TECHNOLOGY IN

HIGHER EDUCATION MATHEMATICS:

A MIXED METHODS STUDY

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Abstract:

The integration of technology has become a high priority at various levels of education, including higher education. This study focused on discovering and describing the technology being used in higher education mathematics content courses by faculty members at colleges and universities. The research questions focused on what technology was being used by higher education mathematics faculty, how it was being used, what factors would encourage the incorporation of technology, the description of an adopter of technology, who is most likely to use technology to engage students in learning, and challenges that must be overcome to implement technology. The study uses an explanatory sequential mixed methods design which allowed for gathering qualitative data through semi-structured interviews and a vignette to support the quantitative data, which was gathered from a general technology survey administered electronically. The participants included 68 faculty members from research universities, regional public and private universities, and community colleges in a Midwestern state. Results from the study found that technology used by faculty included computers, projector systems, calculators, word processing software, learning management systems, e-mail communication, and the Internet. Technology was found to be predominately used for classroom instruction as a visual aid to present multiple forms of mathematical representations. Factors that could influence the integration of technology into mathematics content courses include the need for a technology resource bank that has appropriate and high-quality tasks that correspond to content and the need for additional time to investigate and implement new technologies. The description of an adopter of technology that evolved during the study was not adequate, but the analysis did show that the attitudes and beliefs of faculty toward technology influenced technology-use preferences. Future research is needed to identify a complete description of an adopter of technology. The study also reinforced the idea that technology-rich classrooms offer an avenue to engage students in learning mathematics. Lastly, the study highlighted challenges that faculty encounter when integrating technology including demands from administration, time for exploration, the need for additional training opportunities, and the lack of technical support.

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CHAPTER 1

INTRODUCTION

Technology has become a dominate force in the workplace, in education, in communications, and in entertainment (Czaja et al., 2006). Specifically in the area of education, some leaders have viewed technology as the key to reforming our educational system. “Technology is no ‘silver bullet’ for transforming education,” but with the necessary changes in teaching pedagogy and actively involving students in the learning process, technology has the potential to change the way learning occurs in the classroom (Means, Olson, & Singh, 1995, p. 69; Prensky, 2008).

This study focused on discovering and describing the technology being used in higher education mathematics courses, which faculty use the technology, how faculty use the technology, and why faculty use the technology the way they do. This research was a mixed methods study that focused on the perceptions of higher education mathematics faculty members who self-identified themselves as *adopters* or *non-adopters* of technology. The results and findings of this study provide information for higher education mathematics faculty and university and college mathematics departments to evaluate how technology is utilized in their own courses.

This chapter provides a brief overview of the study, giving background information on the use of technology that framed the study. To set the stage for the study, the research problem, purpose of the research, and the research questions are outlined. A synopsis of the research design and methods provides a framework for how the data was collected and the data analyses were conducted. Also included in this chapter are the limitations, delimitations, potential ethical issues arising in the study and general assumptions for the study. The chapter ends with a list of key terms and their definitions allowing the meaning of certain words and phrases to have an equivalent interpretation by each reader.

Background and Context

A variety of technologies are currently used in the field of education, but for whom is the use of technology beneficial and how is the use of technology productive to learning? In a poll conducted by SmartBrief, almost 60% of teachers who responded indicated that they implement technology into instruction and assessment in the core subjects (Haber, 2013). According to Haber (2013), mathematics teachers utilize technology more than other educators in their instruction. The study further narrowed the use of technology into three categories: classroom technology, mobile technology, and school-wide technology and reported that the most common use of technology based on the findings is as classroom technology. Classroom technology includes the implementation of interactive whiteboards, clicker systems, and calculators as just a few examples. In using technology to improve mathematics achievement, only 20% of teachers polled by SmartBrief specify that achievement is greatly improved as a result of integrating technology and approximately 50% believed that technology improved achievement at only a moderate level (Haber, 2013).

Educational technology has a significant and important place in education. The utilization of technology will continue to grow at each level as teachers and students are introduced to the greater benefits in learning when using technology in the classroom. Peck and Dorricott (1994) supports this by naming ten reasons why technology can revolutionize a student's work and thinking process, becoming an integral part of the learning process:

A. Students learn and develop at different rates.
B. Graduates must be proficient at accessing, evaluating, and communicating information.
C. Technology can foster an increase in the quantity and quality of students' thinking and writing.
D. Graduates must solve complex problems.
E. Technology can nurture artistic expression.
F. Graduates must be globally aware and able to use resources that exist outside the school.
G. Technology creates opportunities for students to do meaningful work.
H. All student need access to high-level and high-interest courses.
I. Students must feel comfortable with the tools of the Information age.
J. Schools must increase their productivity and efficiency. (pp. 13-14)

Technology ultimately allows mathematics educators to individualize instruction through specialized technological roles such as a tool, a tutor, to explore, and to communicate. Technology provides mathematics education with “visual images of mathematical ideas, they facilitate organizing and analyzing data, and they compute efficiently and accurately” (Dick & Hollebrands, 2011, p. 121). With the new technology becoming the standard in higher education mathematics courses, it is necessary for educators to adapt their instructional strategies and concentrate on meeting the needs of the digital learners. Technology allows for these changes to be accomplished smoothly and effectively.

Educators are integrating technology into classroom instruction, but how is it being implemented and which educators are implementing the technology? Previous data shows that within the general population, the adoption of technology is influenced by a person’s level of education, socioeconomic status, attitudes toward technology, perceived benefits, and access to the technology (Czaja, et al., 2006). These characteristics could potential be reflected by college and university faculty that participated in this study, along with factors that may have bearing on whether mathematics department faculty members become adopters of technology.

Research Problem

The higher education setting is changing and traditional students who are entering colleges and universities now have never experienced life without some form of digital technology. These students have always had access to cell phones, computers, digital cameras, digital music players, the internet, email, graphing calculators and the majority of these students are *texting* masters. Today’s students are being referred to as not only the *millennial generation,* who have a what it all and want it now attitude, but also as *digital natives* (Ng, Schweitzer, & Lyons, 2010; Prensky, 2001). *Digital natives* are defined as those individuals born in or after 1980. This generation not only possesses "sophisticated skills in using digital technologies, but also that, through their exposure to these technologies, they have developed radically new cognitive capacities and learning styles" (Margaryan, Littlejohn, & Vojt, 2011, p. 429; Prensky, 2001). Researchers that are working to understand this generation question whether higher education faculty members are prepared and equipped to meet the needs of digital native students that are entering our college and university classrooms, particularly the mathematics classrooms (Walden University, 2010). Higher education faculty must come to understand the very important role they play in combining technology and content knowledge. This requires faculty to model their "confidence with technology, guiding minds toward constructive educational purposes and teaching students the … new skills of the competitive world" (Walden University, 2010, p. 28).

College and university faculty members continue to ask themselves difficult questions about the use of technology in the mathematics content classrooms. These questions include whether or not the needs of the digital native students being met, if technology is or can be utilized to meet those needs and how must the instructional techniques and strategies change with the use of technology. Using technology as a mechanism for learning may be the key to answering these questions. In a 2010 study connecting educators and technology, 46% of mathematics teachers identified themselves as "moderate to frequent" users of technology (Walden University, 2010). The education profession understands that mathematics educators have numerous opportunities to incorporate technology into mathematics instruction, but what is currently unknown is what motivates educators to become adopters of technology, what characteristics these adopters have in common, and how the technology is actually integrated into class preparation and instruction to enhance student learning.

Research Purpose and Research Questions

The researcher views technology in higher education mathematics courses as an important topic based on her own recent experiences of integrating technology into the mathematics content she teaches in a higher education institution. Basic mathematics technology, including calculators and mathematical software, had been used in this particular department, but the integration of an interactive whiteboard (IWB) technology caused a great deal of discussion. One veteran faculty member, who taught the general education mathematics courses in the largest room in the building, refused to have the interactive whiteboard installed in her room. She informed the chair that she was too close to retirement to have to learn a new system. Other faculty members in the department welcomed the new technology, adapting course preparation and classroom instruction to integrate the IWB surface and software. The department continued to add an IWB to the classrooms each year. The students have commented on how they appreciate the IWB because most faculty members provided guided notes based on the lesson that is presented and faculty members save the notes and upload them to the learning management software that is used by the university. Because of the departmental discussions concerning the implementation of this new technology and the student comments, the researcher became interested in how technology was used and implemented in other college and university mathematics departments around the state.

The purpose of this mixed methods study was to discover and describe how technology is being utilized in mathematics courses based on the first-hand knowledge of higher education mathematics faculty at comprehensive universities, regional universities, and community colleges in a mid-western state. The study addressed the technology usage in mathematics content classrooms at the higher education level. An explanatory sequential mixed methods design was used and involved collecting quantitative data first and then explaining the quantitative results with in-depth qualitative data.

Technology usage is generally defined as any type of technology that is used for the planning and preparation for instruction, delivery of mathematical content knowledge, and student learning and engagement. The definition of technology used for this study comes from the National Council of Teachers of Mathematics (NCTM). Technology is defined for this study as "all forms of electronic devices, including computers, calculators, and other handheld devices, telecommunications equipment, and the multitude of multimedia hardware, including the software application associated with their use" (Masalski & Elliott, 2005, p. ix; NCTM, 2000).

To fully understand the perspectives of higher education mathematics faculty members regarding what technologies are being used, how the technology is being used, who is using the technology, and why they are using the technology, this study answered the following research questions:

1. What kinds of technology are being used in higher education mathematics content courses?
    a. How is the technology being used?

   b. What factors would encourage higher education mathematics faculty to incorporate technology into their classroom preparation, instructional opportunities, and classroom learning?
2. What is the description of an adopter of technology?
3. Who, adopters or non-adopters, are most likely to use technology to engage students in learning mathematics?
4. How have technology adopters overcome challenges of implementing technology into higher education mathematics content courses and enhance student learning?

Research Design Overview

This study is an explanatory sequential mixed methods design and involved collecting quantitative data first and then explaining the quantitative results with in-depth qualitative data. The philosophical and theoretical framework is grounded within Bandura's Social Cognitive Theory, which incorporates social interaction and self-efficacy (Bandura, 1977, 1986). Social interaction and self-efficacy play a major role as an individual decides whether or not to become an adopter of technology (Straub, 2009). The Technology Adoption Theory illustrates the stages that an individual moves through as they become an adopter of technology (Straub, 2009; Toledo, 2005).

Multiple sources of data, including survey data, individual vignettes of technology events that occur in the participants' classrooms, and semi-structured interview data were collected and analyzed. The initial survey provided demographic information and details that describe the general technology use of higher education mathematics faculty. Chosen from the survey results, six individuals were selected to complete semi-structured interviews that will provide a detailed description of technology use, thus providing data for the explanatory sequential design and methodology. More explicit information for the research design is contained in Chapter 3 of this study.

Assumptions

The following assumptions, based on the organization of the study, were made:

- Subjects will give an honest response – to the best of their knowledge;
- Survey return rates would be greater than 30% of the total sample population;
- At least six subjects will volunteer for the follow-up semi-structured interviews; and
- Data will inform higher education mathematics education faculty about the potential use of technology in mathematics courses.

Limitations of the Study

The limitations of this study are potential weaknesses that might affect the results of this study. The first limitation is most likely to be the response rate of the electronic survey. A response rate of 30% is deemed to be appropriate for electronic surveys, which for this study would translate to receiving responses from approximately 170 participants. Another limitation could be the General Technology Survey. This survey was developed by the researcher, but has not been widely tested for validity and reliability. The survey has been distributed to experts and field tested for additional feedback. The last limitation of the study is the possible errors in data collection and data analysis. All precautions will be taken to collect and report the data as accurately as possible.

Delimitation of the Study

A delimitation of this study is that the study does not distinguish between mathematics and mathematics education faculty members. This distinguishing characteristic does not exist at all higher education institutions that were included in the study; therefore, it was not separated for the study. All faculty members listed on the mathematics and/or statistics department websites were included in the sample.

Potential Ethical Issues

Ethical considerations may have arisen during this study related to the instrument administration and issues with confidentiality. The initial survey was administered electronically so participants could complete the survey at their leisure, but the researcher monitored the process to make sure that little variation occurred. Confidentiality considerations are always important when working with human subjects. Data from the electronic survey was stored securely within the *Qualtrics Survey Software* program and only the researcher and individuals responsible for research oversight had access to the records. The *Qualtrics* account is password protected. The data gathered through the semi-structured interviews was kept in a locked cabinet in the researcher’s locked office. Anonymity was kept for all participants, except to the researcher, throughout the research and analyses. The researcher made every effort to keep personal bias out of the data collection, analyses, and interpretations.

Key Terms

Certain words or phrases in this study may have numerous definitions depending on the context in which they are used. To ensure that readers of the study do not assume meanings the researcher has not intended, the following key terms have been defined to create equivalent meanings for the readers.

<u>Technology</u> – All forms of electronic devices, including computers, calculators, and other handheld devices, telecommunications equipment, and the multitude of multimedia

hardware, including the software application associated with their use" (Masalski & Elliott, 2005, p. ix; NCTM, 2000)

Faculty – Individuals that are employed by a college or university that teach mathematics and/or statistics courses. The status of employment can be full-time, part-time, adjunct instructors, lecturer, lab instructor, teaching assistant, and/or graduate student.

Mathematics Course – Any undergraduate or graduate level class offered through mathematics and/or statistic department that contains mathematical content and theory. Examples of content knowledge areas could include, but are not limited to algebra, geometry, calculus, probability, statistics, numerical analysis, number theory, topology, and logic.

Research University – Institution of higher education, usually comprising a liberal arts and sciences college and graduate and professional schools that confer bachelor, master, and doctoral degrees in various fields. The functions of the research universities as designated by the Constitution of a specific Midwestern state (State of Oklahoma, 2012, p. 3.2.3) include:

A. Both lower-division and upper-division undergraduate study in a number of fields leading to the baccalaureate or first-professional degree.
B. Graduate study in several fields of advanced learning leading to the master's degree.
C. Graduate study in selected fields leading toward the doctor's degree.
D. Organized basic and applied research.
E. Statewide programs of extension study and public service.

F. Statewide programs designed to promote the economic development of a specific Midwestern state.

G. To the extent resources are available, to carry out limited programs and projects on a national and international scale.

Regional University – Institution of higher education, usually comprising a liberal arts and sciences college usually conferring bachelor and sometimes master degrees in various fields. This type of institution is considered a 4-year institution and is usually smaller. The functions of the regional universities as designated by the Constitution of a specific Midwestern state (State of Oklahoma, 2012, p. 3.2.4) include:

A. Both lower-division and upper-division undergraduate study in several fields leading to the baccalaureate degree.

B. A limited number of programs leading toward the first-professional degree when appropriate to an institution's strengths and the needs of the state.

C. Graduate study below the doctor's level, primarily in teacher education but moving toward limited comprehensiveness in fields related to a specific Midwestern state's manpower needs.

D. Extension and public service responsibilities in the geographic regions in which they are located.

E. Responsibility for institutional and applied research in those areas related closely to their program assignments.

F. Responsibility for regional programs of economic development.

G. Perform other functional or programmatic responsibilities as authorized by the State Regents.

Community College – Institution of higher education, usually comprising a liberal arts and sciences college usually conferring technical certificates and associate degrees in various fields. This type of institution is considered a 2-year institution and is usually smaller. The functions of the community colleges as designated by the Constitution of a specific Midwestern state (State of Oklahoma, 2012, p. 3.2.5) include:

A. Provide general education to all students.
B. Provide education in several basic fields of study for those students who plan to transfer to a university or complete a baccalaureate degree.
C. Provide one- and two-year programs of technical and occupational education to prepare individuals to enter the labor market.
D. Provide programs of remedial and developmental education for students who lack required high school academic requirements for college admission or competency in the basic academic skills areas, consistent with the remediation policy.
E. Provide both formal and informal programs of study especially designed for adults and out-of-school youth in order to serve the community generally with a continuing education opportunity.
F. Carry out programs of institutional research designed to improve the institutions' efficiency and effectiveness of operation.
G. Participate in programs of economic development independently or with universities to meet the needs of each institution's geographic service area.
H. Perform other special or programmatic responsibilities as authorized by the State Regents.

Conclusion

This study illustrates how technology is utilized in higher education mathematics content courses based on the faculty perspective. A mixed method design using an initial survey and follow-up semi-structured interviews culminated in a mixed methods study highlighting technology adoption and a description of adopters. The structure of the following dissertation begins with a review of literature in Chapter 2. Chapter 3 provides an in-depth description of how the study was completed. Results of the data collection and analyses are presented in Chapter 4. Chapter 5 detailing the findings of the research questions and the implications of the study will end the study.

CHAPTER 2

REVIEW OF LITERATURE

Today's students, now more than ever, are learning new skills that are essential to their success in positions in the global marketplace (Project Tomorrow, 2012). For the most part, these are the students who have always had access to cell phones, texting, computers, digital cameras, digital music players, internet, email, and graphing calculators. Born between 1980 and 1994, these students are called *digital natives* who are characterized by their "familiarity with and reliance on information and communication technologies (ICTs)" (Kennedy, Krause, Judd, Churchward, & Gray, 2006, p. 4). The *digital natives* have advanced through their PK-12 education with their styles of learning and knowledge capabilities developing with technology as the center (Prensky, 2001). Students that are considered *digital natives* have been raised in a culture that has had information at their fingertips. These students find it very natural to collect, retrieve, organize, manage, evaluate, and synthesize information all through the use of a mobile device that fits in the palm of their hand (Wade, Rasmussen, & Fox-Turnbull, 2013). Technology, specifically mobile technology, is providing an avenue for students to be more active thinkers, executing new skills and making education decisions based on a task. With the integration of technology into learning environments, the digital environment that it creates expands the learners "access beyond classroom walls; creat[ing] access opportunities where none existed before; and provid[ing] support and collaboration experiences not previously possible" (Wade, et al., 2013, p. 165).

Essential skills these students must possess are most notably grounded in the continually changing technology that is being introduced throughout the workforce. With the vast array of emerging technologies, the education system must provide learning opportunities that include the advanced technology that students will use outside the classroom and the skills to adapt to new technologies. As new technological devices and services become available to individual students, educators should look closely at which products can be utilized effectively within the mathematics content classroom and the level of support that would be necessary to allow for efficient implementation. To keep students up-to-date and current on new technologies, the higher education faculty must be conversant with the benefits in learning produced with and through the use of technology. Grunwald and Associates (Walden University, 2010) published a report relating educators, technology, and the 21st century skills. This report listed benefits of technology and the set of skills acquired from the act of learning with technology as accountability, collaboration, communication, creativity, critical thinking, ethics, global awareness, innovation, leadership, problem solving, productivity and self-direction (Walden University, 2010). Interacting and experimenting with new technology not only creates these benefits and skills, but also allows students and faculty to comprehend the power of technology.

