator would help the pre-service teacher to build the necessary skills required to foster reasoning in students (CBMS, 2012; CCSSI, 2016b; NCTM, 2000).

There was a lack of detail in the participants' course syllabi concerning expectations from acquiring a membership with NCTM. Joining NCTM alone does little to aid the pre-service teacher in developing skills with calculators or sound mathematical pedagogical skills. Mathematics methods syllabi assignments should include a deep study of the various sections of the PSSM, especially the principles and process standards. As a minimum requirement the pre-service teacher should have to compose an essay detailing the main points of the PSSM and NCTM's position statements and the importance of these points for their future students. According to the findings of this study, teacher educators who participated in this study appeared to believe they were following NCTM guidelines in regard to technology, as well as following all of the NCTM principles and standards. One recommendation would be that faculty engage in a deep discussion of the principles and standards within the mathematics methods coursework and with mathematics faculty who teach content courses.

Mathematics Faculty: The pre-service teacher educators who participated in this study believed that the mathematics educators at their institutions were not embracing teaching with calculators nor were calculators used in their mathematics classes. This was evident when Reuben replied that his students were "anti-calculator" (NCTM SEC5-93) because "several math professors don't let them use calculators at all" (NCTM SEC5-98) and was reiterated when Linda shared that the mathematics educators did not allow calculators "in some of the classes where I teach" (NCTM ML3-77). Again, there is a need for teacher educators and those teaching mathematics faculty members teaching content courses to pre-service teachers to regularly dialogue in order to ensure that pre-service teachers are adequately prepared to appropriate merge content and pedagogy.

This study provided answers that were not always what could be considered the 'right answer'; however, in my reflexive journal during data analysis I stated, "With only a couple of exceptions, I think these educators really believe they are doing the right thing as far as calculators are concerned" (RJ4.13.16-33). I also added "I just think they (the math methods educators) have forgotten the fact that somewhere, someday these pre-service teachers will be actual teachers with students" (RJ4.13.16-35). All educators should remember that the end consumer is the student and tailor their classes to reflect such.

Further Research

Based on the review of literature and the findings of this study, new studies should be conducted concerning how frequently and in what situations students use calculators. More recent studies would be especially enlightening as most of the studies concerning calculator use with students were completed over 20 years ago and there have been many technical advances during that time. For example, almost every cell phone or tablet now has a scientific calculator as a free application. Knowing this, updating the studies of calculators and specifically those involving TI-Nspire™ might possibly show an even stronger correlation between calculator use as a teaching tool and its positive impact on student achievement.

Research comparing the various syllabi of mathematical methods courses from NCTM and non-NCTM certified institutions could reveal differences and similarities in practices. Studies involving the syllabi may possibly reveal both strengths and deficiencies the preparation of pre-service mathematics teachers and could become the basis for reforming teacher educator programs as needed.

My findings suggest an update to NCTM's Technology Principle should be undertaken preferably with research to support the updates. It is essential that NCTM develop the necessary procedures to revise the Technology Principle and other Principles perhaps as frequently as biennially.

After revising NCTM's Technology Principle, guidelines by which higher education institutions' teacher preparation programs become NCTM certified should also be reviewed and revised as warranted. These guidelines should reflect current calculator and technology use in the mathematics classroom. Furthermore, CAEP and NCTM should establish guidelines which could be continually monitored so that all certified institutions maintain superior preparation of pre-service teachers.

Implementation of a plan of action for teacher educators to stay current on mathematics education issues should also occur. For example, NCTM's principles and standards should be well known and upheld by not only NCTM certified institutions but also CAEP certified institutions. One major approach would be to require the pre-service teachers to study mathematical methods which strongly incorporate the principles and standards as to how they apply to PK-12 students. This would require mathematics faculty members who teach content to pre-service teachers to also be familiar with the NCTM principles and standards.