This study sought to identify the technology usage and profile of technology users who teach mathematics content courses at the higher education level by describing their common characteristics. Using an explanatory sequential mixed methods research design, the following research questions were addressed:

1. What kinds of technology are being used in higher education mathematics content courses?
    a. How is the technology being used?
    b. What factors would encourage higher education mathematics faculty to incorporate technology into their classroom preparation, instructional opportunities, and classroom learning?
2. What is the description of an adopter of technology?
3. Who, adopters or non-adopters, are most likely to use technology to engage students in learning mathematics?
4. How have technology adopters overcome challenges of implementing technology into higher education mathematics content courses and enhance student learning?

The following focused review of literature provides an in-depth look at technology in society as well as in the educational setting. The following review will cover briefly the history of technology, the relation of technology to classroom learning, and how the integration of technology effects student achievement. The purpose of this study was to bring to light how and to what extent technology is being used in college-level mathematics content courses to empower and support students' efforts to learn.

What is technology?

What is *technology*? Defining this word is even more difficult than creating a complete list of the world's technology. Utilizing today's most widely used piece of technology, the World Wide Web, the Bing on-line dictionary (Bing, 2003) gave three definitions for technology including:

1. application of tools and methods: the study, development, and application of devices, machines, and techniques for manufacturing and productive processes;
2. method of applying technical knowledge: a method or methodology that applies technical knowledge or tools; and
3. machines and systems: machines, equipment, and systems considered as a unit.

The *Oxford Dictionary* ™ defines technology as "the application of scientific knowledge for practical purposes, especially in industry" (Oxford University Press, 2013). Another website, *YourDictionary*, listed technology simply as the "application of knowledge to solve problems or invent useful tools" (LoveToKnow Corporation, 2013). The dictionary also listed synonyms for technology which include skill, knowledge, expertise, know-how, equipment, machinery, and tools. From this general definition stems multiple definitions that vary based on specific organizations that have defined their own version of technology. These could include, but are not limited to educational technology, information technology, communication technology, digital technology, and medical technology.

At the collegiate level, two major associations are proponents of technology use in mathematics. The Mathematical Association of America (MAA) and the National Council of Teachers of Mathematics (NCTM) both include statements concerning technology usage in their guidelines and standards. NCTM sets the standards for PK-12 mathematics education programs across the nation. Within these standards, numerous references are made to integrating technology into classroom instruction and learning.

Definition of Technology
All forms of electronic devices, including computers, calculators, and other handheld devices, telecommunications equipment, and the multitude of multimedia hardware, including the software applications associated with their use.

Figure 1. Definition of Technology (Masalski & Elliott, 2005, p. ix)

NCTM defines technology as "all forms of electronic devices, including computers, calculators, and other handheld devices, telecommunications equipment, and the multitude of multimedia hardware, including the software application associated with their use" (Masalski & Elliott, 2005, p. ix). Although MAA does not specifically define technology within their guidelines, the association devotes a complete section to how technology should be employed within mathematical sciences departments at the higher education level. MAA specifies that technology should be incorporated into mathematics by providing opportunities that "foster teaching and learning, increase the students' understanding of mathematical concepts, and prepare students for the use of technology in their careers or their graduate study" (Mathematical Association of America, 2003, p. 10). These guidelines emphasize that faculty members need to consider the multiple ways that technology can be implemented in the mathematics classroom to facilitate faculty-student interaction. Although this study is not primarily focusing on mathematics education courses, the definition from NCTM will be used as the definition of technology for this study.

History of Technology in Society

Technology has been in our world since arrival of human kind. Because an accurate definition of technology seems elusive, it is hard to say what people at the beginning of time might have considered as *technology*. Some believe that the invention of tools made out of stone during the Stone Age were some of the first technology. These tools were used to break down larger objects, for sharpening, and as weapons. These tools lead to the creation of the wheel that allowed for more effective travel and ease in moving larger objects. Copper was considered the first metal that was discovered by civilizations during the Stone Age and was later mixed with tin to create bronze, which was more durable and stronger than the two metals alone. In regard to mathematics, the abacus, which is the first known type of calculator, was created by the Babylonians in 2400 B.C. Later in 300 B.C. the binary number system was defined and is now the underlying base for computer programming.

Moving to 1280 A.D., individuals were able to see better with the invention of the eye glasses. The 1500s introduced the ball bearing, first mechanical calculator, and a programmable robot. Galileo made contributions to the study of mechanics in the early 1600s with the pendulum, thermometer, and microscope. The adding machine, barometer, and the pressure cooker came about during the 1600s. Great technological discoveries occurred during the 1700s with the flying shuttle, Franklin stove, lightening rod, spinning jenny, hot air balloon, steamboat, and vaccinations all being introduced to society. In the 1816, the technology tool most associated with the medical profession, the stethoscope, was invented. The electric motor was introduced in 1821 by Michael Faraday and this one piece of technology spawned a plethora of technology that would revolutionize the world. Technological developments continued to increase during the 1800s with the invention of the phonograph, typewriter, dynamite, and the sewing machine. The incandescent lamp developed by Edison lit up the world in 1878 and Edison and Alexander Graham Bell both discovered telephone technology three years apart.

The 20th century brought about tremendous technological inventions. The important technology of the early 1900s focused on automobiles made possible by Ford and Benz, airplanes courtesy of the Wright brothers, and radio signals developed by Marconi and DeForest, which soon dominated Saturday night entertainment. The mid-1900s intrigued us with the development of the laser in 1960 and the ATM in 1967. Technology continued to explode from there with numerous versions of the computer as well as other electronic devices. In 1983, Time magazine named the computer the "Machine of the Year" (Intel, 2006). Today, the majority of the world's population utilizes computer technology in some form on a daily basis. The creations of the internet, computer technology, and cellular devices have been the changing technology of the 1990s.

The creation of the Internet and the World Wide Web changed the way most individuals live their lives. Although the vision and first trials of the internet occurred in the early 1960s, it was not made available to the public commercially until November 1992 when full internet service was offered by the Delphi company. The National

Science Foundation, at one point, was the backbone of the internet, but now has taken a step back and is focusing on creating K-12 and local public library access for all, as well as researching how the internet has changed our society (Howe, 2012). The internet offers not only information, but on-line shopping, entertainment, social networking, documents and many other features. Access to the internet started with dial-up through telephone lines, but has moved to universal wireless access in several areas.

The rise in the development of technology progressed into the 21st century and fourteen years into the century, technology is still changing daily. Not a day goes by that companies are not releasing a new piece of technology or a new version of an existing one. Individuals today walk the streets with a piece of technology seemingly glued to the palm of their hand or listening to their own personal music device. Cellular devices of today are what computers were to the society of the 1990s; users can phone, text, type, surf the internet, listen to music, and set their home thermostats with a flick of a button. Advancements in technology will continue whether individuals choose to embrace them or not. Some new technologies are very helpful like the cell phone when you have an emergency, but others may seem like a nuisance like the voice on a global positioning system (GPS).

History of Educational Technology

Educational technology is also referred to as *learning technology* or *instructional technology*. The certainty of one specific definition does not seem to exist. The early definitions first focused on the devices and materials used in an educational setting, but the focus has changed numerous times with the introduction of each newly developed technology. The common thread among the definitions include a focus on both the process of applying tools and the specific tools and materials used for educational purposes (Roblyer & Doering, 2012). Technology has been in our classrooms for centuries, and what we would not consider as technology today was considered "new" technology as early as the 1700s. Some early technologies include paper, pencils, slate boards, and globes.

The historical perspective of educational technology is influenced by four professional education entities: 1) media and audiovisual communications, 2) instructional systems and design, 3) vocational training, and 4) educational and instructional computing (Roblyer & Doering, 2012). Media and audiovisual communications entered the educational technology realm around the 1930s when instructors incorporated concrete visuals in their lectures by including slides and films. Televisions were considered an influential piece of technology in the classroom around the 1950s. By the 1960s, over fifty educational television channels were available across the U.S. Media has continued to be a resource for teaching in today's classrooms providing students learning opportunities via television, internet sources, and interactive whiteboard capabilities.

Technology Influences			
media and audiovisual communications	instructional sytems and design	vocational training	educational and instructional computing

Figure 2. Technology Influences (Roblyer & Doering, 2012)

An additional historical influence on technology was the introduction of specific instructional systems and design (Roblyer & Doering, 2012). The use of instructional systems and design was necessitated by post-World War II military personnel returning to the job market. Large numbers of veterans were transitioning back into the workforce requiring industrial trainers to develop a systematic approach to teaching this new workforce the required skills. In designing and creating these instructional systems, trainers worked with universities and K-12 schools to enhance and strengthen the instructional system technologies. This early work is, in part, responsible for the rapid advances we see today. The National Defense in Education Act (NDEA) in 1958 pushed for more money and technology to be brought into public schools, but schools had yet to see that the use of technology was beneficial for their students. In 1963, the Vocational Education Act put more money into schools specifically designated for the use of technology. Schools found that the use of the mainframe and minicomputers did not work well with their single teacher strategy (1 computer – 30 students) because of the time involved in batch processing methods. Due to apprehension from classroom educators, the curriculum remained unchanged by the minimal use of the computers (Roblyer & Doering, 2012).

In the 1980s, educational technology transitioned again moving the focus from the "regular" classroom into vocational training programs (Roblyer & Doering, 2012). Emphasis was placed on ways to prepare students to use technology that would exist in their future jobs when students joined the work- force. The K-12 industrial arts curriculum and vocational education program curriculum shifted the focus from training primarily devoted to woodworking and metal works to courses that were more reflective of high-tech laboratories, desktop publishing, graphics, electronics, computer-assisted design (CAD), and robotics (Roblyer & Doering, 2012).

The most recent historical shift in educational technology began in the 1950s and still continues today. This perspective pushed for educational and instructional computing to begin using computer-operating systems (Roblyer & Doering, 2012). Computer-operating systems were making their way into businesses and industrial trade training programs which required students to have a working understanding of the systems functions and uses. From this point, computer system technology seemed to grow by leaps and bounds.

The decade of the 1970s will be known for the creation of the Apple I computers and the “floppy disc.” The 1980s brought the IBM PC and the Apple IIe. During this time, schools installed approximately one computer for every 92 students (Wikibooks contributors, 2011). Now, that has changed so there is a ratio of approximately one computer for every 4 students. The push to incorporate computer systems grew throughout the 1980s and 1990s and brought about the invention of numerous versions of computer systems that are more user-friendly and mobile than the earlier models. In 1992, the Internet was declared public domain by congressional edict and the World Wide Web grew exponentially (Howe, 2012). With easy access to the internet, multiple sites sprung up appropriate for use in educational settings including Google and learning management software such as Blackboard™ and Desire2Learn™ (D2L).

The new century brought with it more powerful technologies including smartphones, interactive whiteboards, Twitter™, and Facebook ™ as an introduction to social networking. In 2010, iPads were introduced combining the technology of the iPhone and the Mac laptop. The iPad has become quite useful in the classroom with multiple apps and touch-screen capabilities focused on the learning of mathematics and other subjects.

With technology as an important component of classroom instruction, schools are finding ways to make as much technology as possible available to students. Even with the challenges of funding, training, and access, students and teachers together are learning to incorporate technology in the PK-12 classroom to support the learning of content knowledge and understanding, especially in mathematics. Incorporating technology into PK-12 and higher education classrooms prepares our students, not only to progress through formal education, but to enter a technologically-savvy workforce that has become the norm in the current society.

The Role of Technology

In current research, the role or function of technology has been categorized in multiple ways dependent upon the purpose and perspective of the researcher. In her book, *Technology and Education Reform: The Reality Behind the Promise* (1994), Barbara Means categorized technology into four broad domains based on the proposed use of the technology. These domains include technology used as a tool, as a tutor, as a device for exploration, and as a means of communication (Figure 3).

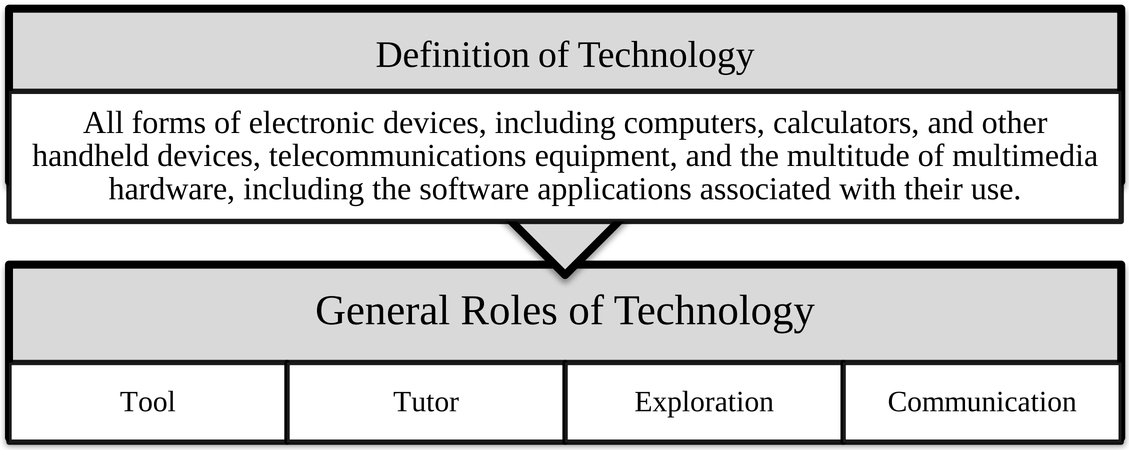

Figure 3. General Roles of Technology (Means, 1994; NCTM, 2000)

Technology as a Tool

Technology used as a tool is the most common function. The technology serves as an assistant to aid in completing tasks and activities, and has usually become an important part of a home or workplace environment (Means, 1994). These tools are not designed especially for the use in an educational setting, but are already incorporated into most schools in some way. The most commonly used mathematically-related tools that are calculators, computer software, and computer algebra systems.

Some form of calculator technology can be found in most homes and classrooms, including basic four-function calculators, scientific calculators, or graphing calculators. Some adults use calculators to balance their bank statements, some use them in their line of business, and still others use calculator technology to engineer the building of tall skyscrapers. Children usually experiment with calculators, checking their homework, or just trying to outsmart the technology. Calculators are usually the first type of technology people think when thinking about mathematics. Graphing calculators, in particular, were introduced in 1986 by Casio and have revolutionized mathematics teaching and learning (Waits & Demana, 1998). Previously teachers had incorporated computers only for demonstrations, to illuminate iterations, or to solve problems. When calculators became readily available, this technology tool was quickly adapted by educational institutions because the cost of hand-held calculators was less than that of computers, the calculators were simpler to use, and this new technology was smaller and more portable.

Bert Waits and Franklin Demana (Demana & Waits, 1990; Waits & Demana, 1998) are the most notable researchers in the area of early calculator technology integration. Waits and Demana began their endeavors with the Computer and Calculator Pre-Calculus (C^2 PC) program and the Computer and Calculator Enhanced Calculus (C^3E) program. Both projects focused on fully integrated graphing technology and computer graphing into mathematics curriculum not by replacing the traditional pedagogy, but by using calculators and computers to show the power of the mathematics content through visualizations and representations (Waits & Demana, 1998). Even with their enthusiasm about fully integrating graphing calculators, Waits and Demana understood that a balanced approach integrating the traditional paper/pencil methods and the enhanced technology is necessary for optimal learning.

Throughout Demana and Waits' research on the relationship of learning mathematics with technology, it was important for them to convey to educators that technology would ultimately produce students that were improved problem-solvers, had a better understanding of algebraic concepts and procedures, and were able to adapt to new technology as it advanced through the years. Demana and Waits continually pushed educators to understand that technology tools such as calculators, computer symbolic algebra software, and computer interactive geometry were the best available resources to illustrate and to enhance students' mathematics content knowledge. Early in their research, Demana and Waits emphasized that because of technology:

> expectations of school mathematics should be increasing students' ability to set up problems with appropriate operations rather than focusing on the computations and manipulations involved; increasing students' ability to deal with open-ended, realistic problems rather than contrived, simplified ones; increasing students' ability to understand the many connections between different representations of the same problem; and increasing students' appreciation of the utility and value of mathematics. (Demana & Waits, 1990, pp. 27-28)

Technology brought about major challenges for educators that, according to Waits and Demana, could not be ignored. Some paper and pencil methods are still necessary to help students develop mathematical automaticity, but technology is replacing several of the tasks in the mathematics classroom used as a tool to build mathematical intuition and understanding.

Another beneficial use of technology is found in the incorporation of computer software. Computer software that is focused on mathematics has the potential to influence student learning outcomes through the interactive use of the technology. Examples of software programs commonly used in mathematics classrooms fall into three categories: tools, dynamic manipulation, and tutors (Masalski & Elliott, 2005). Examples of software tools are word processing, spreadsheets, presentation, and database creation software. Derive™, Mathematica™, Maple™, Geometer's Sketchpad™, SMARTBoard Interactive Software™, Fathom™, Tinkerplots™, and virtual manipulatives are examples of dynamic software tools. Software packages are considered as a tutoring tool when using cognitive tutors through education websites, ALEKS™, or drill and practice software. Software technology is housed on computers and can be readily displayed in classrooms with interactive whiteboard technology or through a projector. Software packages implemented into classroom activities and discussions provide the students with visual representations that can be manipulated and changed, adding another dimension to successful student understanding and learning.

One type of software that is currently very popular in the mathematics classroom is dynamic geometry technology. This technology presents Euclidean geometry by constructing and relating concepts about lines, points, segments, rays, circles, and angles (Olive, 2000). The technology can instantly measure certain angles or lengths and some versions include animations properties (Hannafin, Burruss, & Little, 2001). The most common dynamic geometry technology found in classrooms is the Geometer's Sketchpad™, which is available for personal computers and tablet technology. In a study that focused on the teachers' and students' role and reactions to a student-centered instructional geometry program, Hannafin, Burruss, and Little (2001) concluded that Sketchpad™ was successful as a technology tool to support effective teaching and enhanced learning of geometry. Teachers, who facilitate learning instead of lecturing about facts, release the control of learning important concepts to the students who explore, make conjectures, and substantiate their arguments through the use of the technology. Students liked this approach to learning geometry and enjoyed the freedom to work at their own pace individually or with a partner using the Sketchpad™ software. Dynamic geometry technology is a useful technology tool that is capable of promoting mathematical understanding.