Mathematics departments along with education departments should work together to ensure that pre-service mathematics teachers are afforded the finest methods education classes possible. Along with the partnership between the two departments comes a responsibility to model using the calculator not only as an appropriate tool for students but as an essential tool in mathematical pedagogy for pre-service teachers.

When I was taking mathematics classes some 20 years ago, I was not allowed to use a calculator in class, and my mathematics professors did not teach with a calculator. I also completed several methods courses in which the calculator was never mentioned. According to the findings of this study, a common practice in teacher preparation programs has been to not address calculators in either content or methods courses. Two obvious points emerged from the findings of this research study: (a) the mathematics teacher educators focused more on the *appropriate* use of a calculator while NCTM believes the calculator is an *essential* tool, and (b) while the participating teacher educators said they agreed with NCTM's Technology Principle their comments and syllabi indicated a limited perspective of the importance of using calculators as an instructional tool, thus inhibiting the pedagogical development of pre-service mathematics teachers.

Young people today have a natural interest in all forms of technology. Consider the progress that could be made in students' mathematical understanding by creating a bridge between their natural interest in technology to the use of calculators in the mathematics classroom. Real world connections are always a crucial element of lesson planning for all teachers regardless of their field or age of student. Calculators could help build anticipation and exploration in each mathematics lesson from kindergarten through graduate school. The practices of individuals teaching mathematics could be greatly enhanced by effective use of calculators for both content and pedagogical purposes.

BIBLIOGRAPHY

Amara, R. (n.d.). In *List of eponymous laws.* Retrieved from en.m.wikipedia.org

appropriate. (n.d.) In *Dictionary.com.* Retrieved from http://www.dictionary.com/browse/appropriate?s=t

Aspray, W. (1990). *Computing before computers*. Ames, IA: Iowa State University Press.

Bahr, D., Monroe, E., & Eggett, D. (2014). Structural and conceptual interweaving of mathematics methods coursework and field practica. *Journal of Mathematics Teacher Education*, *17*(3), 271-297. doi: 10.1007/210857-103-9258-z

Banks, S. (2011). A historical analysis of attitudes toward the use of calculators in *junior high and high school math classrooms in the United States since 1975.* (Master of Education Thesis). Retrieved from Science and Mathematics Education Commons, DigitalCommons@Cedarville, (Paper 31)

Bell, L. (Ed) (2001). Preparing tomorrow's teachers to use technology: Perspectives of the leaders of twelve national education associations. *Contemporary Issues in Teacher Education* [Online Serial], *1*(4) 517-534.

Blair, R., Kirkman, E. E., & Maxwell, J. W. (2013). *Statistical abstract of undergraduate programs in the mathematical sciences in the United States: Fall 2010 CBMS survey.* Washington, DC: American Mathematical Society.

Bradford, A. (2015). Deductive reasoning vs. inductive reasoning. Retrieved from http://www.livescience.com/21569-deduction-vs-induction.html

Brown, E. T., Karp, K., Petrosko, J. M., Jones, J., Beswick, G., Howe, C., & Zwanzig, K. (2007). Crutch or catalyst: Teachers' beliefs and practices regarding calculator use in mathematics instruction. *School Science and Mathematics, 107*(3), 102-116. doi:10.1111/j.1949-8594.2007.tb17776.x

Bullock, E. C. (2013). An Archeological/Genealogical historical analysis of the National Council of Teachers of Mathematics standards documents. *Middle-Secondary Education and Instructional Technology Dissertations*. Retrieved from http://digitalarchive.gsu.edu/msit_diss. (Paper 110)

Burke, G., Jr. (2001). *Computers and calculators in schools: A status report* (pp. 2-8, Rep.). Itta Bena, MS: Mississippi Valley State University. (ED460857). Retrieved from http://eric.ed.gov/?id=ED460857

calculate. (n.d.). In *Online Etymology Dictionary*. Retrieved from http://dictionary.reference.com/browse/calculate

calculus. (n.d.). In *Online Etymology Dictionary*. Retrieved from http://dictionary.reference.com/browse/calculus

Campbell, P. F., & Stewart, E. L. (1993). Calculators and computers. In R. J. Jensen (Ed.), *Research ideas for the classroom: Early childhood mathematics.* New York, NY: Simon and Schuster Macmillan.