Another valuable resource that is slowly making its way into the college-level mathematics classroom is interactive whiteboard technology (IWB) which can be beneficial to the teaching of mathematics. Smith, Higgins, Wall, and Miller (2005) conducted a review of the current literature regarding the use of IWBs and discovered that school districts adopted IWBs because the software applications provided teachers flexibility and versatility in presenting important concepts; engaged students in multimedia/multisensory presentations; led to efficiency in presenting material; assisted teachers in planning, printing and saving lessons; enhanced lessons through the use of Information and Communication Technology (ICT); and encouraged interactivity and participation among the students and with outside experts (Kennewell, Tanner, Jones, & Beauchamp, 2008; Smith, et al., 2005, p. 92).

The IWB technology software and capabilities allow teachers the benefit of flexibility and versatility in classrooms as a teaching tool which can be used across all age groups and in a variety of settings (Smith, et al., 2005). Students with underdeveloped fine-motor skill may find a keyboard or mouse difficult to maneuver, but by physically standing at the IWB, the student is able to complete tasks. The IWBs multimedia capabilities offer educators the options to incorporate sound, video, and other images that can provide visual enhancement for any lesson in any discipline. Efficiency is another benefit because the IWB adds depth to the lesson, allowing for more discussion, and enables smooth transitions to be made from lesson to tasks (Smith, et al., 2005). Educators are also finding that the functions of the IWB software eventually reduce planning time for lessons and activities because prepared lessons can be saved, shared with colleagues, revised, printed, and saved for future use. Teachers are free to take more time to reflect and to make changes to the lessons they have saved from the previous year, thus incorporating new ways to continually meet the needs of learners.

The presentation of learning materials by an interactive whiteboard technology allows for the modeling of information and communication technology (ICT) skills due to the dimensions of the board and clarity of the material that is projected upon the IWB (Kennewell, et al., 2008; Smith, et al., 2005). Information and communication technology skills that are modeled by the teacher or another student demonstrate how to manipulate objects by physically touching the surface, instead of watching the teacher move the mouse pointer. Teachers have more time to focus on the students' ideas instead of making changes at a computer. The last, and maybe the most notable benefit, is the interactivity that encourages participation of students with the IWB technology. The interactivity at the board increases the motivation of learners and brings about more discussion opportunities that lend themselves to deeper understanding (Kennewell, et al., 2008). These benefits come together to show that the IWB technology is a tool that supports learning and provides unique interactive opportunities for all levels of student learners.

Technology as a Tutor

Technology that is used as a tutor instructs students directly through a lecture-style or workbook manner. This use of technology offers explanations, demonstrates exercises for the particular mathematics lesson, provides practice to hone the introduced skills, and remediates as necessary (Means, 1994). All assessment for understanding is completed by the tutor technology offering solutions and explanations of the practice exercises. The most familiar mathematics technology that functions as a tutor is *computer-aided instruction (CAI).*

Computer-aided instruction is a technology that allows a wide range of students to have their specific needs in mathematical understanding met through practice. Two systems most common in mathematics classrooms are WebAssign™ and MyMathLab™. A product developed by *Pearson Education*, MyMathLab™ is being included in numerous course redesign projects. With this instructional software used as a tutor, studies have shown that students tend to stay on task longer than compared to a traditional lecture classroom (Stewart, 2012; Twigg, 2011). This tutoring system requires students to solve problems and provides instructional support as they become more successful in mathematics. A CAI program provides the students tutoring as needed, gives instant feedback, grades their work, builds skills, and remediates problem areas. One professor who integrated MyMathLab™ into her calculus courses reported attendance rates increased from 40% to 70% during the semester (Stewart, 2012). School administrators who are searching for ways to retain students find the rise in attendance impressive and work with teachers to help students become successful in mathematics. Some critics purport this type of technology will replace the teacher in the classroom, but “instead it gives the teacher the opportunity to play a bigger role” (Stewart, 2012, p. 13). The professor went on to say that her students viewed her more as a mentor, rather than as an “instructor” and saw her as a positive influence in their learning (Stewart, 2012). These systems are being used in higher education, as well as in some secondary schools as a tool for practice and remediation. Academic systems, such as MyMathLab™ are changing the look of the classroom experience.

Technology for Exploration

Information exploration and explanation have become key aspects in reform efforts in mathematics education. Exploration through mathematical content provides an outlet for students to discover and make their own connections between content knowledge and application (Means, 1994). Using technology to prompt exploration has even greater benefits. Technology that is available through the World Wide Web now offers mathematics demonstrations at our students' fingertips. Some well-known information exploration technology that is available on the internet comes from the major websites including Youtube™, Khan Academy™, and search engines like Google™ and Yahoo ™. Youtube™ is not only a source for entertainment, but offers many types of video demonstrations appropriate for the mathematics classroom. Students are able to search for a topic, watch videos that demonstrate certain mathematical concepts, and explore historical and current information. Khan Academy™ has become the go-to site for many secondary and higher education mathematics students (Thompson, 2011). This website consists of over 3,800 videos that cover K-12 mathematics through calculus and even some topics in science. The videos are free to anyone and can be used as a natural progression through topics in mathematics. Numerous examples and simplified explanations are created by a small team of faculty that focuses on providing education materials around the globe. Sites such as Khan Academy™ have provided the impetus for "flipped" classrooms where students go home, review the procedures for solving assigned content application problems, and then use the in-school class time for solving problems, working with classmates, and asking questions all under the watchful eye of their teacher (Thompson, 2011).

The most accessible type of internet technology used for information exploration is a search engine, such as Google™, Yahoo™, and Bing™. These search engines locate millions of pieces of data in seconds on infinite topics. The concern with using just a general search engine is that some content on the internet may not correct and can lead to misunderstandings and inaccurate information. Exploration with technology offers students an entire world of information at their fingertips that relates to mathematics. After continued use, students learn which sites are mathematically user-friendly and provide the best references explanation for the tasks at hand.

The internet offers a seemingly unlimited number of educational applications. One type of software that works extremely well as an exploration tool in elementary classrooms and could be incorporated easily into secondary classrooms, is virtual manipulatives (Moyer, Niezgoda, & Stanley, 2005). Virtual manipulatives are interactive models that are web-based and represent accurate visual replicas of the concrete manipulatives. Examples of these virtual models include Cuisenaire rods, geometric solids, base-ten blocks, pattern blocks, fraction models, and algebra-related models. Students are able to manually manipulate the objects either with a mouse on a computer screen or with their fingers on an interactive whiteboard. These models are useful for teachers with access to a computer lab so every student can have his/her own experiences, and compared to the cost of providing a physical set of each type of mathematical manipulative for every student seemingly inexpensive. Virtual manipulatives are considered a type of physical and pictorial representation (Moyer, et al., 2005). The interactivity that virtual manipulatives provide enhances student exploration and engagement during problem-solving tasks and aids understanding.

To fully understand the impact of virtual manipulatives in the classroom, two elementary educators and a researcher came together to study children's use of this technology and how it enhanced mathematical understanding of concepts and skills (Moyer, et al., 2005). Two classes, one kindergarten and one 2nd grade spent multiple days working with both concrete manipulatives and virtual manipulatives. Observers recorded notes about small groups of students while they were working through tasks with both types of manipulatives. The kindergarten group, using pattern blocks, was found to be able to create a greater number of patterns using virtual manipulatives than using the actual physical models. The second grade class, using base-ten blocks to compute addition exercises, tended to draw on their paper the movement of the blocks that they experienced when using the virtual base-ten blocks. These visual images students were able to move physically assisted the students in developing mathematical meaning and allowed for exploration and experimentation (Moyer, et al., 2005).

Technology to Communicate

The last important function of technology is for communication purposes. There are two types of communication, synchronous and asynchronous (Rogers, 2000). Synchronous communication is any communication where all involved parties are present at the same time of the conversation, whether face-to-face, video chat, instant messaging, or telephone conversations. Asynchronous communication occurs through email, discussion boards, and texting. Our society has gradually moved toward a more asynchronous society, in which we would rather not communication directly with one another. Technology is becoming the medium of choice for people to communicate and is slowly diminishing direct face-to-face communication. New electronic devices and programs allow teachers and students to send and receive messages at any time. Examples of communication technology include electronic mail (e-mail), cellular phones, and video chatting. On-line courses, using learning management systems make completing an education course or training as simple as owning a computer, using it to communicate with instructors, and completing assignments.

Communication technology has changed the face of education by making on-line coursework possible. On-line learning requires teachers to set up coursework via the internet. Course design could include email, discussion boards, video lectures, on-line chatting with other students, and electronic quizzes and test. The students in a totally on-line course never actually meet the instructor or classmates in person, but interact with them throughout the course. Because there is no face time, instructors have to insure that they clearly communicate the objectives of the course and provide sufficient support to the students enrolled in the course (Lee, Srinivasan, Trail, Lewis, & Lopez, 2011). Communication by the instructor could include email, announcements on the learning management system, clearly written instructions and explanations, and student assignments to discussion groups. In a 2011 study on the relationship between the students' perceptions of support, course satisfaction, and learning outcomes of on-line learning, researchers found that course satisfaction was directly linked to how well instructors offered support (Lee, et al., 2011). Sufficient support had to include instructional support from the instructor, peer support from other students in the course, and technical support. The success of on-line learning seems to lie in the support and communication offered by instructors within their on-line courses. Effective communication is almost always the key to student success.

For on-line learning to be possible, learning management system have to have sufficient features to facilitate a successful course, including communication support. Learning management systems (LMS), including Blackboard™ and Desire2Learn™ (D2L), are technology-enabled learning systems that allow for instructors and teachers to share, submit, receive, and communicate course materials. These systems, although used predominately for on-line coursework, can also be used to support traditional courses. Instructors can upload handouts, make announcements, and have students turn in homework without having to use class time to do it.

Lonn and Teasley (2009) conducted a study to explore the uses and benefits of learning management systems. Using surveys from instructors and students, the data showed, and the researchers concluded, that both instructors and students valued this tool for communication as well as for the built- in teaching and learning features. Learning management systems can be an element of organization for instructors but also a place for students to stay abreast of vital course information. Technology used to communicate, such as learning management systems, play an essential role in effective on-line learning and offer additional benefits to traditional classroom teachers.

Role of Technology in a Mathematics Classroom

Technology has become a major part of today's education. Everywhere we look in educational settings we see multiple types of technology being utilized. Examples of technology used in classrooms, but not limited to, include computers, internet, calculators, email, iPads, cell phones, digital games, electronic books, televisions, and interactive whiteboards. Speak Up 2011, a national report of K-12 teachers, librarians, and administrators, stated that educators could not "truly appreciate the value of a new technology tool until we have realized a direct benefit for its use in our personal life or in our work life" (Project Tomorrow, 2012, p. 5). Today's educators have to familiarize themselves with many forms of technology to remain current with their students and effectively utilize the technology for learning and assessment of content knowledge.

To fully understand the implementation of technology into education, it is important to consider the conceptual framework necessary to make educational technology integration successful. Technological Pedagogical Content Knowledge (TPCK) is a conceptual framework that combines technology, pedagogy, and content knowledge used by educators to integrate technology into their classroom (Mishra & Koehler, 2006). This framework assists educators in understanding traits that are necessary to implement technology appropriately into the classroom. The TPCK theory is based on the following attributes of the educator:

- understanding of the representation of concepts using technologies;
- implementing techniques that use technologies in constructive ways to teach content;
- understanding the knowledge of what makes concepts difficult or easy to learn and how technology can help redress some of the problems that students face;
- relying on students' prior knowledge and theories of epistemology to enhance learning; and
- understanding of ways technologies can be used to build on existing knowledge and to develop new epistemologies or strengthen old ones (Mishra & Koehler, 2006, p. 1029).

TPCK is an extension of the Pedagogical Content Knowledge (PCK) theory created by Shulman in 1986. He initially made the claim that pedagogy and content knowledge should be mutually exclusive in research, but then proposed that the relationship between the two was necessary to understand the connection between the subject matter and instruction. The authors of this theory extended the theory to include technology and created the three-way relationship diagram seen in Figure 4. The addition of the technology aspect within the theory created two additional relationships one between technology and content knowledge and the second between technology and pedagogy.

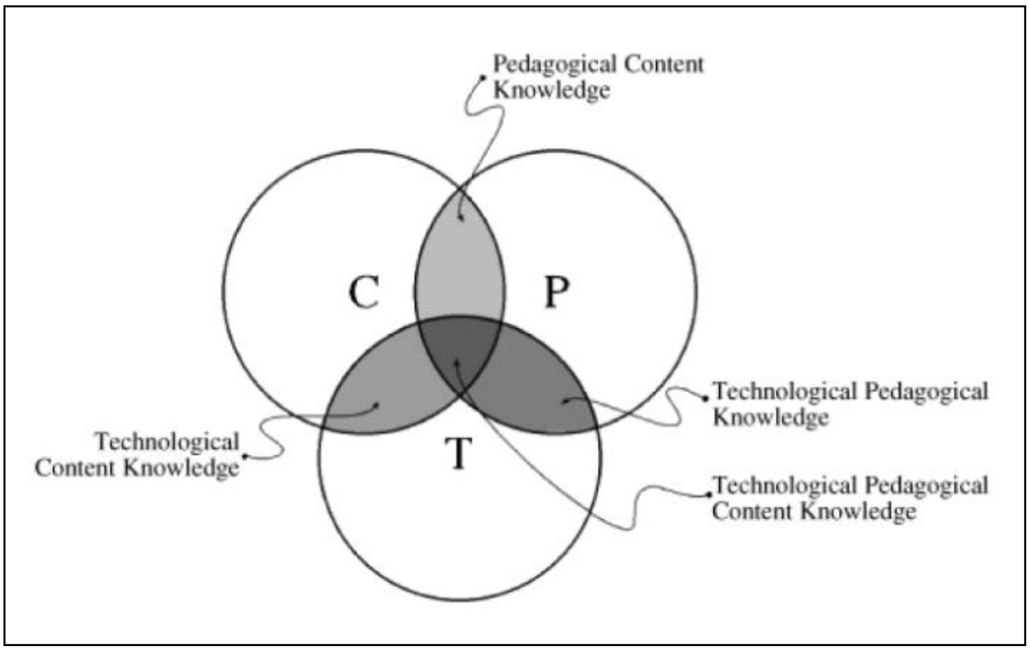

Figure 4. Pedagogical Technological Content Knowledge (Mishra & Koehler, 2006)

As teachers incorporate technology into their classroom instruction, this framework helps teachers understand the relationship that must exist between the technology and the teaching of the subject matter to enhance learning. The TPCK framework also creates a bridge that can be used to determine if the technology is being used appropriately in relation to the implementation of the pedagogy and content knowledge.

Technology continues to make strides in motivating students to become increasingly engaged in the mathematical learning process. Raines and Clark (2011) commented that "incorporating and using technology in the teaching of mathematics can encourage students to become active participants in the classroom" (p. 1). Through a review of literature, Raines and Clark (2011) concluded that the technology that was found to be most effective in a mathematics classroom included graphing calculator technology, presentations software, and computer/web-based instruction and practice. The use of graphing calculators provides students an outlet to explore more difficult mathematical content instead of being bogged down with mind-numbing paper and pencil calculations. The use of presentation software provides the students a structured learning environment that places emphasis on organizing and summarizing content. Computer/web-based instruction and practice "has had a positive impact on and assists students in learning mathematics concepts" (Raines & Clark, 2011, p. 4). Incorporating any technology into mathematics instruction has the potential to provide some benefit to students and increase student engagement in the learning process.

Technology has the potential to make an impact on the learning and achievement across all content areas and age of learners. In a review of 219 research studies, published from 1990 to 1997, Jay Sivin-Kachala (1998) found three consistent patterns of the effects of technology on learning and achievement. The findings showed that students in a rich technological environment showed positive effects on achievement in all subjects, increased achievement in preschool through higher education students that included both regular and special needs learners, and attitudes of students improved consistently when computers were utilized during instruction (Sivin-Kachala, 1998). This idea of a technologically-rich learning environment and the positive results that were found in this research is but one example where technology can be a benefit to all age groups. Providing technology to students at the PK-16 levels allows these individuals to be technologically competent as they enter society and may be more likely to include technology in their career and personal life.

SRI International (Means & Olson, 1995) conducted research on education technology reform that explored nine school sites where technology was being incorporated in ways that supported educational reform. Teachers and administrators from the nine schools expressed six different reasons why they were pushing for increased technology usage. The school personnel believed that technology could support thinking processes, stimulate motivation and self-esteem, promote equity, prepare students for the future, support changes in school structure, and explore technology capabilities (Means & Olson, 1995). Challenges to reform the use of technology in classrooms were also found by this research team. These challenges included providing adequate technology access, equalizing technology access, involving a majority of teachers in the planning and delivery, and providing technical support for technology use and maintenance. The individuals who can provide the most usable feedback concerning the implementation of technology are the teachers themselves (Means & Olson, 1995). The teachers have first-hand knowledge of what technology is being used, how the technology is being used, and how the students are responding to the increased use of technology. Educators currently in PK-16 classrooms play a vital role in understanding the impact technology can have on the educational system.

The integration of technology into education involves taking into account student learning outcomes. These learning outcomes must be made a priority by teachers and school administrators when incorporating and utilizing technology. Barbara Means explains that "most educators will expend the effort needed to integrate technology into instruction when, and only when, they are convinced that there will be significant payoffs in terms of student learning outcomes" (Means, 2010, p. 287). As with anything new, there will always be hurdles that have to be jumped and hills that have to be climbed. The benefits of integrating technology in education more than outweigh the negative side effects. The availability and use of technology in the classroom allows teachers to meet the needs of more learners in multiple ways, thus empowering students to be successful, life-long learners.

Technology in the Mathematics Classroom

The roles of technology in the mathematics classroom have some similarities to the functions of technology in general that were presented by Barbara Means – tool, tutor, exploration, and communication. The *Focus in High School* Mathematics book series published by the National Council of Teachers of Mathematics includes a book that is focused on technology, *Technology to Support Reasoning and Sense Making*. Dick and Hollebrands (2011) introduced the idea of two roles of technology that support sense making and reasoning in the mathematics classroom – action and conveyance.