Chamblee, G. E., Slough, S.W., & Wunsch, G. (2008). Measuring high school mathematics teachers' concerns about graphing calculators and change: A year long study. *Journal of Computers in Mathematics & Science Teaching, 27*(2) 183-194.

Common Core State Standards Initiative. (2016a). About the standards. Retrieved from http://www.corestandards.org/about-the-standards

Common Core State Standards Initiative. (2016b). Standards for mathematical practice. Retrieved from http://www.corestandards.org/Math/Practice

Council for the Accreditation of Educator Preparation. (2015a). History. Retrieved from http://caepnet.org/about/history

Council for the Accreditation of Educator Preparation. (2015b). List of recognized programs per accredited institutions for National Council of Teachers of Mathematics. Retrieved from http://caepnet.org/provider-search?state=&program=NCTM&tab=program#progresults

Council for the Accreditation of Educator Preparation. (2015c). Vision, mission, and goals. Retrieved from http://caepnet.org/about/vision-mission-goals

Council for the Accreditation of Educator Preparation. (2015d). What is accreditation. Retrieved from http://caepnet.org/accreditation/about-accreditation/what-is-accreditation

Conference Board of the Mathematical Sciences. (n.d.). About CBMS. Retrieved from http://www.cbmsweb.org/Members/about_cbms.htm

Conference Board of the Mathematical Sciences. (2012). The mathematical education of teachers II. *Issues in mathematics education.* Providence, RI: American Mathematical Society.

Dedoose. (n.d.). About us. Retrieved from http://www.dedoose.com/about-us/

Dewey, J. (1924). The classroom teacher. In D. J. Simpson & S. F. Stack (Eds.), *Teachers, leaders, and schools: Essays by John Dewey* (pp. 153-160). Carbondale, IL: Southern Illinois University Press.

Dion, G., Harvey, A., Jackson, C., Klag, P., Liu, J., & Wright, C. (2001). A survey of calculator usage in high schools. *School Science and Mathematics, 101*(8), 427-438.

Donoghue, E. F. (2003). Emergence of a profession: Mathematics education in the United States, 1890-1920. In J. Kilpatrick & G. M. Stanic (Eds.), *A history of school mathematics (Two-Volume Set)* (Vol. 1, pp. 159-193). Reston, VA: National Council of Teachers of Mathematics.

Edwards, T. G. & Ozgun-Koca, S. A. (2009, September). *A comparison of mathematics teachers' and students' views on the new generation handheld technology*. Paper presented at the 31st Annual Meeting of the Psychology of Mathematics Education of North America, Atlanta, GA.

Einstein, A. (n.d.). BrainyQuote.com. Retrieved from http://www.brainyquote.com/quotes/quotes/a/alberteins133991.html

Electronic Testing Service (2015a). State requirements. Retrieved from http://www.ets.org/praxis/states

Electronic Testing Service. (2015b). Technical manual for *The Praxis Series*® and related assessments. Retrieved from https://www.ets.org/praxis/states_agencies/resources

Electronic Testing Service. (2015c).Test development. Retrieved from https://www.ets.org/praxis/states_agencies/about/test_development/

Electronic Testing Service (2015d). *The Praxis Series®* passing scores by test and state. Retrieved from http://www.ets.org/praxis/scores/

Ellington, A. J. (2012). The impact of calculators on student achievement in the K-12 mathematics classroom. In J. Hattie & E. M. Anderman (Eds.), *International guide to student achievement* (pp. 303-306). New York, NY: Routledge.

Ellington, A. J. (2003). A meta-analysis of the effects of calculators on students' achievement and attitude levels in precollege mathematics classes. *Journal for Research in Mathematics Education, 34*(5), 433-463. doi:10.2307/30034795

Erlandson, D. A., Harris, E. L., Skipper, B. L., & Allen, S. D. (1993). *Doing naturalistic inquiry: A guide to methods*. Newbury Park, CA: Sage.

essential. (n.d.) In *Dictionary.com*. Retrieved from http://www.dictionary.com/browse/essential

Fontana, A., & Frey, J. H. (2000). The interview: from structured questions to negotiated text. In N. K. Denzin & Y. S. Lincoln (Eds.), *Handbook of qualitative research* (2nd ed., pp. 645-672). Thousand Oaks, CA: Sage.

Gainsburg, J. (2012). Why new mathematics teachers do or don't use practices emphasized in their credential program. *Mathematics Teacher Educator, 15*, 359-379.

Glaser, B. G., & Strauss, A. L. (1967). *The discovery of grounded theory: Strategies for qualitative research*. Chicago, IL: Aldine.

Guskey, T. R. (1986). Staff development and the process of teacher change. *Educational Researcher, 15*(5), 5-12.

Hardy, M. D. (2008). Preparing preservice mathematics teachers to teach with technology. *Proceedings of the Society for Information Technology & Teacher Education International Conference, Las Vegas, NV, 2008*(1), 4468-4473.

Heller, J. I., Curtis, D.A., Jaffe, R., & Verboncoeur, C. J. (2005). *The impact of handheld graphing calculator use on student achievement in Algebra I.* Retrieved from ERIC database. (ED493688)

Heller, J. I., & Paulukonis, S. T. (2000). *Discovering Algebra learner verification study: 1999-2000 results.* Emeryville, CA: Key Curriculum Press.

Hembree, R., & Dessart, D. J. (1986). Effects of hand-held calculators in precollege mathematics education: A meta-analysis. *Journal for Research in Mathematics Education*, *17*(2), 83-99. doi:10.2307/749255

Ifrah, G. (2001). *The universal history of computing: From the abacus to the quantum computer*. New York, NY: Wiley.

Kastberg, S., & Leathem, K. (2005). Research on graphing calculators at the secondary level: Implications for mathematics teacher education. *Contemporary Issues in Technology & Teacher Education, (5)*1, 25-37.

Kenney, J. M., Hancewicz, E., Heuer, L., Metsisti, D., & Tuttle, C. L. (2005). *Literacy strategies for improving mathematics instruction.* Alexandria, VA: Association for Supervision and Curriculum Development.

Koehler, M. J., Mishra, P., & Cane, W. (2013). What is technological pedagogical content knowledge (TPACK)? *Journal of Education*, *193*(3), 13-19.

Leech, N. L., & Onwuegbuzie, A. J. (2011). Beyond constant comparison qualitative data analysis: Using NVivo. *School Psychology Quarterly*, *26*(1), 70-84.

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. Beverly Hills, CA: Sage.

Lott, J. W., & Nishimura, K. (Eds.). (2005). *Standards and curriculum: A view from the nation: A joint report by the National Council of Teachers of Mathematics (NCTM) and the Association of State Supervisors of Mathematics (ASSM): Park City, Utah, July 21-24, 2004*. Reston, VA: National Council of Teachers of Mathematics.

Lynch-Davis, K. (2015). Debunking the calculator myth. Retrieved from http://www.nctm.org/Publications/Teaching-Children-Mathematics/Blog/Debunking-the-Calculator-Myth

Maeda, Y., Newton, J., Alexander, V., & Senk, S. L. (2014). Development of a national survey for secondary mathematics teacher education programs. *Assessment Update*, *26*(3), 5-6, 12-13.

Mason, A. (2010). *Integrating calculators in the secondary mathematics classroom: Teacher's attitudes and perspectives*. Retrieved from ERIC database. (ED510595).

Mathematical Association of America. (2016). Mathematical communication. Retrieved from http://mathcomm.org/courses/planning-the-term/

Merriam, S. B. (2009). *Qualitative research: A guide to design and implementation*. San Francisco, CA: Jossey-Bass.