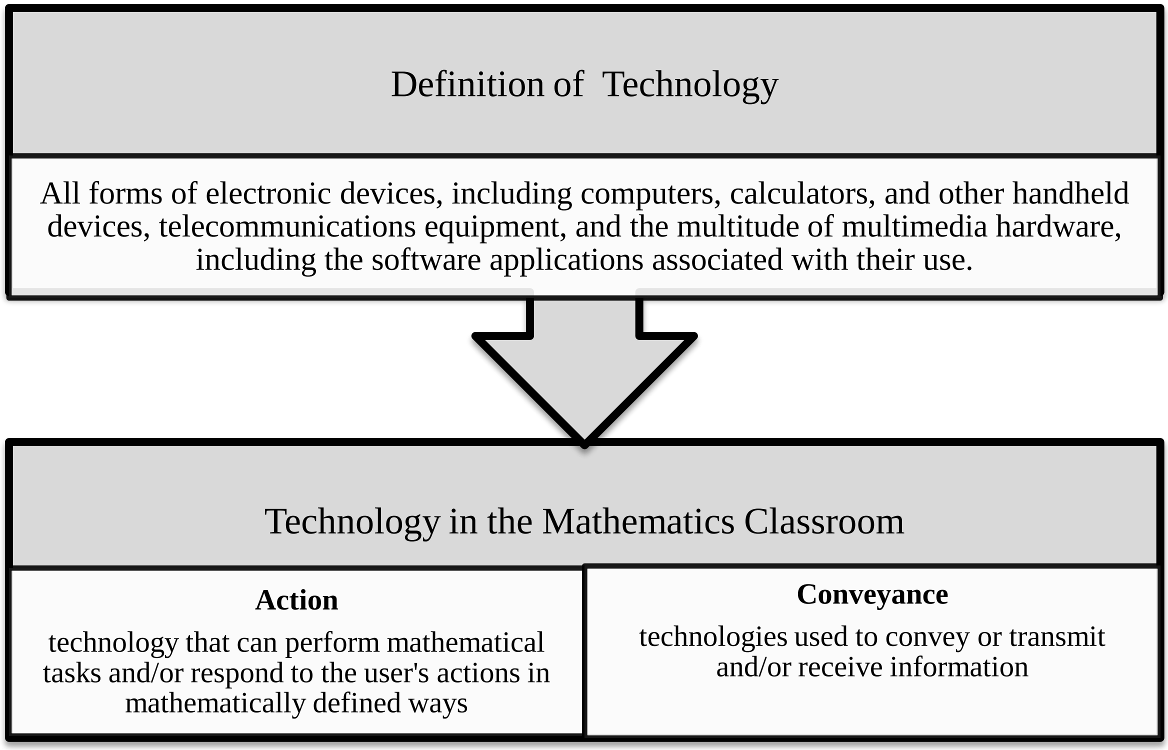

Figure 5. Technology in the Mathematics Classroom (Dick & Hollebrands, 2011)

Action technologies are pieces of technology that "can perform mathematical tasks and/or respond to the user's actions in mathematically defined ways" (Dick & Hollebrands, 2011, p. xii). Conveyance technologies are defined by the authors as "those used to convey, this is, to transmit and/or receive information" (Dick & Hollebrands, 2011, p. xi). As seen in Figure 6, technology can be defined so it can be identified as either *action technology* or *conveyance technology*.

The purpose of action technologies in the mathematics classroom is to carry out a variety of tasks or chores that are mathematical in nature. Dick and Hollebrands emphasize that technology has the potential of being a "platform for setting the stage for student insights and for developing understanding, with opportunities for students to explore and investigate patterns of mathematical behavior" (2011, pp. xiiii-xiv).

Action Technology

- Computational/ Representational tool kits
  - graphing calculators
  - computer algebra systems
  - spreadsheets
- Dynamic geometry environment
  - construction tools
  - measurement
  - virtual geometric objects
- Microworlds
  - virtual manipulatives
- Computer simulations
  - parameter-driven vitural enactments of physical phenomena

Conveyance Technology

- Presentation technology
  - interactive boards
  - slide-presentation software
  - document cameras
  - display monitors
- Communication technology
  - intranet
  - Internet
- Sharing/ Collaboration technology
  - shared view of individuals' work or common work area
- Assessment/ monitoring/ distributation technology
  - clicker systems
  - individual device screens
  - formative assessments
  - feedback

Figure 6. Action Technology vs. Conveyance Technology (Dick & Hollebrands, 2011)

Action technology has the ability to expand a student's mathematical reach by using the technology to number crunch, manipulate symbols, graph data or functions, construct geometric figures, and produce accurate measurement of figures. For action technology to be effective in the mathematics classroom students have to become good managers on when and how to use the technology. Managing the tools requires students to analyze a problem and understand what tool to use; implement a strategy to utilize the technology to progress to a solution; seek and use different mathematical representations; and reflect on solutions to problems and to determine if the solution is logical, reflect on the limitations of the technology, and interpret the results.

Conveyance technologies are typically used for presenting, communicating, and collaboration between teachers and students (Dick & Hollebrands, 2011). The purposes of these technologies are not necessarily mathematics specific and usually are most effective when the technology is thought about the least as a task is completed. This means that the attention of the student should be entirely on completing the mathematical task and not on the technology itself, potentially serving as a catalyst to enhance student learning. Conveyance technology provide opportunities for students to share ideas, explanations, solutions, and justifications to a problem, therefore engaging students in sense making and reasoning opportunities as well as productive discourse.

Pedagogical Roles of Technology in the Mathematics Classroom

A study of the inclusion of technology into mathematics classrooms requires a brief overview of additional ways technology can be utilized. In 2005, the National Council of Teachers of Mathematics (NCTM) focused their 67th Yearbook publication on mathematical learning environments that were technology-supported (Masalski & Elliott, 2005). This was in response to the growing call for education reform in the United States in grades PK-12 mathematics education. Peressine and Knuth authored an article in this same NCTM yearbook that outlined the role of technology in mathematical situations. From their work with both in-service and preservice mathematics educators, Peressine and Knuth (2005) articulated five pedagogical roles that technology plays in the mathematics classroom. The five roles of technology (Figure 6) include the use as a management tool, a communication tool, an evaluation tool, a motivational tool, and a cognitive tool. With each of these roles comes a specific purpose in meeting the primary goal of assisting “teachers in their efforts to integrate technology into their own classrooms” (Peressini & Knuth, 2005, p. 278).

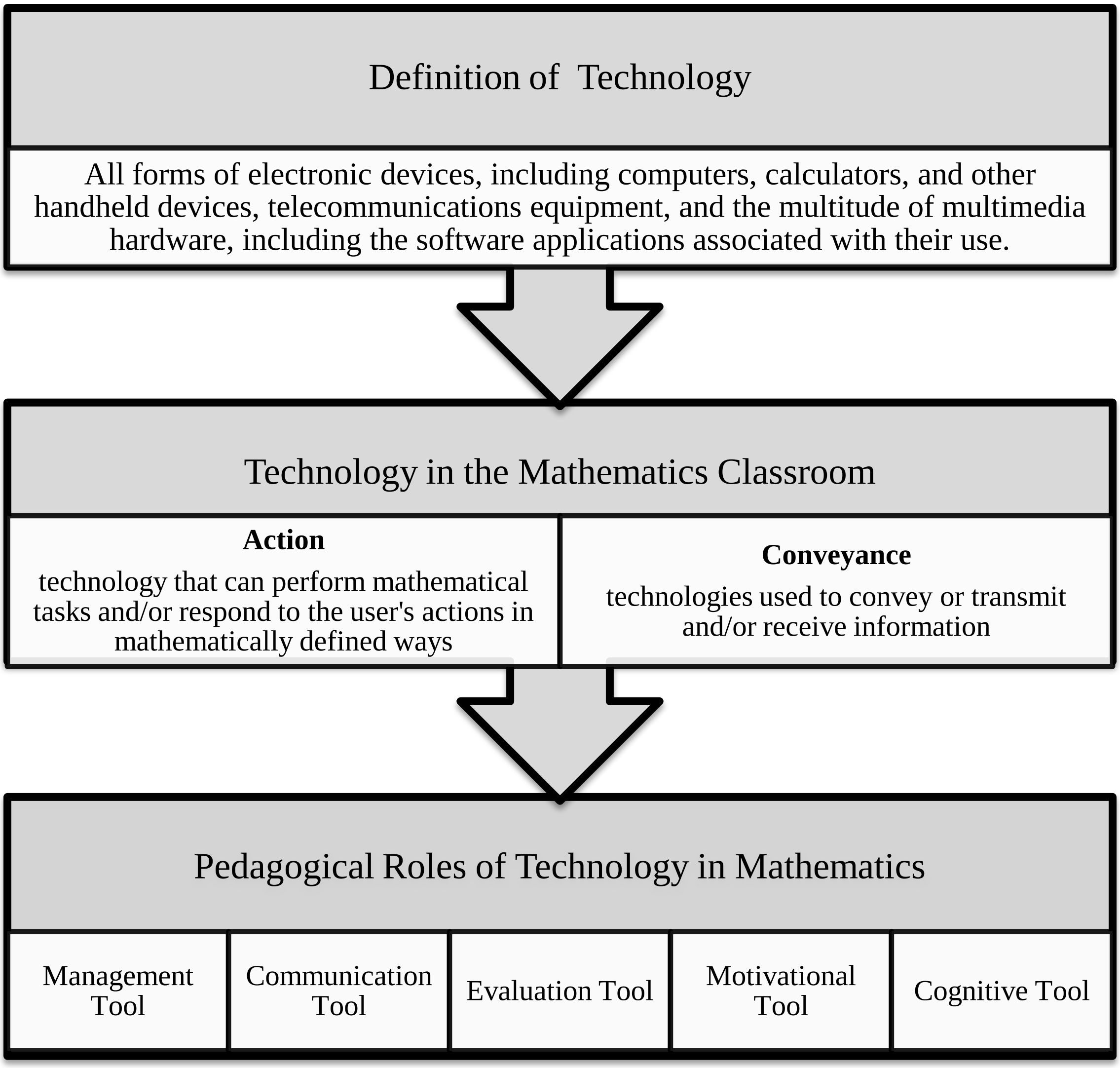

Figure 7. Pedagogical Roles that Technology Play in Mathematics Education
(Dick & Hollebrands, 2011; NCTM, 2000; Peressini & Knuth, 2005)

Management Tool

Technology used as a management tool offers mathematics teachers and students alike a way to work more efficiently and effectively on tasks and activities (Peressini & Knuth, 2005). These types of tools allow teachers to be more organized, to use technological resources for lesson preparation, and to modify and update instruction more quickly. Technology that assists educators with efficiency can include mathematics-focus internet sites, class management software, electronic grade books, spreadsheets, and word processing applications. Management tools assist students in being more productive through their own use of technology. Students also have access to mathematics-focused internet sites which provide learning opportunities for students to explore mathematical information as they complete course work. To complete assigned tasks and activities, not just in math class, students have technology resources available to them to create, modify, and make adjustments. These types of management tools provide instances for both teachers and students alike to be more productive and work more accurately, permitting more time for focused, mathematical learning.

The implementation of educational technology into classroom instruction requires administrators and school officials to consider the practices and management issues that arise with the implementation of new equipment. The most popular management tool, mathematics software, was looked at in a study by Means (2010). The intent of the study was to understand what classroom-level practices and school-level practices were associated with increased achievement using mathematics software. Means (2010) found four school-level practices and two classroom-level practices that supported or impeded the implementation of technology using observations of and interviews with teachers, technology supervisors, and administrators in thirteen schools. The school-level practices that encouraged teacher adoption of the software included establishment of a consistent instructional vision, the administrators' support for software use, teacher collaboration around software use, and satisfactory on-site technical support. Classroom level practices included reviewing software reports for all students weekly and managing the classroom effectively (Means, 2010). From her study, Means determined that educators should focus on learning how to utilize the assessment tools that are available in the software and how to optimize the classroom management options (Means, 2010). Teachers and students who truly embrace the options that management tools offer allow technology to become a natural part of the education experience.

Communication Tool

Another important role technology plays is as a communication tool. One role technology plays in a mathematics classroom is to provide an opportunity for educators to communicate with other educators either within their district or across the state (Peressini & Knuth, 2005). Examples of types of effective communication tools include electronic mail (email), on-line discussion groups, and blogs. In-service teachers can use communication tools to correspond with students, parents, and also the community. Technology as a communication tool also provides benefit for preservice teachers. Teacher education departments have the opportunity to be virtually connected with the pre-service teachers who are completing their final student teaching experience (Simonsen, Luebeck, & Bice, 2009). Dialogue between education professors, student-teachers, and their cooperating teachers, as well as video sources, is available to support mentoring, review teaching strategies, and to engage in productive discussions. Having productive communication and discourse with all parties involved in the education process allows for improved educational support opportunities utilizing communication technology tools with a goal of enhancing student achievement.

Technology used as a communication tool can be very beneficial in supporting beginning teachers as they make their way in the education field. Beginning teachers can be paired with mentors who are able to ask questions, provide guidance and support, and assist in developing confident, effective educators. In a study focused on beginning science and mathematics teachers, Simonsen, Lubeck, and Bice (2009) investigated whether private on-line discussions with mentors are an effective way to enhance knowledge and quality of instruction. Thirty-nine beginning teachers with less than three years teaching experience were paired digitally with a mentor that had at least five years classroom experience in the specific content area and were willing to communicate through the on-line medium. Over one academic year, 1,653 messages were compiled by the mentee-mentor pairings and coded into four categories – life/logistics, pedagogical knowledge, pedagogical content knowledge, and content knowledge. Results of the study show that 57% of the messages are focused on the three types of knowledge categories with the other 43% falling into the life/logistics category (Simonsen, et al., 2009). Out of the 940 messages that fell under the three knowledge categories, pedagogical content knowledge and pedagogical knowledge were the focus of the majority of the messages. Results indicated that beginning educators are comfortable with their content knowledge, in this case mathematics or science, but needed additional support in connecting content with pedagogy. The conclusion from the study shows mentoring through on-line communication tools is an "effective venue for exploring and constructing new knowledge about the pedagogical needs and concerns of beginning teachers" (Simonsen, et al., 2009, p. 65). Technology that serves the communication function provides an outlet for educators to have a non-biased opinion coming from an experienced educator who can guide new teachers through the local politics, frustrations with students, parents, fellow educators or administrators, joys, and positive experiences. The type of technology necessary to carry out this type of mentoring program is already at educators' fingertips with email and social networking. The challenge lies in finding the unbiased experienced educator who can guide less experiences teachers toward professional success in the classroom.

Evaluation Tool

The third role of technology in mathematics education is as an evaluation tool. Peressine and Knuth (2005) offer that technology has the potential to provide educators an outlet to reflect on classroom instruction. This reflection can ultimately lead back to growth and development of the educator and offer insight into student learning outcomes. Advancements in technology have provided evaluation tool examples such as video observation and the use of interconnected graphing calculators and computer screens (Peressini & Knuth, 2005). Video observation of the teacher and students provides valuable feedback. Educators can watch a lesson they presented and focus on how the students responded to mathematical content, pedagogy, and classroom culture. Teachers can see parts of a lesson when students lose focus or teachers can critic themselves on how they designed and carried out the lesson. Watching a lesson progress shows gaps in instructional time where guiding discussion questions could be asked to prompt deeper understanding for students (Chapin, O'Connor, & Anderson, 2009). The other evaluation tool mentioned in the study is the use of screen captures with either graphing calculators or computer screens. Educators now have the technology to see all of the students' hardware screens from one central computer. This provides a more efficient way for teachers to know when students are on task as well as observe common mistakes that students make, allowing for correction to be made and additional instruction to be offered. Specific technology that is utilized as an evaluation tool provides insight into individual students' thinking, their mathematical mindset, and to monitor student understanding.

Technology as an evaluation tool can provide an opportunity for educators to take an in-depth look into one's own pedagogical understanding and delivery and learn from that experience. One specific activity that teachers can carry out fairly easy is to video themselves and their classroom as instruction is in progress (Calandra, Brantly-Dias, Lee, & Rox, 2009). Reviewing videos allows teachers to self-assess instructional time and reflect on the content, the teaching pedagogy, the student involvement, and the management of the classroom. Positive changes can be made to improve and teachers can work toward enhancing students understanding as effectively as they can. One research study on the use of digital video technology by teachers compared two groups, one group that reflected on their teaching based on their memory of the lesson and the other group that reflected after they had viewed the digital video (Calandra, et al., 2009). Results of this particular study show that "participants who worked through the video-enhanced reflective process tended to write longer and more pedagogically connected reflective pieces" than the group that did not use video for reflection (Calandra, et al., 2009, p. 81). Those not using video tended to focus more on interpersonal relationships and classroom management while the focus of the other group was on pedagogy. Evaluation tools that are technology based are beneficial for teachers as they review their classroom instruction. Educators willing to use technology for self-assessment and reflection demonstrate their concern about the task they have before them as an effective teacher and are willing to make modifications as a way to provide the best educational instruction for their students.

Motivational Tool

Motivating students is sometimes a struggle in mathematics classrooms. What better way to motivate this generation of students than to thrust what they love the most upon them – technology. Another role technology plays is as a motivational tool. Technology can be used to "encourage and engage students in learning mathematics" (Peressini & Knuth, 2005, p. 280). Technology provides an opportunity for students to become active participants in the learning process through the use of the most common mathematics technology, a calculator. The argument will always be present in mathematics education research as to whether and how calculators should be used, but that is not the focus of the current research. Any type of technology that can be used to motivate today's students and involve them in critical thinking and problem solving is well worth the time it takes to implement it into classrooms.

Using motivational tools to actively engage students in mathematics can occur in multiple ways. In a study on the perspective of technology mediated learning, Goos, Galbraith, Renshaw, and Geiger (2003) found that technology can support and motivate classroom learning in both small group interactions and whole class discussions. Using computers, graphing calculators, and projection technology as motivational tools, students were able to show the importance of technology as the *master*, *servant*, *partner*, and *extension of self*. Motivational technology tools act as a *master* when a student's knowledge is limited and they are dependent on the technology to pull them through a task. Technology is a *servant* when it serves as an appropriate replacement for paper and pencil calculations. The task does not change because of the technology, but it is used as a "supplementary tool that amplifies cognitive processes" (Goos, et al., 2003, p. 78).