Miller, C. (1995). In-depth interviewing by telephone: Some practical considerations. *Evaluation and Research in Education*, *9*(1), 29-38.

Milou, E. (1999). The graphing calculator: A survey of classroom usage. *School Science and Mathematics*, *99*(3), 133-140. doi:10.1111/j.1949-8594.1999.tb17461.x

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record*, *108*(6), 1017-1054. doi:10.1111/j.1467-9620.2006.00684.x

National Council for Accreditation of Teacher Education (NCATE) (2010, November). *Transforming teacher education through clinical practice: A national strategy to prepare effective teachers*. Report of the Blue Ribbon Panel on Clinical Preparation and Partnerships for Improving Student Learning. Washington, DC: Author. Retrieved from http://www.ncate.org/LinkClick.aspx?fileticket=zzeiB1OoqPk%3d&tabid=715

National Council of Accreditation of Teacher Education. (2014). NCATE: Home. Retrieved from http://www.ncate.org/Home/tabid/680/Default.aspx

National Council of Teachers of Mathematics. (1980). *An agenda for action: Recommendations for school mathematics of the 1980s*. Reston, VA: Author.

National Council of Teachers of Mathematics. (1987). *The use of computers in the learning and teaching of mathematics.* Reston, VA: Author.

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

National Council of Teachers of Mathematics. (1991). *Professional standards for teaching mathematics.* Reston, VA: Author.

National Council of Teachers of Mathematics. (1995). *Assessment standards for school mathematics.* Reston, VA: Author.

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

National Council of Teachers of Mathematics. (2003). NCATE/NCTM program standards. Programs for initial preparation of mathematics teachers: Standards for secondary mathematics teachers. Retrieved from http://www.nctm.org/Standards-and-Positions/CAEP-Standards/

National Council of Teachers of Mathematics. (2011). Calculator Use in Elementary Grades. Retrieved from https://www.nctm.org/uploadedFiles/Standards_and_Positions/Position_Statements/Calculator_Use_in_Elementary_Grades.pdf

National Council of Teachers of Mathematics. (2012). NCATE NCTM standards. Programs for initial preparation of mathematics teachers: Standards for secondary mathematics teachers. Retrieved from http://www.nctm.org/Standards-and-Positions/CAEP-Standards

National Council of Teachers of Mathematics. (2014). *Principles to actions ensuring mathematical success for all.* Reston, VA: Author.

National Council of Teachers of Mathematics. (2015a). Calculator Use in Elementary Grades. Retrieved from http://www.nctm.org/Standards-and-Positions/Position-Statements/Calculator-Use-in-Elementary-Grades/

National Council of Teachers of Mathematics. (2015b). NCTM CAEP Program Recognition Decision Rule. Retrieved from http://www.nctm.org/Standards-and-Positions/CAEP-Standards/NCTM-CAEP-Program-Recognition-Decision-Rule/

National Council of Teachers of Mathematics. (2015c). Overview – Mission Statement. Retrieved from http://www.nctm.org/About/

Nyberg, J. A. (1924). *First course in Algebra.* New York, NY: American Book Company.

Polly, D. (2008). Modeling the influence of calculator use and teacher effects on first grade students' mathematics achievement. *Journal of Computers in Mathematics and Science Teaching, 27*(3), 245-263.

Pomerantz, H. (1997). The role of calculators in math education. In *Dallas superintendents' forum, Dallas, TX, 1997*. Dallas, TX: Texas Instruments.

principle. (n.d.). In *Dictionary.com*. Retrieved from http://www.dictionary.com/browse/principle

Roberts, D. L. (2002a). *National Council of Teachers of Mathematics Oral History Project Records: Interview with Dr. Shirley A. Hill.* (Box 4RM109). Archives of American Mathematics. Dolph Briscoe Center for American History, University of Texas, Austin.

Roberts, D. L. (2002b). *National Council of Teachers of Mathematics Oral History Project Records: Interview with Dr. Edgar L. Edwards, Jr.* (Box 4RM109). Archives of American Mathematics. Dolph Briscoe Center for American History, University of Texas, Austin.

Rowland, T., Turner, F., & Thwaites, A. (2014). Research into teacher knowledge: a stimulus for development in mathematics teacher education practice. *Mathematics Education, 46*, 317-328. doi: 10.1007/s11858-013-0564-9

Santos, M., Aguero, E., Borbon, A., & Paez, C. (2003, July). *Students' use of technology in mathematical problem solving: Transforming technological artifacts into mathematical tools.* Paper presented at the 27th International Group for the Psychology of Mathematics Education Conference, Honolulu, HI. Abstract retrieved from ERIC database. (ED501092)

scientific calculator. (2016). In *Oxford dictionaries.* Retrieved from http://www.oxforddictionaries.com/us/definition/american_english/scientific-calculator?q=scientific+calculator

Schmidt, M. E., & Callahan, L. G. (1992). Teachers' and principals' beliefs regarding calculators in elementary mathematics. *Focus on Learning Problems in Mathematics, 14*(4), 17-29.

Seidman, I. (1998). *Interviewing as qualitative research: A guide for researchers in education and the social sciences* (2nd ed.). New York, NY: Teachers College Press.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4-14. doi:10.3102/0013189x015002004

Shulman, L. S. (1990). Reconnecting foundations to the substance of teacher education. *Teachers College Record, 91*(3), 300-310.

Shulman, L. S., & Shulman, J. H. (2004). How and what teachers learn: A shifting perspective. *Journal of Curriculum Studies, 36*(2), 257-271. doi:10.1080/0022027032000148298

Simmt, E. (1997). Graphing calculators in high school mathematics. *Journal of Computers in Mathematics & Science Teaching, 16*(2), 269-289.

Stone, J. C., & Millis, J. F. (1906). *A first algebra: For beginners.* Chicago, IL: Benjamin H. Sanborn.

Strauss, A., & Corbin, J. (1998). Basics of qualitative research: Techniques and *procedures for developing grounded theory.* Thousand Oaks, CA: Sage.

Sturges, J. E., & Hanrahan, K. J. (2004). Comparing telephone and face-to-face qualitative interviewing: a research note. *Qualitative Research, 4*(1), 107-118. doi: 10.1177/1468794104041110

Texas Instruments. (2014). *Middle grades math*. Growing patterns teacher notes.pdf. Retrieved from http://education/ti.com

Tondeur, J., Van Braak, J., Sang, G., Voogt, J., Fisser, P., & Ottenbreit-Leftwich, A. (2012). Preparing pre-service teachers to integrate technology in education: A synthesis of qualitative evidence. *Computers & Education, 59*, 134-144.

tool. (n.d.). In *Online Etymology Dictionary*. Retrieved from http://dictionary.reference.com/browse/tool

Underwood, I. (2000). Logic definitions. *Ask Dr. Math.* Retrieved from http://mathforum.org/library/drmath/view/55620.html

University of Phoenix. (2016). Teaching methods: Secondary mathematics. Retrieved from http://www.phoenix.edu/courses/med563.html

Walen, S. B., Williams, S. R., & Garner, B. E. (2003). Pre-service teachers learning mathematics using calculators: A failure to connect current and future practice. *Teaching and Teacher Education*, *19*, 445-462. doi:10.1016/S0742-051X(03)00028-3

Willoughby, S. S. (1983). Curriculum trends: Mathematics. *Educational Leadership, 41*(1), 76-77.

APPENDICES

A. HRPP APPROVAL LETTER

TEXAS TECH UNIVERSITY
Vice President *for* Research

October 13, 2015

Shirley Matteson Curriculum & Instruction Mail Stop: 1071

Regarding: 505466 Teacher Preparation Programs and Calculator Pedagogy Dr. Shirley Matteson:

The Texas Tech University Protection of Human Subjects Committee has approved your proposal referenced above. The approval is effective from October 13, 2015 to September 30, 2016. This expiration date must appear on all of your consent documents.