Acting as a *partner,* motivational technology tools assist students in presenting and promoting mathematics ideas. The technology allows students to include others in the discussion, further deepening the understanding and learning process. The last way a motivational tool can be used in a mathematics classroom is as an *extension of self*. This means that a student is able to involve and incorporate their "technological expertise as a natural part of their mathematical and/or pedagogical repertoire" (Goos, et al., 2003, p. 80). This occurs when students are so in tune with technology in the mathematics classroom that it is second nature to complete tasks using the technological functions. Motivational tools have the capabilities to facilitate discussion and shared learning within the mathematics classroom, in addition to challenging our students to become problem-solvers using both content knowledge and technology.

Cognitive Tool

The final role of technology in a mathematics classroom is in the capacity of a cognitive tool which is considered "technologies, tangible or intangible, that enhance the cognitive powers of human beings during thinking, problem solving, and learning" (Jonassen & Reeves, 1996, p. 693). Peressine and Knuth (2005) deemed this the most important tool based on the school reform that is pushing for students to have a better understanding of mathematical algorithms, procedures, concepts, and problem-solving situations. Cognitive technology tools support the students' innate desire to explore what is digitally available to them. Technology can be used in two ways as a cognitive tool: 1) to represent mathematical tasks and 2) to explore from a conceptual perspective instead of procedural process.

In the 1996 *Handbook of Research on Educational Communication and Technology*, Jonassen and Reeves suggest that cognitive tools and learning environments should become intellectual partners supporting critical thinking and higher-order learning. Placing the cognitive tools, like computers or calculators, into the hands of students shifts the focus to the learner rather than on the teachers allowing opportunities for students to make mathematical connections by analyzing, accessing, interpreting, and organizing information that leads to understanding. The researchers concluded that students, when acting as authors, designers, and constructors of knowledge using cognitive tools, develop critical thinking skills and learn more through the process instead of through the curriculum itself (Jonassen & Reeves, 1996). Educators' desire for students to be critical thinkers, but most teachers have not provided students with the appropriate materials to develop these mathematical skills at a young age and continue honing these thinking skills through secondary and higher education. Technology, placed in the hands of students, encourages them to discover and make connections in mathematics on their own under the mentoring support of their teachers.

Technology's Impact on Learning

Improving student learning and retention of mathematics content knowledge is being called for by current education standards and the integration of technology is an attempt to foster growth and development of knowledge (Common Core State Standards Initiative (CCSSI), 2010). Technology should not be used as a reward, but as part of the everyday mathematics classroom atmosphere. Lawless and Pellegrino (2007) emphasize that powerful learning environments are created when students develop conceptual knowledge through active engagement with technology. Teaching and learning with technology forces educators to develop and employ the most effective instructional methods when relating technology and mathematical content. Technology creates opportunities for educational improvement through seamless, coherent instruction and assessment (Lawless & Pellegrino, 2007). Adopting new approaches to instruction with technology is important, but educators must be able to incorporate the technology with ease.

Increased technology in educational settings pushes for research on how technology impacts learning and retention of material. In 1991, Salomon, Perkins and Globerson made the declaration that "no computer technology in and of itself can be made to affect thinking" (p. 3). These researchers used the term *computer technology* to encompass all educational technology at the time and used the term, in their words, for brevity. They followed up this statement by explaining that the social and cultural climates where instruction takes place also plays a major role along with the technology in improving thinking and understanding. The study concluded that the effects of technology can enhance and redefine student achievement when partnered with appropriate social and cultural climates. Partnering classroom culture with technology, numerous variables must change to determine the impact technology has on learning and understanding. These variables to be considered include instructional models, activities and tasks, goals and learning outcomes, physical classroom structure, and the role the teacher plays. Taking into account the "cloud of correlated variables," redesign and reform of the mathematics classroom is necessary to utilize the technology for its intended purposes (Salomon, et al., 1991, p. 8).

With the push to increase the use of technology in classrooms, educators want to know if student achievement is changed based on the quantity or quality of their technology experiences. Lei and Zhao (2007) considered how technology is used by students, what technology is popular in the classroom, and which technology might be responsible for improving student achievement. Using surveys and semi-structured interviews, middle school students and their teachers provided data to answer these questions. The findings show that a positive impact was found on student achievement when technology was focused on the specific subject area and student construction of knowledge. Lei and Zhao (2007) also found that when students spend more than three hours on computer technology, student achievement is actually lowered. The most commonly used technology was the internet and word processing software. Data also show that the specific subject area technology tools that were the most effective in influencing achievement were actually used the least and unpopular with students. This finding shows that just using the technology is not enough. Technology usage in a mathematics classroom must be focused on mathematical content that provides connection-making opportunities that will lead to full understanding (Lei & Zhao, 2007).

Enhancing mathematics achievement has been a positive outcome that has been produced by the addition of effectively used educational technology. Cheung and Slavin (2013) completed a meta-analysis on research that examined the effects that technology application used in education had on mathematics achievement in K-12 classrooms. The researchers worked with seventy-four studies that included a total of 56,886 individuals within the sample. Studies included in the meta-analysis were coded based on features of the study and an effect size was calculated for each study and also the overall effect size.

The findings of this study "suggest that educational technology applications generally produce a positive, though modest effect (ES = +0.15) in comparison to traditional methods" (Cheung & Slavin, 2013, p. 88). The authors went on to say even with the positive effect, the type of technology applications integrated into the mathematics classroom does make a difference on achievement. The types of educational technology were found to have the best achievement outcomes including supplemental computer-aid instruction, computer-management learning and research programs. This study concludes that the "question is no longer whether teachers should use educational technology or not, but rather how best to incorporate various education technology applications into classroom settings" (Cheung & Slavin, 2013, p. 102).

A teacher's level of proficiency with technology is an element that can influence mathematical learning and understanding. In a national study of technology's impact on mathematics achievement, Wenglinsky (1998) evaluated the effects of simulations and higher-order thinking technologies. He used a national sample of fourth graders and eighth graders that completed the mathematics portion of the National Assessment of Educational Progress instrument. His positive findings show that 8^{th} grade students had gains in math scores as well as students whose teachers participated in professional development on using computers. A positive correlation was found between the use of computers and professional development with both the 4^{th} grade and 8^{th} grade students. This correlation shows that computers used for simulations and applications are related to technology training the teachers have received, which collectively increase student achievement and helped create a more positive school climate. Before teachers introduce new pieces of technology into the mathematics classroom, the teachers need to be proficient in the navigation and use of the technology.

In an extension of his previous study, Wenglinsky (2005/2006) again focused on the impact using technology has on student achievement and whether there had been changes since the time of his last study in 1998. He claimed that even with the technology advances from 1998 to 2005, teachers could not assume that students have adequate skills to work with technology. To change the level of skills students had, Wenglinsky recommended implementing computer courses for all students. Instead of having to take time to teach how to use the technology before being able to complete activities, teachers could then develop classroom instructional activities assuming that students can use technology. The final conclusion to the assessment of the use of technology is that the primary way to increase student achievement is by providing content-specific digital tasks to naturally integrate both technology and mathematics (Wenglinsky, 2005/2006). Today's students automatically gravitate toward technology to complete tasks. Mathematics students of today do not consult their book for information to complete exercises, but often launch the internet and look for explanations. Because of the students' inclusion of technology into every part of life, educators will be required to change the way they approach educational instruction and the use of the available technology.

Technology or Instructional Procedures: Which causes change in the classroom?

Arguments exist as to whether learning and understanding occur in students based on the technology itself or the instructional procedures that incorporate the technology. Many of today's classrooms still reflect traditional classroom instructional methods that are described as more teacher-centered. In these classrooms, the focus is on the teacher explaining information and then having the students work independently and quietly on a task. For technology to enhance student learning, classroom instruction must become student-centered which requires educators to give up control of the instructional dynamics and allow students to work together to build their understanding. Bilimoria and Wheeler (1995) set specific guidelines on how to implement a student-centered learning environment, which is also known as a learning-centered classroom. These guidelines "suggest that teachers (a) reconceptualize education as driven by learning; (b) provide opportunities for self-directed learning; (c) reshape the authority relationship in the classroom; (d) adopt a relational learning approach; (e) pay attention to the context, inputs, and processes of learning; and (f) foster lifelong learning" (Bilimoria & Wheeler, 1995; Conklin, 2013, pp. 505-506). The student-centered classroom focuses on investigative learning by students and, with the assistance of technology, mathematical student achievement can be reached.

In a review of literature on how technology can be a transformative force to education, Wade, Rasmussen, and Fox-Turnbull (2013) explain that "successful technology use in the classroom invariably mandates a cultural transformation from traditional teacher-directed to innovative student-centered learning" (p. 164). With this shift to student-centered learning, students become more engaged through innovative learning opportunities that a focused around teamwork, critical thinking, and problem solving (Wade, et al., 2013). Some teachers are very reluctant to shift to a student-centered classroom because of their own lack of knowledge about this type of learning environment, as well as the technology and mobile devices that are necessary for the transformation. Wade, Rasmussen, and Fox-Turnbull reiterate the same notion that was found in 1994 by the *Apple Classrooms of Tomorrow* research completed by Dwyer (1994); learning environments can be student-centered and interactive "where the students [are] no longer the blank slate or the empty vessel, but rather a collaborator in an environment in which the teacher [is] a partner in the learning process – and, at times, even the learner" (Wade, et al., 2013, p. 164). With the assistance of technology in a student-centered classroom, students are able to explore connections through inquiry and interpretation, as well as showcase their new knowledge through digital presentation and portfolio capabilities. Transforming a classroom does not just occur because technology is added to the curriculum; transformation is reached when technology is viewed by teachers, administrators and policy makers as an agent of change that can fully establish a student-centered learning environment (Wade, et al., 2013).

In a study to determine how teachers incorporate technology into mathematics education, researchers identified six types technology integration and explained which of the integrations ultimately created the most productive learning environments (Drijvers, Doorman, Boon, Reed, & Gravemeijer, 2010). Using videotaped class sessions, questionnaires, and interviews, the six classroom orchestration types included *Technical-demo, Explain-the-screen, Link-screen-board, Discuss-the-screen, Spot-and-show,* and *Sherpa-at-work.* The first three categories of technology integration fall into the category of a teacher-centered approach which means that the teacher dominates the classroom communication and leads the interaction. *Technical-demo* is the demonstration of technology by the teacher with students viewing and listening to the demonstration. *Explain-the-screen* goes beyond just a demonstration to include mathematics content, but is still orchestrated by the teacher explaining what is being displayed on a screen. The third technology integration that is teacher-centered is the *Link-screen-board*, which emphasizes how mathematics content may or may not differ when displayed with technology and when displayed on paper, in a book, or on a blackboard. Within these three categories, input by the student on the content that is presented is restricted. Technology used in this manner is not conducive to influencing student achievement.

The orchestration types that do influence student achievement are the last three *Discuss-the-screen, Spot-and-show,* and *Sherpa-at-work,* all student-centered approaches (Drijvers, et al., 2010). *Discuss-the-screen* consist of a whole-class discussion which allows students to ask questions or make comments concerning what is happening with the technology. The *Spot-and-show* consists of intentionally using student reasoning to lead discussions, allowing other students to react to the reasoning and provide feedback themselves. The last type, *Sherpa-at-work,* provides opportunities for students to share their work using the technology. Educators are often hesitant to completely change their teaching style just because technology has entered the education settings. Perhaps this occurs because "technology amplifies the complexity and, as a consequence, challenges the stability of teaching practices; techniques that are used in 'traditional' settings can no longer be applied in a routine-like manner when technology is available" (Drijvers, et al., 2010, p. 214; Lagrange & Monaghan, 2009). The usefulness of technology and its relationship to achievement both reside in how the technology is utilized and integrated into classroom instruction.

Teacher Perceptions

Teacher perception plays a major role in how technology is incorporated into the mathematics classrooms. Pierce and Ball completed a study in 2009 that assessed what affects teachers' decisions or intentions to change from a traditional approach of teaching mathematics using technology. Responses were also reviewed to determine what attitudes and barriers were present during the contemplation time. Survey results indicated that teachers saw technology positively and had the perception that it could engage students in an increased number of real-world application exercises, and some teachers said they felt technology made mathematics more enjoyable and motivational for students (Pierce & Ball, 2009). Teachers indicated they felt that certain barriers kept them from integrating technology into the classroom. These barriers included school leaderships' philosophy of technology, lack of adequate funding, equity of technology availability for all students, and time constraints. Many teachers still believe that students must learn mathematics with paper and pencil first before they can use technology. An overall consensus did indicate that teachers thought technology could improve student learning (Pierce & Ball, 2009).

Technology in PK-12 Mathematics

The current set of mathematics standards being adopted by most states are referred to as the Common Core State Standards for Mathematics (CCSSM). The CCSSM includes a section on mathematical practices with regard to PK-12 learners. The Standards for Mathematical Practice (Common Core State Standards Initiative (CCSSI), 2010) consist of eight fundamental ideas that educators should develop in their students, no matter the grade level. The necessity of integrating technology into the classroom is discussed within Standard 5 – Use appropriate tools strategically. This standard calls for students to become proficient with technological tools that can assist them in problem solving. Technology allows students to delve into mathematical modeling with tasks enabling them to "visualize the results of varying assumptions, explore consequences, and compare predictions with data" (Common Core State Standards Initiative (CCSSI), 2010).

The National Council of Teachers of Mathematics (NCTM) also strongly endorses and promotes the use of technology in PK-12 mathematics classrooms. The technology principle from the *Principles and Standards for School Mathematics* calls for technology "not to be used as a replacement for basic understanding and intuitions; rather, it can and should be used to foster those understandings and intuitions" (NCTM, 2000, p. 25). NCTM supports the idea that technology enhances mathematics learning, supports effective mathematics teaching, and influences what mathematics is taught. Student learning is enhanced by technology through its ability to create multiple representations that allow students to explore ideas and to make and support conjectures. Learners with special needs can also benefit from technology when teachers adapt instruction utilizing the functions of the technology. Technology, when used appropriately and effectively by the educator, will support effective teaching. Educators can develop and select mathematical tasks that take advantage of the technology and allow opportunities for students to focus on the investigation of the task rather than on the procedure. NCTM also supports the notion that technology can influence the mathematics that is taught and also the order in which a topic appears in the curriculum (NCTM, 2012). By using technology, students are able to learn content at an earlier age.

Integrating technology into the mathematics classroom also allows for algebra, geometry, and data analysis to no longer be seen as separate topics but as a cohesive whole learned together (Common Core State Standards Initiative (CCSSI), 2010). Merging these areas of mathematics allows students to make connections in the content both in the classroom and to the world outside.

Technology provides learning opportunities for students through technological-rich classroom instruction. Including technology, even in the smallest way, into a mathematics lesson opens the door for students to engage in a conceptual conversation with their teacher as well as other students. In their article for the NCTM's 67th yearbook, Knuth and Hartmann expressed this idea to be true in that "technology offers a unique and powerful means of fostering students' understanding and intuitions of the mathematics they study…play[ing] an important role in classroom instruction" (2005, p. 151). Intentionally creating opportunities for students to visually see mathematics representations brings about conversations through the use of technology that emphasize the relationships and explanations more than the techniques and procedures. Teachers should select tasks that will be meaningful to students, highlight the mathematics content using technology, lead to extensive and deep classroom discussions, and encourage the students to make decisions about the appropriateness of their solution (Chapin, et al., 2009; Knuth & Hartmann, 2005). Students that are able to make mathematical decisions will be able to describe their reasoning and make conjectures toward other mathematical concepts, pushing them toward mathematical understanding. The current educational technology that is available can provide dynamic visual illustrations, multiple representations, and interactivity that support an educators' effort to create opportunities for in-depth mathematical understanding (Knuth & Hartmann, 2005).

Technology in Higher Education Mathematics

The inclusion of technology into higher education has been a challenge for faculty and administration. Higher education is being pressured to step-up their use of technology. This urgency to integrate more technology into the classroom stems from competition between schools, pressure from students, and technology competency standards that are currently evaluated by accrediting bodies (Rogers, 2000). Today's students are in-tune with the latest and greatest technology and they desire those capabilities within the university that they choose. This pressure from students to have the latest technology is responsible for the competition between universities. Higher education must embrace these technology requests if we are to continue recruiting students and raising both retention and graduations rates.

Technology has become a prominent issue with accrediting institutions. Teacher education programs have technology standards that must be met in education coursework to have an accredited program. Oklahoma teacher education programs, also known as professional education units, are currently accredited by the National Council for Accreditation of Teacher Education (NCATE). NCATE, which is currently in transition to merge with another accreditation group and become the Council for the Accreditation of Educator Preparation (CAEP), uses the standards from each specialized professional association (SPA) to determine whether teacher education programs meet the education goals based on a submitted institutional program review. Higher education institutions have multiple options available to complete the program review. Some variation of a technology standard is included in every set of standards from the specialized professional associations. Mathematics teacher education programs use the NCTM standards which include a technology component. The technology component for NCTM is Standard 4e stating that preservice teacher candidates must be able to

> Apply mathematical content and pedagogical knowledge to select and use instructional tools such as manipulatives and physical models, drawings, virtual environments, spreadsheets, presentation tools, and mathematics-specific technologies (e.g., graphing tools, interactive geometry software, computer algebra systems, and statistical packages); and make sound decisions about when such tools enhance teaching and learning, recognizing both the insights to be gained and possible limitations of such tools. (NCTM, 2012, p. 3)

Educators and workforce officials have both identified that technology literacy is a 21st century skill and are calling for and supporting higher education institutions to increase the amount of learning opportunities that have been integrated with a variety of technology (Walden University, 2010).

Incorporating technology into higher education has not come without resistance. Some administrators believe that if technology was simply provided to faculty members, they would embrace the technology quickly and without question. This has not been the case in that some faculty are resisting the new technology because they have not been trained to use technology or experienced how technology has improved and can increased student learning. Implementing technology into the higher education classroom requires the motivation of faculty to buy-in to the changes being made.

To encourage faculty buy-in, proponents of technology use must first show how faculty members are using educational technology in higher education classrooms. As technology is evolving, some educators are feeling pressured to change their instructional methods to incorporate more technology. A study was completed at a Midwestern university to explore how technology is incorporated into higher education mathematics content courses (Gueldenzoph, Guidera, Whipple, Mertler, & Dutton, 1999). The researchers used a mixed methods survey to relate the use of technology to gender, age, experience, rank, discipline, and teaching style. Significance is found in the area of experiences, where faculty with fewer years experience tended to integrate more technology than their more experienced co-workers. Prior research has shown that the mathematics, computer science, and engineering disciplines were more likely to utilize technology, but this study found no significance. Perceptions about technology from faculty members who view technology as effective were more likely to use it and that administrative support is a critical factor that can have influence on whether faculty incorporate the technology or not.

The speed and extent to which technology is implemented into higher education can be based on internal factors including resources, organizational culture, faculty readiness, anticipated degree of resistance, and the degree of variance from the status quo (Roberts, 2008). Resources to support technology are not restricted just to funding, but also can include training, time commitments, and academic freedom. The organizational culture that can affect the use of technology is in relationship to the authority figures and policies that support the institution. Universities have to make recommendations to faculty that will increase their willingness to incorporate technology and do so with the least amount of resistance. When considering the addition of more technology, higher education officials should anticipate resistance attitudes and include plans in the design process that will assist faculty as they work through the transition. The last consideration when implementing technology is how the infusion will allow instructional practices to vary from the norm. The researchers found that by raising faculty awareness of the potential of technology, showing the relevance of implementation, building confidence through mentoring, and rewarding the satisfactory use of technology, faculty moved toward increasing the amount of technology used in the higher education mathematics classrooms (Roberts, 2008; Surry & Land, 2010). As with the implementation of anything new, the integration of technology needs to be carefully planned by university administration and faculty to ensure that technology will introduced and utilized in the most efficient manner.

To allow the integration of technology to be successful for faculty in higher education, cohesive training programs must be developed “with an emphasis on learning and provide adequate technical support that will assist faculty in integrating technology into instruction” (Rogers, 2000, p. 19). To utilize technology to its fullest potential, faculty must be willing to shift their classrooms from teacher-centered to focus on student learning. Integrating technology “creates shifts in the skill requirements of faculty from instructional delivery to instructional design” (Rogers, 2000, p. 21). Focusing on instructional design requires teachers to fully understand how to relate and use technology to the specific content that they teach. By relating technology to the content knowledge, students will benefit from this integration as they enter the workforce and encounter the technology that is relevant to their field.

Conclusion

Technology has drastically changed the way our society functions at home, in the workplace, and within the field of education. Wade, Rasmussen, and Fox-Turnbull (2013) reiterate the fact that technology can do nothing by itself, but "technology, in conjunction with engaged, excited, and motivated students, and innovative teachers and administrators can change the world" (p. 168). Chapter 2 has provided a thorough look at what technologies are in general, the roles and functions of the technology in general and specifically to mathematics education, and the effect technology has on classroom preparation, instructional opportunities and classroom learning. Technology functions in the form of multiple tools, as a tutor, for exploration of information, and provides various avenues to communicate. The role of technology in the within the mathematics learning environment has some overlap with the general functions of technology, but places a brighter spotlight on how the specific technology is used within the education setting.

In the next chapter, Chapter 3, the researcher will provide a detailed account of the structure of the study as well as a detailed account of data collection and data analysis. This will include a thorough description of how the study was administered, who participated in the study, and the exact pieces of evidence that were used to answer and support the research questions.

CHAPTER 3

METHODS

Technology is “essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students’ learning” (Dick & Hollebrands, 2011, p. 121). When technology is utilized in higher education mathematics courses, the learning needs of today’s students can be met to a greater extent than instruction without technology. This study addressed the technology use in higher education mathematics content courses. The purpose of this study was to identify what technology is being used and the role that technology plays in classroom preparation and planning, mathematics content instruction, and student learning in higher education mathematics classrooms. The specific research questions for this study are:

1. What kinds of technology are being used in higher education mathematics content courses?
    a. How is the technology being used?

b. What factors would encourage higher education mathematics faculty to incorporate technology into their classroom preparation, instructional opportunities, and classroom learning?

2. What is the description of an adopter of technology?
3. Who, adopters or non-adopters, are most likely to use technology to engage students in learning mathematics?
4. How have technology adopters overcome challenges of implementing technology into higher education mathematics content courses and enhance student learning?

Organization of Chapter

The components of this chapter include descriptions of procedures that were used to conduct the study and ultimately led to the answering of the research questions. The first section details the research design of the study, including research sample, sampling strategies, research site, and an overview of information needed. The next section includes specific methods and procedures that were used to collect data and the strengths and weaknesses of each procedure. Information regarding the data collection methods is followed by the data analyses and synthesis section reporting how the data was managed, organized, and analyzed in preparation for reporting the findings. The chapter ends with a discussion of ethical considerations, issues of trustworthiness, and limitations of the study that arose and how they were handled throughout the research process.

Brief Overview of the Study

The study was a mixed methods study blending quantitative assessment of survey responses with semi-structured interviews from a small sample of participants. The study began with a technology survey that was sent to mathematics faculty at private and public colleges and universities in a Midwestern state. The survey was sent via e-mail and completion of the survey was considered as consent to participate in the study. E-mail addresses were gathered from college and university websites that are available to the public. Those participants completing the survey were given an opportunity to be considered for the interview portion of the study, and, if they agreed, they provided their contact information. Initially, the researcher anticipated selecting six subjects to participate in semi-structured interviews conducted by the researcher. Final selection of interview participants was based on their self-identification as *adopters* or *non-adopter* of technology and as representatives from a balance of respondents from the type of college or university in which they are employed. The survey data, semi-structured interview transcripts, and participant vignettes were analyzed to provide the basis for a description and profile of technology *adopters* and *non-adopters* in higher education mathematics content courses.

Philosophical and Theoretical Foundation

The theoretical framework upon which this study is based is founded in current literature surrounding the use of technology in higher education mathematics courses. The results from this study serve to support the research methodology and theoretical framework as well as provide a foundation for the data analysis, interpretation, and conclusions drawn from the study results. To provide a strong theoretical rationale, it is necessary to discuss the five elements of the research process that inform one another with regard to the use of technology in higher education mathematics. These five elements are: epistemology, theoretical perspective, theoretical lens, methodology, and method and are of vital importance for a research study and its outcomes to be viewed as reliable, convincing, and provides empirical evidence (Crotty, 2010). As shown in Figure 8, elements of the philosophical and theoretical elements must fit together to lay the foundation for a well conceived study.

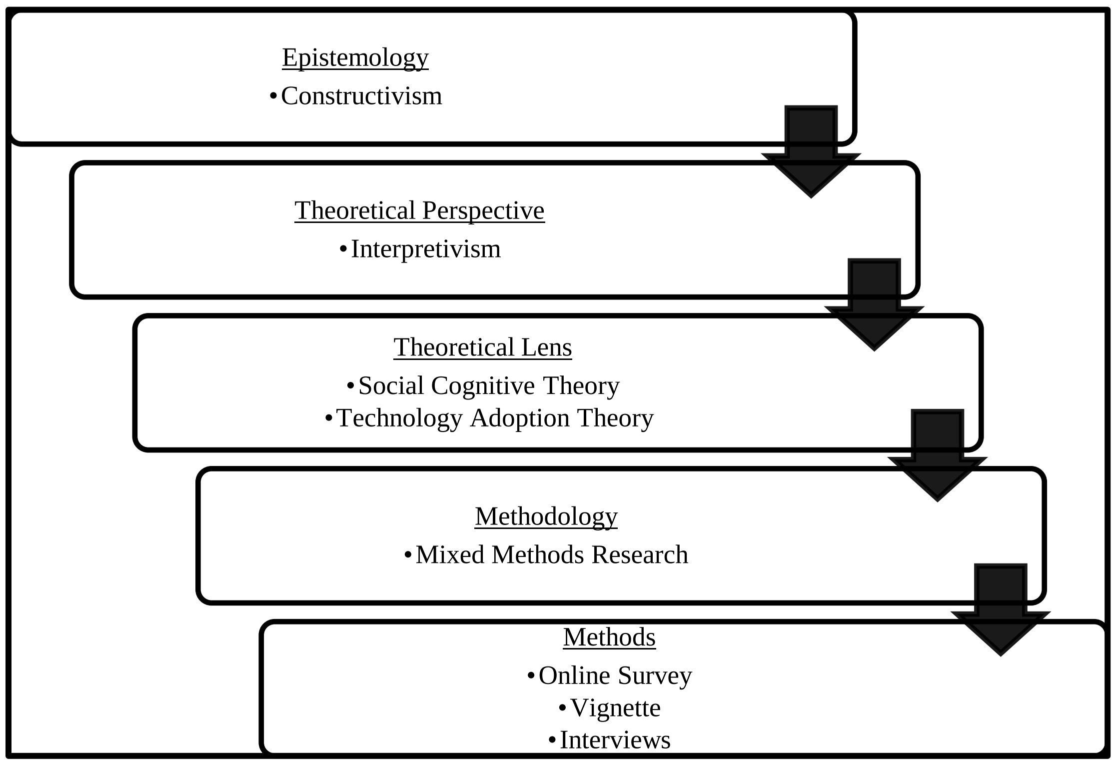

Figure 8. Theoretical and Philosophical Foundation Elements for Best Fit

Constructivism, positioned as the epistemology, serves as the cognitive theory that supports the methodology and methods for this study. The theory of constructivism was established by Jean Piaget. Constructivism centers on the ways individuals form internal knowledge. Piaget proports that individuals are not “mere receivers of knowledge” (Fischbein, 1999, p. 48), but active participants in formulating their own knowledge based on their intellectual responses to certain experiences and observations (Peterson, 2012). Piaget’s theory of constructivism appears to be present when individuals add to their technology usage and assists with their understanding of how the visualization and variation of differing technology offers learners. As individuals begin to organize their new knowledge, they can begin to compartmentalize aspects of the newly acquired knowledge by topic or learning outcomes. Mathematics faculty who utilize technology provide opportunities for their students to *see* concepts virtually which supports the current learning styles of today's digital learner. Piaget's theories consistently call for a one-on-one relationship between the learner and his or her environment. The integration of technology into the higher education mathematics environment, allows students to interact with concepts as never before. Seeing, manipulating, and experimenting with parameters in real time provides students learning opportunities that are not possible without the technology. Students are now in the position to create their own connections and build new ideas.

The theoretical perspective, or paradigm, for this study is *interpretivism*. Interpretivism underlies the individual's overall need to understand an object through the reconstruction of meaning, whether independently or collectively. Multiple realities can exist within this theoretical perspective that differs based on time and place. These realities can include both human reality and social reality and are "culturally derived and historically situated interpretations of the social life-world" (Crotty, 2010, p. 67). Interpretivism provides the researcher an avenue to explore and to provide details of a situation that illustrates the central phenomenon of the study.

The theoretical framework for this study starts with a broad interpretation of Bandura's Social Cognitive Theory. The framework then shifts focus to the next level of the Adoption Theory and then moves to the more specific level of the Technology Adoption Theory. Each part of the theoretical framework stands alone in the theory, but with regard to this study, has a hierarchical effect. This hierarchy starts at a broad foundation in Baundura's Social Cognitive Theory that includes the distinctive ideas of understanding change, attitude and belief development, and self-regulation. This hierarchy then funnels down to the Adoption Theory which is comprised of social learning and self-efficacy. The narrowest level of the framework is the Technology Adoption Theory. This theory describes how the integration of technology requires a change in perception. Figure 9 outlines the theoretical lens, framework, and includes the components of each level of the theory.

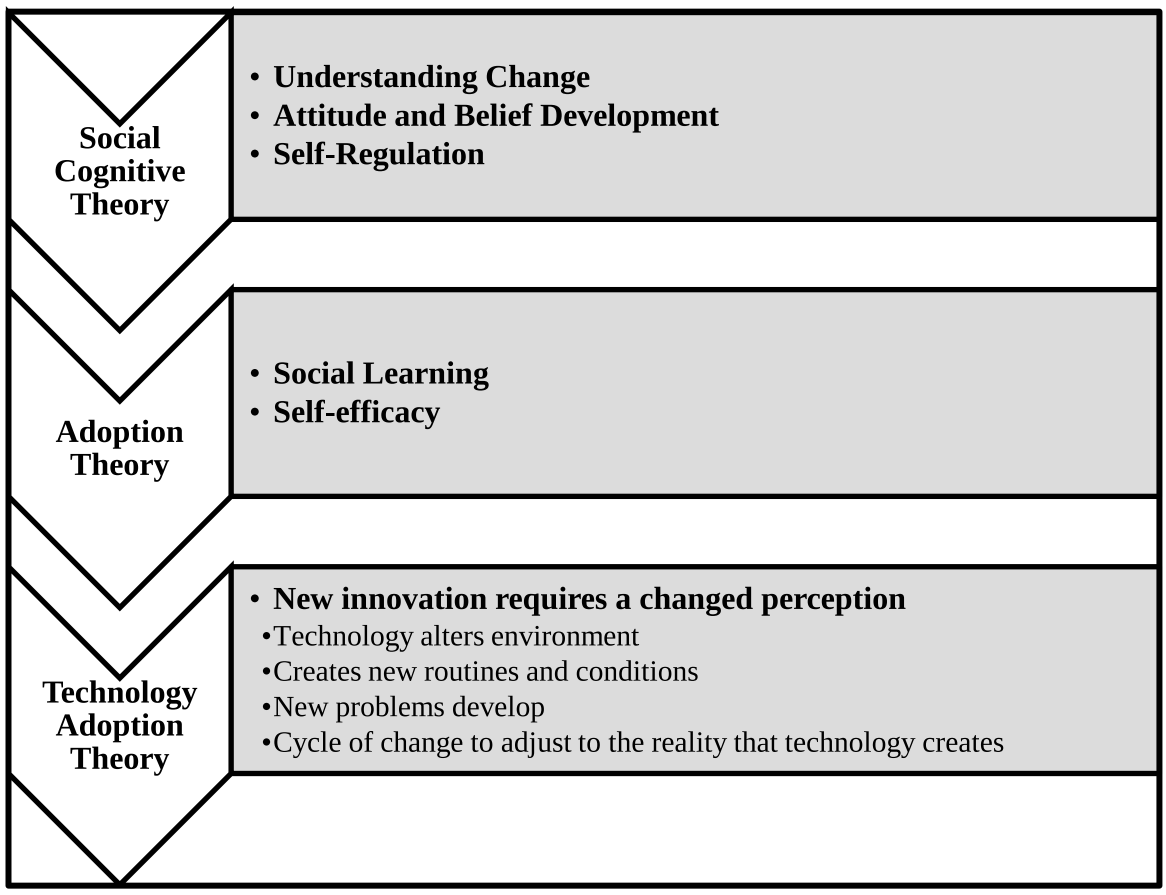

Figure 9. Theoretical Lens and Framework

(Bandura, 1977, 1986, 1997; Denler, Wolters, & Benzon, 2012; Straub, 2009)

The theoretical lens for the integration of technology and technology adoption into higher education mathematics courses is best understood through Bandura's Social

Cognitive Theory (1977, 1986). The Social Cognitive Theory is comprised of characteristics that are "applicable to understanding change and adoption, including attitude and belief development, self-regulation, and affect" (Straub, 2009, p. 628). Primary elements of the Social Cognitive Theory suggest that learning is gained by observation through modeling key ideas or features; self-reflection and self-regulatory processes have a great influence over outcomes; and attention, retention, production, and motivation are the processes behind observational learning (Denler, et al., 2012). Observational learning allows individuals to develop expectations and based on the Social Cognitive Theory, outcome expectations shaped by "the decision people make about what actions to take and which behaviors to suppress" (Denler, et al., 2012, p. 3). The Social Cognitive Theory assists individuals in learning as well as using previous knowledge to visualize the future, discover potential outcomes, and then create a plan to achieve these goals.

The theoretical framework of this study is the Adoption Theory. The Adoption Theory refers directly to the specific individual's decision whether or not to integrate new innovations into one's particular environment. Social Cognitive Theory and adoption theory are linked through two specific aspects – social learning and self-efficacy (Straub, 2009). Social learning, which is a foundational concept of the Social Cognitive Theory, supports the adoption theory through the modeling of knowledge and allows individuals to observe other adopters of a particular innovation. Individuals will be more inclined to consider becoming adopters of innovations themselves if they have viewed other users of innovations. Self-efficacy also is an integral part of the adoption theory with strong ties to the Social Cognitive Theory. Self-efficacy is the "beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments" (Bandura, 1997, p. 3; Straub, 2009). In relation to the Adoption Theory, the opinions individuals create based on the usage of a certain innovation is linked to whether or not they will use the innovation in the future. Both social learning and self-efficacy play a major role in whether individuals are willing to adopt new innovations into their lifestyle.

More specifically, the Technology Adoption Theory focuses on the adoption of technology into an environment and by each individual. The common thread between the Technology Adoption Theory and the Social Cognitive Theory is through self-efficacy. Future technology integration by individuals can be linked to the "judgments individuals make about their capability for completing technology tasks" (Straub, 2009, p. 629). The Technology Adoption Theory is based on the need for individuals to change their perceptions. In relation to education, technology has the potential to alter the educational environment which requires teachers and students to create new routines and conditions within the learning system. Because of the new routines, new problems develop within the learning environments that require a cycle of change to adjust to the reality that technology has created.

Three proponents of the Technology Adoption Theory, Rogers, Gladhart, and Russell (Toledo, 2005), have created three separate models that explain the stages that adopters move through as they incorporate new innovations. As shown in Figure 10, the stages for each of the proponent's models of adoption are compared.