We will remind you of the pending expiration approximately eight weeks before September 30, 2016 and to update information about the project. If you request an extension, the proposal on file and the information you provide will be routed for continuing review.

Sincerely,

Kelly C. Cukrowicz, Ph.D.
Chair, Institutional Review Board for the Protection of Human Subjects
Associate Professor, Dept. of Psychological Sciences

Box 41075 | Lubbock, Texas 79409-1075 | T 806.742.3905 | F 806.742.3947 | www.vpr.ttu.edu An EEO/Affirmative Action Institution

B. HRPP MODIFICATION APPROVAL LETTER

Feb 8, 2016 10:50 AM CST

Shirley Matteson
Curriculum and Instruction CI

Re: 505466 Teacher Preparation Programs and Calculator Pedagogy Findings: Addition of the existing co-investigator from the initial protocol.

Dear Dr. Shirley Matteson:

A Texas Tech University IRB reviewer has approved your proposed modification to the protocol referenced above within the exempt category of Category 2. Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, or reputation.

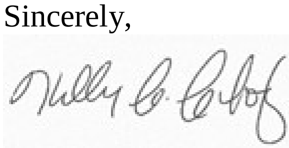
Exempt research is not subject to annual review by the IRB. Any change to your protocol requires a **Modification Submission** for review and approval prior to implementation.

Your study may be selected for a Post-Approval Review (PAR). A PAR investigator may contact you to observe your data collection procedures, including the consent process. You will be notified if your study has been chosen for a PAR.

Should a subject be harmed or a deviation occur from either the approved protocol or federal regulations (45 CFR 46), please complete an **Incident Submission** form.

Once your research is complete, please use a **Closure Submission** to terminate this protocol.

Sincerely,



Kelly C. Cukrowicz, Ph.D.
Chair, Texas Tech University Institutional Review Board Associate Professor, Department of Psychological Sciences 357 Administration Building, Box 41075
Lubbock, Texas 79409-1075
T 806.742.2064 F 806.742.3947
www.hrpp.4u.edu

C. INTERVIEW PROTOCOL

Hello, my name is Philena Farmer. I am a graduate student at Texas Tech University and am calling you as per our agreement in your email dated ---------. May I please record this for accuracy purposes? Thank you.

1. How long have you taught at this university?
2. Tell me about the degrees you have earned and majors?
3. What is your academic rank?
4. How long have you taught math courses at the college level?
5. Which courses have you taught?
6. How long have you taught the particular math course that prepares mathematics teachers?
7. What classes do you teach which prepare mathematics teachers?
8. Are pre-service teachers in separate classes from math majors or engineer majors? If yes, what is the reason for a separate course?
9. When was the first time you remember using a calculator?
10. Thinking back to your school years, what do you remember about using a calculator in mathematics classes?
11. How did you learn to use a calculator as an instructional tool?
12. Describe how you use calculators in your math classroom.
13. Describe how students use calculators in your math classroom.
14. What is your impression of using calculators in math class?
    a. In grad classes
    b. In under grad classes
    c. For your own child
15. Are there other instances of technology that you feel are beneficial in math class?
16. In a position statement in July of 2011, concerning the use of calculators, NCTM stated, “the proper implementation of the Technology Principle depends on teachers’ creating approaches to classroom instruction that appropriately integrate the use of technology into lessons focused on learning mathematics.” What is your impression of this?
17. For what topics or concepts do you feel calculators are appropriate?
18. What is your philosophy of calculator use?

Thank you so much for your time today. I will be emailing you a Word document, with Review feature on, so that you may edit incorrect/incomplete responses. You should receive this email with a copy of the transcribed work within the next week. If I have not heard from you with corrections by ---------, I will use the document as sent. Once again thank you for your help with my dissertation.