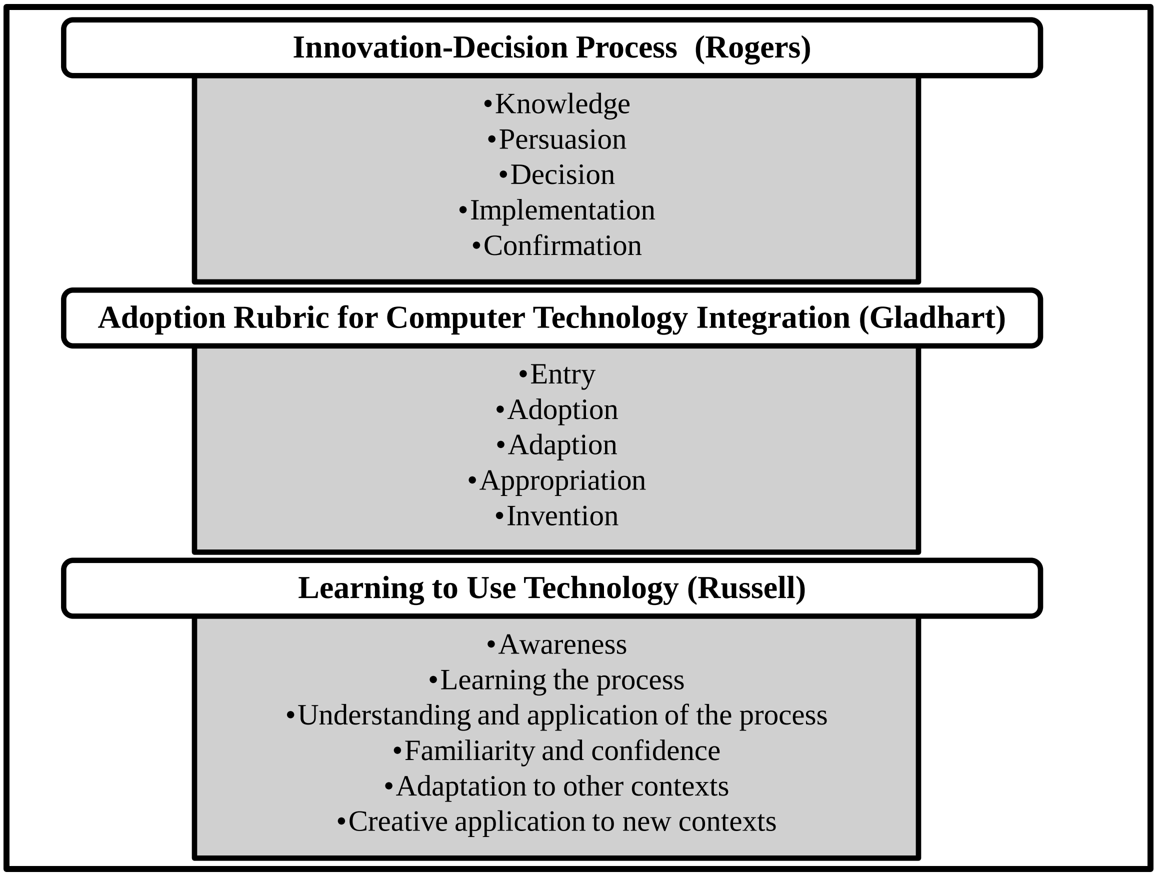

Figure 10: Summary of Models of Stages of Adoption of an Innovation
(Toledo, 2005)

Rogers (1960,1995) introduced the "Innovation-Decision Process" which includes five stages:

- *knowledge* of the new innovation;
- *persuasion* which includes the forming of attitudes concerning the innovation;
- *decision* or the seeking of additional information to make an informed decision;
- *implementation* of the innovation with regular use and continued information; and
- *confirmation* as to whether or not the innovation will continue to be used based on benefits and drawbacks.

Gladhart's levels in his adoption model was developed through the adaptation of the Apple Classrooms of Tomorrow (ACOT) study which was completed by Dwyer, Ringstaff, and Sandholtz (1992). This model titled the "Adoption Rubric for Computer Technology Integration" included five steps and is focused on issues of teacher behavior, student behavior, and technological tools. The five steps in this model that specifically focus on teacher behavior toward an innovation include *entry, adoption, adaptation, appropriation,* and *invention.* Most levels are very comparable to Rogers' "Innovation-Decision Process" stages except for a few minor details. At stage two, *adoption*, Gladhart was actually able to observe educators incorporating the new technology skills into their learning environments. At stage four, *appropriation,* educators had readily "shifted their instructional methods to use technology to provide a more learning-centered approach" (Toledo, 2005, p. 179). At the *invention* stage of Gladhart's model, the educators had included technology as an active, creative, and socially interactive approach to learning (Toledo, 2005).

The last model that reflects the Technology Adoption Theory is the "Learning to Use Technology" model created by Russell (1996). This model contains six stages through which individuals move as they interact with and learn to use technology. These six stages include *awareness, learning the process, understanding and application of the process, familiarity and confidence, adaptations to other contexts,* and *creative application to new contexts* (Russell, 1996; Toledo, 2005). This model also varies slightly from the other two. In stage two, *learning the process,* Russell pushed for educators to use the technology to develop the skills. Differences also occurred in stage four, familiarity *and confidence,* where Russell saw educators feeling more comfortable using the technology and also troubleshooting any problems that might occur. The last two stages differed greatly. Stage 5, *adaptation to other contexts*, pushed educators to use technology within the curriculum to support the transference of knowledge for students. The last stage, which was not included in the other models, allowed for the creative endeavors of educators to utilize the technology in ways beyond the scoop of what already has been done.

Although these three models have similarities and differences, each leads back to the Technology Adoption Theory and explains the process that adopters of technology progress through when they encounter new technology and other innovations. As individuals progress through each stage of adoption, their foundational beliefs concerning change and adoption will be altered to establish new routines and continue the cycle of adjustment to new technological realities.

Rationale for Mixed Methods Research

A mixed methods design including both qualitative and quantitative data collection and analyses was incorporated to identify and understand technology use in higher education mathematics courses. The design for this study is an explanatory sequential mixed methods design (Figure 11) with the initial data collection through quantitative survey procedures and as a follow-up, qualitative data collection through semi-structured interviews as a device to offer explanations for the initial Likert-type scale data. In this design, the researcher first collects and analyzes the quantitative (numeric) data. The qualitative (text) data are collected and analyzed second in the sequence and are used to help explain, or to elaborate on, the quantitative results obtained in the first phase. The second, qualitative phase builds on the first quantitative phase and the two phases are connected in the intermediate stage of data analyses for the study.

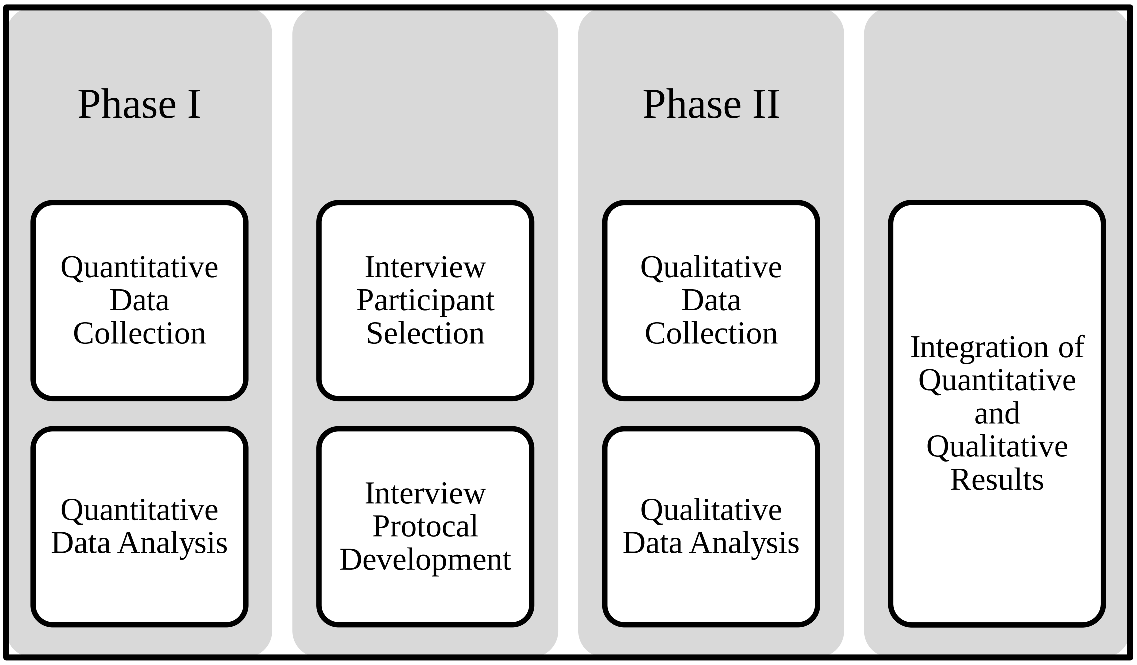

Figure 11: Diagram for an Explanatory Sequential Mixed Methods Design (Creswell & Plano-Clark, 2011)

The rationale for this approach is that the quantitative data and its subsequent analyses provide a general understanding of the research problem. The qualitative data and its analyses have the potential to refine and explain those statistical results by exploring participants' views in more depth. The explanatory mixed methods design is very straightforward to implement since only one type of data is collected and analyzed at a time. Challenges for this design include the length of time needed to implement both phases of data collection and analyses and the difficulty that may ensue in attempting to obtain institutional review board approval because details of the exact qualitative questions used in the second phase are dependent on which aspects of the responses require additional study. This approach is the follow-up explanations variant which supports the emphasis placed on the quantitative first phase.

Research Sample

The sampling strategy for the technology survey was a convenience sample using the contact information for mathematics faculty as posted by the departments on the college or university webpage. Selecting participants in this way may limit the available pool since some of the instructors may have left the school and new instructors may not have been added which might pose a potential limitation to the study. The sampling strategy for the semi-structured interviews was to identify an extreme or deviant case sampling with the intended purpose of choosing individuals that represent the extreme ends of technology usage, thus attempting to explain how higher education faculty use technology in mathematics content courses.

The sample population for this study was higher education mathematics faculty members from comprehensive universities, regional universities, and community colleges in a Midwestern state. "Faculty" in this study included full-time faculty, part-time faculty or adjunct instructors, and graduate assistants who teach mathematics content courses. Including part-time faculty or adjunct instructors and graduate teaching assistants will ensure that a broad spectrum of background in and experience with technology is addressed. The categories in which the population was separated was based on the position they hold at their respective institution. The categories used in this study include chair/assistant chair, full professor, associate professor, assistant professor, instructor, lecturer, teaching assistant, and adjunct instructor.

The population from which participants were drawn for this research study was identified in a database. First, the researcher secured a list of colleges and universities that are acknowledged by the State Regents for Higher Education. This alphabetical list contained twenty-four public and private 4-year institutions and twelve 2-year institutions. From the list, the researcher went to each institution's public website on the Internet, searched for the mathematics department, and created a database of faculty members, their specific institution, position at the institution, and the corresponding email account listed. The sample included 550 individuals. This database was then used to supply the email addresses for the electronic survey.

The research sample or participants for this study were the faculty who responded to the technology survey sent by electronic mail. Demographic information gathered by the survey was used to describe the sample. The identification of these demographic characteristics allowed the researcher to tease out subtle differences that could explain whether a higher education faculty member would identify as an adopter or non-adopter of technology. Demographic information that was collected by the general technology survey was used to describe the participants of the study. The study collected the following demographic information: gender, age, ethnicity, position, years of experience, degree earned, teaching certification, and courses taught.

The participants in this study included 85 faculty members that represented comprehensive, regional, and community college. The gender demographic of participants in the study included 42 males and 39 females. Of the 85 individuals that started the survey only 68 individuals completed the survey. For the study, only the individuals who completed the survey were considered participants and only their data was used for the data analyses.

The research sites for this study were the locations where the semi-structured interviews were carried out perhaps in a classroom and/or office of the higher education faculty members at their respective college or university. The initial technology survey was administered via Qualtrics ™, and, therefore, did not correlate to a specific research site.

Overview of Information Needed

The contextual information needed for this study was the culture and environment which influenced the behavior of the faculty members. This culture and environment can potentially explain whether faculty members are adopters or non-adopters of technology. Based on the theoretical framework, specific contextual information for this study included, but was not limited to, the vision of technology usage as held by the higher education administration, faculty beliefs and attitudes, teaching and learning objectives, content delivery, and student support. Some of this information was collected through the General Technology Survey (Appendix A) and during the semi-structured interview portion of the data collection process.

The perceptions of the participants are vital in studying the views of the faculty members concerning technology usage in higher education mathematics courses. These perceptions can influence whether or not the participants utilize technology and to what extent technology is implemented in mathematics teaching and learning. Perceptual information that needed to be uncovered during the semi-structured interview phase included answers to the questions

> how experiences influenced the decisions they made, whether participants had a change of mind or a shift in attitude, whether they described more of a constancy of purpose, what elements relative to their objectives participants perceived as

important, and to what extent those objectives were met. (Bloomberg & Volpe, 2008, p. 70).

The perceptions of the participants are based on what they believe to be true, not necessarily on facts or what is actually true.

Research Design

An explanatory sequential mixed methods research design was used to identify and understand technology use in higher education mathematics. The flowchart in Figure 12 provides a visual representation of the intended research design.

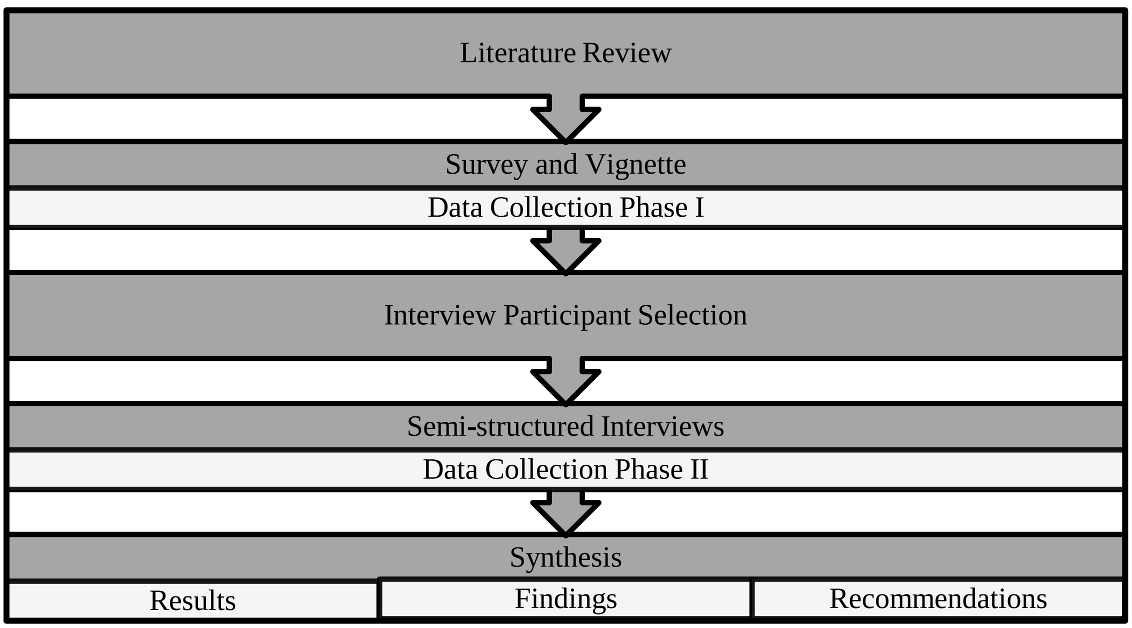

Figure 12. Flowchart of Research Design (Bloomberg & Volpe, 2008)

The research design continues from the literature review that provides an overall view of the use of technology in general as well as in mathematics content courses. The explanatory mixed methods design begins with Phase I, which is the collection of survey data and within the survey, the vignette. The General Technology Survey includes questions concerning demographics, types of technology used, how technology is used, and what elements lead to the usage of technology. The survey also solicited participants to describe in an open response format how technology was specifically used or an activity in which it was utilized. The survey also collected a list of individuals who were willing to be interviewed during Phase II. The survey collected both numerical and text data. Interview participants were selected based on type of institution and adoption of technology preference. Once the interview participants were selected, they completed a semi-structured interview, which is Phase II of the study. The semi-structured interviews were transcribed and coded to lead into the synthesis phase. The last step in the research design was the synthesis of the data. The numerical data was processed using frequencies, percentages, and statistical t-test to determine if there was a difference in means of the two groups. Text data was coded for important trends that could then be used to support the numerical data and also to answer the research questions. Results are discussed in Chapter 4 of this study and findings of the study and recommendations can be found in Chapter 5.

The steps listed below were followed to complete the data collection phase and the analysis of the data as it was collected.

1. Assembled contact list including email and phone numbers of the population by using the Internet;
    a. Located list of colleges and universities on the Higher Education website
    b. Went to each website and located the contact information for each Mathematics departments' faculty members.
2. Acquired information about survey tool, Qualtrics ™, and created account;
3. Created survey and linked survey questions to research questions;
4. Input survey into Qualtrics ™ system;

5. Sent survey to advisor, committee members, and colleagues for feedback on set-up, flow, and content and make changes to survey as necessary;
6. Obtained IRB approval;
7. Sent survey via Qualtrics ™ software to populations with due date;
8. Sent three reminder emails to population through the Qualtrics ™ system;
9. Combined data from survey and vignettes;
10. Downloaded list from the Qualtrics ™ software for survey questions #23 which listed the contact information for those participants who agreed to be considered for a semi-structured interview. Determined sample that met the criteria to be interviewed.
    a. 2 individuals from each type of institution (comprehensive, regional, community college/junior college)
    b. 1 adopter, 1 non-adopter per type of institution;
11. The above sample was not possible from the responders who completed the survey. The following sample was selected.
    a. Adopter and Non-Adopter from a Comprehensive University
    b. Adopter and Non-Adopter from a Regional University
    c. Adopter from a community college/junior college. (No non-adopters were available.
    d. Individual that changed his or her stance on technology use. This individual started as a non-adopter and changed their stance to an adopter at the end of the survey.

12. Created semi-structured interview questions from survey responses and research questions;
13. Contacted Phase II participants to set up a time for semi-structured interview;
14. Analyzed and synthesized numerical data from survey using Microsoft Excel ™;
15. Conducted semi-structured interviews over a specific time span;
16. Transcribed all semi-structured interview data;
17. Coded semi-structured interview data and vignette data;
18. Determined findings and draw conclusions based on research questions; and
19. Make recommendations.

Data Collection Methods

The data collection process for this study of higher education mathematics faculty members warranted three types of data – survey, vignettes, and semi-structured interview transcripts. As seen in Table 1, the research questions have been aligned to the information that was obtained by a specific data collection method.