D: ADULT CONSENT FORM

What is this project studying?
This study is called "Teacher Preparation Programs and Calculator Pedagogy". This study will help us learn how college professors prepare pre-service teachers to use calculators as tools in the classroom. What we will learn will help institutions prepare pre-service teachers according to accreditation standards.

What would I do if I participate?
In this study, you will be asked to share your experiences, thought and feelings. Some questions will be about you. Some questions will be about your thoughts. Some will be about how you feel or what you experienced. The interviews will be audio recorded in order for us to obtain accurate information.

How will I benefit from participating?
Besides providing the project with valuable information, you can take great pride in knowing that you made a difference.

Can I quit if I become uncomfortable?
Yes, absolutely. Your participation is completely voluntary. Dr. Matteson and the Institutional Review Board have reviewed the questions and think you can answer them comfortably. You may skip any question you do not feel comfortable in answering. You can also stop answering questions at any time. Participation is your choice. However, we do appreciate any help you are able to provide.

How long will participation take?
We are asking for 30-45 minutes of your time.

How are you protecting privacy?
Your name will not be linked to any documentation and any use of this material in reports, publications, or presentations will never be associated with participants in this study without permission. No one other than the researchers associated with this project will have access to the raw data. All related documentation will be stored either in a locked file cabinet in the researcher's office or in a password protected file on a password protected computer.

I have some questions about this study. Who can I ask?

- The study is being run by Dr. Shirley Matteson from the College of Education at Texas Tech University. If you have questions, you can call her at 806-834-3841.
- TTU also has a Board that protects the rights of people who participate in research. You can ask them questions at 806-742-2064. You can also mail your questions to the Human Research Program, Office of the Vice President

for Research, Texas Tech University, Lubbock, TX 79409 or email them to hrpp@ttu.edu.

____
Signature

____
Printed Name

____
Date

This consent form is not valid after September 30, 2016.

E: RECRUITMENT LETTER

October 1, 2015

Dear

My name is Philena Farmer. I am a doctoral student at Texas Tech University conducting my dissertation research on the preparation of teacher educators to use calculators in mathematics classrooms. My goal is to understand how pre-service mathematics teachers are prepared to teach with an appropriately use calculators in the classroom.

You have been selected as a potential participant because your institution is in a state where Praxis Content Exams are taken for teacher certification, your institution has a CAEP certified teacher preparation program, and you are the professor for pre-service mathematics teachers methods or mathematics class. If you agree to participate, you will be asked about your methods of using calculators and how you apply them in your classes. The results of this study will benefit teacher preparation programs as well as organizations which certify these programs, such as CAEP and NCTM.

I am hoping that we can find a mutual agreeable time for a phone or Skype interview. This interview will be digitally recorded and should take no longer than 30 minutes and should be closer to 15 minutes. There is no risk during the interview and you, as a participant, may stop at any time. **No personal information will be collected during the interview.**

I hope that you will be willing to participate in this survey since you were specifically chosen based on a list of factors (if you wish I will share these with you). My aim is to interview 20 mathematical teacher educators across various states.

Thank you for your time and consideration in participating in this study.
If you have any questions, please do not hesitate to contact Dr. Shirley Matteson, the Principal Investigator overseeing this study, at Shirley.matteson@ttu.edu or (806) 834-3841.

Sincerely,
Philena J. Farmer

Dr. Matteson, Principal Investigator
College of Education
Texas Tech University
Box 41071
Lubbock, TX 79409-1071
Phone: (806) 834-3841

F: TELEPHONE CALL FORMAT

Hello Dr. ____________________________,

My name is Philena Farmer and I am a doctoral student at Texas Tech University working on my dissertation. I would like to ask you a couple of questions concerning calculator use in your classes. Would that be alright with you?

(If agreement is given, then I would begin with the interview protocol given in Appendix C). You may at any point refuse to answer or end this interview.