Table 1. Research Questions, Methodology, and Survey Matrix
(Bloomberg & Volpe, 2008)

No.	Research Questions	Information Needed What the Researcher Wants to Know	Method	Survey Correlation
1.	What kinds of technology are being used in higher education mathematics content courses?	• Type of technology used • Frequency of technology used	Survey	#16, 17
1a.	How is the technology being used?	• Description of a particular activity or scenario where technology is being used	Vignette Semi-structured interviews	#15, 20
1b.	What factors would encourage higher education mathematics faculty to incorporate technology into their classroom learning and instruction?	• Attitude • Willingness to try new technology • Training • Support • Integration • Education Level	Survey Demographics	#2-14, 18, 19
2.	What is the description of an adopter of technology verses a non-adopter?	• Age • Gender • Educational Background • Years Experience • Courses taught • Type of institution • Attitude • Willingness to try new technology	Survey Semi-structured interview Vignette Demographics	#2-14, 20, 21
3.	Who is most likely to use technology in student learning and engagement?	• Age • Gender • Educational Background • Years Experience • Courses taught • Type of institution	Survey Semi-structured interview Vignette Demographics	#2-14, 20
4.	How have technology adopters overcome challenges of implementing technology into higher education mathematics learning and engagement?	• Obstacles and stumbling blocks of adopters • Attitude • Why did they push through challenges • Drive to overcome	Interview	

General Technology Survey and Demographic Information

A general technology survey served as the first method of data collection. The survey collected demographic information, contextual information and perceptual information. The General Technology Survey (Appendix A) was created based on the information needed to answer the research questions and modeled after the following surveys, *Biennial Educational Technology Assessment* (*BETA) 08-09 Teacher Survey* (BETA, 2008*), BETA 10-11 Teacher Survey* (BETA, 2010*)*, and the *Technology in my Life Survey* (McKenzie, 1999). No questions were taken directly from any of these surveys, but the questions were used as reference points throughout the design process.

The survey consisted of twenty-three questions, with thirteen being demographic information. The non-demographic questions included general technology use for class preparation and instruction, attitudes and beliefs about technology, willingness to incorporate technology, and descriptions of how the technology was used. Responses for this portion of the survey were collected by a 5-point Likert-type scale, rankings, and open-ended questions. Participants had opportunities to write additional comments or justification for each question. The following survey questions were asked and a complete copy of the survey can be found in Appendix A.

- Demographic Information
    - Gender
    - Age
    - Ethnicity
    - Type of institution where employee teaches
    - Position at institution

- Number of years teaching at higher education level
- Courses taught at higher education level
- Highest degree earned and content area description
- PK-12 Teacher Certification
- Number of years teaching at PK-12 level

- Would you consider yourself an adopter or non-adopter of technology?
- Rank the following activities based on how much technology are used in each. (Class Preparation, Classroom Instruction, Individualized Instruction, Student Interaction, Assessment)
- Frequency of technology use for class preparation (Never, Rarely, Sometimes, Often, All the time)
- Frequency of technology use for classroom instruction (Never, Rarely, Sometimes, Often, All the time)
- Rank the following items based on being more willing to use technology if…
    - Training
    - More time to implement new technology
    - Adaptable ideas
    - Teaching lower level courses
    - Lesson creation assistance
    - Up-to-date technology
    - Updated hardware and equipment
    - Integration ideas
    - Curriculum design

    - Colleagues that also embraced technology
- Attitudes and beliefs concerning technology (Strongly disagree, Disagree, Somewhat agree, Agree, Strongly Agree)
- Statement that describes how you utilize technology in your classroom (This will actually be the vignette portion of the data collection process, but will be gather by the survey software during the online survey. (open-ended)

To field test the general technology survey, the researcher sent the survey via e-mail using the Qualtrics Survey Software. The survey was sent to five individuals to check for content, consistency, flow of survey, ease of use, and questions clarity. The five individuals included the dissertation committee advisor, the dissertation committee outside member, a mathematics faculty member, a non-mathematics faculty member, and a technology coordinator and trainer for the State of Oklahoma. Those providing feedback gave the following critiques:

- Items to be ranked in Question 15, specifically the difference between Instruction vs. Direct Teaching.
- Add "not enough time" to question 18 concerning willingness to use technology
- Ranking question needed new format
- Typographical errors

After reviewing the survey and the comments made during the field test, the following changes were made to the survey.

- "Instruction" in question 15 was changed to "individualized instruction." This is to refer to a teacher using technology for instruction with an individual student, as oppose to "classroom instruction" which refers to a teacher using technology for whole class instruction. Planning was also changed to class preparation to be consistent with terminology throughout the survey.

- A option was added to question 18 to include "more time to implement new technology" to complete the sentence*: I would be more willing to use technology if I had … .*
- The ranking questions were left in that format, but reworded for further clarity.
- Typographical errors were corrected.

In addition to the changes above, another question was added to the survey based on the feedback from the field test participants. Survey participants are asked at the beginning of the survey whether they consider themselves to be an adopter or non-adopter of technology. To see if the survey content made anyone reevaluate their position concerning technology use, the same question was asked again at the end of the survey.

The reliability and validity of the General Technology Survey was determined by obtaining feedback from experts in the field of mathematics and education research. The panel of experts approved of the survey and suggested only minor changes to the survey. The panel did offer the following feedback to enhance the survey if used again.

- Ranking Questions: Participants need to be able to opt out of ranking a certain item. As the questions are written, rankings are forced even if the participant does not use the item.
- Open response options would be beneficial when asking participants when they would be more willing to use technology. Because there is no open response, this question could also provide false information.

The survey was administered through the online survey tool, *Qualtrics™,* which is provided by the State University's College of Education. This tool allowed the researcher to create the survey and email the link to the sample through the software. The survey portion of the data collection was completed by the participants on their own time. The entire sample population, 550 faculty members, received the email (Appendix D) containing the link to the online survey, information concerning the study, and were informed that they had six weeks to complete their survey. Three reminders were sent to encourage participation. Eighty-five individuals started the survey with only 68 completing the survey in its entirety. Those that completed the survey are considered participants in the study. The data collected from the survey was compiled in a password protected online database supplied by *Qualtrics™. Qualtrics™* organized the data that was collected and was accessed by the researcher, either as individual participant response data, group response data, or individual question response data. All private information that was recorded was kept confidential and will not be released. Research records for the survey were stored securely within the *Qualtrics™* system and only the researcher and individuals responsible for research oversight have access to the records. The *Qualtrics™* account is password protected and supported by the State University.

Consent to participate in Phase I of the study was met through the online consent form (Appendix B). This form was the first page of the General Technology Survey and included information concerning the investigator, purpose, expectations, risks, benefits, compensation, participant rights and confidentiality, and contact information. The consent form states that individuals who complete and submit the survey agree to be participants in the study. The form also makes a clear statement that individuals are free to withdraw from the study at anytime.

Confidentiality was preserved with the utmost care and procedure. For the semi-structured interviews to be possible, individuals had to be willing to provide contact information. Only those willing to be part of the semi-structured interviews were prompted to provide the additional contact information. If the survey participants did not wish to participate in the semi-structured interviews, they selected “no” on question 22, which moved them to the end of the survey. Contact information remained attached to the surveys until after selection of the semi-structured interview participants. At that time, the data was given a random code before it is analyzed as the survey data. The random codes were kept by the researcher in a locked filing cabinet, which is held behind a locked door. After the completion of the study, the collected survey data and random codes were disposed of through shredding and the data was cleared from the *Qualtrics*™ system. All measures will be followed to keep information completely confidential through-out the entire study.

The strengths of using an online survey to gather data for this study include the cost to administer the survey and the ease of receiving the data in an organized and usable format to begin the analyses. Because the survey tool, *Qualtrics*™ is being used, there is no cost to the researcher to administer the survey. *Qualtrics*™ also has the features that allow the data to be viewed independently or as a group. This provides an array of data analyses opportunities to seek answers to the research questions.

There are weaknesses that also exist when using an online survey. These concerns include the response rate of participants and the inability to collect the reasoning behind the responses. The first concern was about the response rate. With the survey being administered online and the sample contacted only through email, the response rate may not be large enough to provide significances for the results of the study. An ideal response rate would be around 30%. The sample size for the survey was 550 faculty members, which would indicate the appropriate response rate to be approximately 170 participants. The response rate was 68 survey completers out of 550, which is 12.4% of the sample population. The less than ideal response rate was included as one of the limitations to the study. The other concern of using an online survey was that the reasoning behind some of the responses may be disregarded due to the structure of the survey questions. The semi-structured interviews that followed the survey potentially brought out the reasoning behind specific responses.

Vignettes

A vignette is a vividly detailed written description of an activity or an occurrence focusing on a single theme, attitude, setting, or object. The purpose of including the vignette as a data set was to allow participants to provide an exact description, or snapshot in words, of how they used technology in their higher education mathematics classroom. These first-hand descriptions were gathered through the general technology survey that was administered to the entire sample. Individual vignettes were contained within the survey data that was collected by the *Qualtrics™* software. The vignettes serve as another source of qualitative data. The data was coded in the same manner as the semi-structured interviews and provided support for quantitative data and themes that explain the use of technology.

Consent for the vignette data collection method was included within the online survey consent form, since the vignettes are gathered within the survey phase. Participants had the opportunity to provide a description of how they integrate technology into the classroom through instruction and/or activities. These descriptions were used to understand how technology is used in the higher education mathematics classroom and offered insight into who was more likely to become an adopter or non-adopter of technology.

Semi-structured Interviews

The semi-structured interviews that were completed for Phase II of the data collection process provided an in-depth, rich description of the participants' perceptions and perspectives on their use of technology in mathematics teaching and learning. Semi-structured interviews were selected as a data collection method to gain further knowledge from the faculty member by exploring their ideals and opinions of their personal technology use. The interviews were semi-structured and took place over the phone or through online video conferencing capabilities. The data collected explained and described the interaction between the researcher and the participant as well as the culture surrounding the technology usage. Based on the responses on the initial technology survey, appropriate structured interview questions were created. These questions were designed to gather additional information to enhance the responses and refine the data from the general technology survey. These interview questions allowed the researchers to delve into the participants' use of technology, their perceptions of the technology in a mathematics content course, and how they implemented technology within the mathematics classroom. The dialogue from the semi-structured interviews were transcribed and coded for significant themes. These themes have been used to answer and support the study's research questions. The overall themes and specific responses were used to supplement and add depth to the data that was collected from the general technology survey and the vignettes.

The interviews were conducted with participants who volunteered to participate. At the end of the general technology survey, the participants were asked if they were willing to be contacted for a semi-structured interview concerning their technology use. If they chose "YES," they were directed to a question that asked for personal contact information including name, phone number, email, and the institution in which they are employed. If participants chose "NO," they were directed to the end of the survey and did not provide personal contact information.

Six individuals were selected to participate in the semi-structured interviews. The first criterion to be selected was based on the type of institution: comprehensive, regional, or community college/2-year college in which the participant teaches. Within these three categories, the phase two participants were divided into two categories, adopters and non-adopters of technology. This was determined by question 14 on the survey which asked whether participants consider themselves to be an adopter or non-adopter of technology. The optimal selection would be six individuals, two participants from each type of institution, one that is an adopter and one that is a non-adopter of technology. The list of potential interview participants was analyzed and the researcher found there was not a non-adopter of technology within the community college/2-year college category. Changes were made to the selection process of the six individuals. The following sample was selected.

- Adopter and Non-Adopter from a Comprehensive University
- Adopter and Non-Adopter from a Regional University
- Adopter from a community college/junior college. (No non-adopters were available.)
- Individual that changed their stance on technology use. This individual started as a non-adopter and changed their stance to an adopter at the end of the survey.

The participant that was added to the interviews was a person who indicated he or she was a *non-adopter* of technology at the beginning of the survey, but changed his or her stance to an *adopter* of technology when the question was asked at the end survey. This actually occurred with four participants in the survey; two changed from an adopter to a non-adopter and two changed from a non-adopter to an adopter. The researcher believed this group needed to be represented in the semi-structured interview process.

Participants selected to be interviewed were contacted to set up a time to be interviewed. Semi-structured interviews were completed in a way that worked best for the participant. Interviewees were given the options of a face-to-face interview, phone interview, or online interview via online communication capabilities. The semi-structured interviews were audio-recorded to ensure that participant responses were interpreted correctly. Audio recordings were transcribed and coded for themes that answered the study's research questions.

Consent forms for the interview portion of the study (Appendix C) were provided to the participants before the semi-structured interviews were conducted. The consent forms were sent by email to each participant. They were instructed to read the information, sign the consent form, and send the form back to the researcher by fax or scanned email. The participants were again informed that they are free to withdraw from the study at anytime. Participants were provided a copy of the consent form for their records. The confidentiality of the semi-structured interview participants is very important. Any interview data that was included in the findings of the study has been kept anonymous using alternative names. The audio-recordings and the transcriptions were kept in a locked filing cabinet behind a locked door. All data will be appropriately destroyed at the end of the study.

The strength of using semi-structured interviews to collect a more in-depth look at technology usage was that interviews allowed the researcher the flexibility eliciting from the participants to augment their responses on the survey. The semi-structured interviews were also recorded so data will be accurately accounted for within the results of the study. The weakness of using semi-structured interviews was that the validity and reliability of the results can be affected if the questions are not standardized and the meaning of the question is not expressed the same way by each participant. Denzin (1989) explained that it is not necessary to use the exact same wording for each question to each participant, but the researcher must be able to convey equivalence of meaning among the set of responses.

Data Analysis and Synthesis

The data gathered by the three data collection methods was analyzed in three manners. The first data analysis came after the General Technology Survey that was completed by all participants. The researcher looked at just the survey responses that indicated participants were willing to submit to a semi-structured interview. From those participants, the researcher sorted the responses by type of institution and whether they responded as adopters or non-adopters of technology. The selection was then made as to who completed the semi-structured interviews. The second data analysis occurred for the General Technology Survey. Only participants that completed the entire survey were included in the data analysis. The participants' surveys were considered as a whole group, but were also compared based on whether they selected themselves to be adopters or non-adopters. Figure 13 shows the basic steps for the data analysis of a survey. The survey was first read over very carefully by the researcher noting any interesting trends that are very prominent in the data.

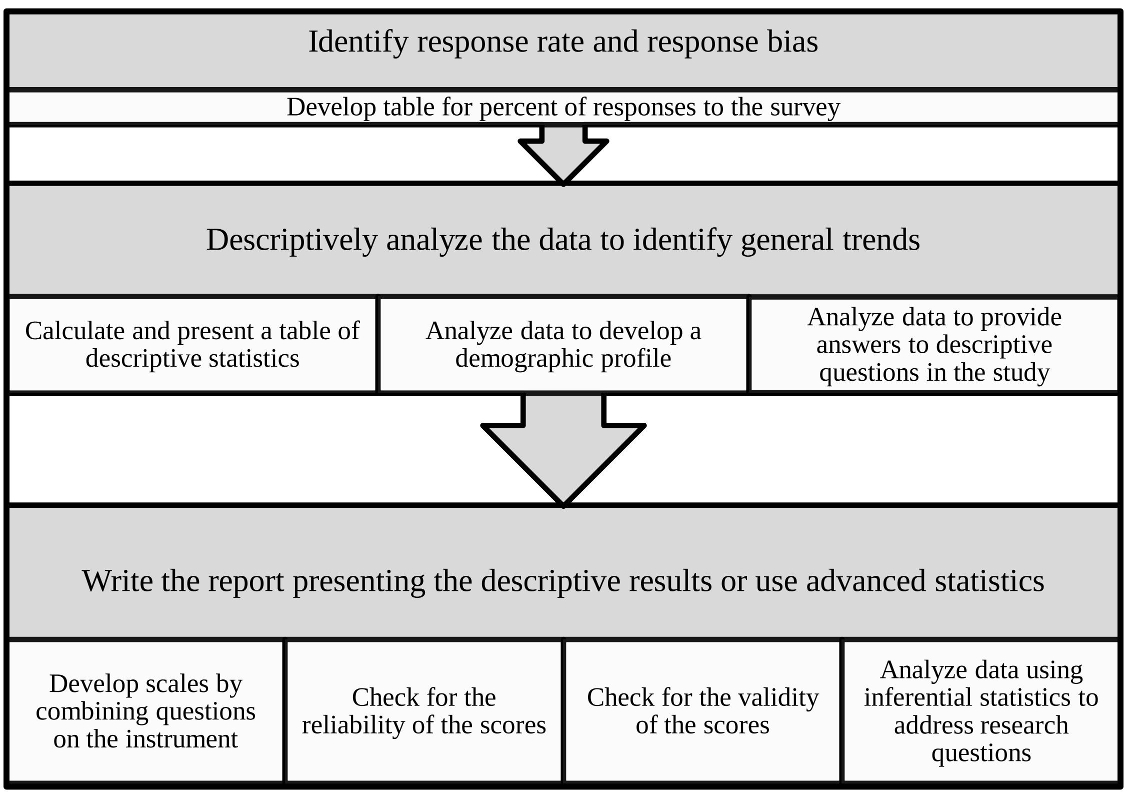

Figure 13. Data Analysis and Representation for General Technology Survey (Creswell, 2008)

Creswell (2008) instructs researchers to then identify the response rate of the survey. With this being an electronic survey, the optimal rate of response is around 30%. The response rate for this survey was 12.4%. The survey data was then analyzed for general trends, data that directly answered to research questions, and descriptive statistics were calculated. The descriptive statistics that were used in the analysis of the numerical data were frequencies, percentages, and averages. Inferential statistics, including t-tests and confidence intervals for independent samples, were calculated using the means and variances of the data set. The t-tests and confidence intervals were used to show if there was a difference in means between adopters and non-adopters of technology on certain survey questions. The last step was to report the results of the survey in a usable format that includes narratives, tables, and figures.

The semi-structured interview data consisted of transcribed interviews that were organized into a spreadsheet. Although field notes were taken during the interviews by the researcher, audio recordings were also taken to ensure that the data was represented correctly. Figure 14 illustrates the general steps that were followed to analyze and represent the interview data into a usable form. The first step was to manage and organize the large amount of data that was collected from the six participant interviews. The recordings were transcribed into a text document that could be further broken down into data that was ready to be coded. The transcribed interviews were sent via email to the participants to read through and make sure that the information was accurate. The transcribed interviews were then read through, with the researcher making notes of any major themes. The data was broken apart into segments. Important segments from the semi-structured interview transcriptions were then copied to index cards for coding. Each card was also labeled to whether the segment came from an adopter or non-adopter as well the data source. Cards were sorted multiple times to insure that the themes that arose were supported by the data. Once coded and sorted, the data was interpreted based on the research questions as well as possible themes that emerged. The data and results were presented as an in-depth picture of a case using narratives, tables, and figures.

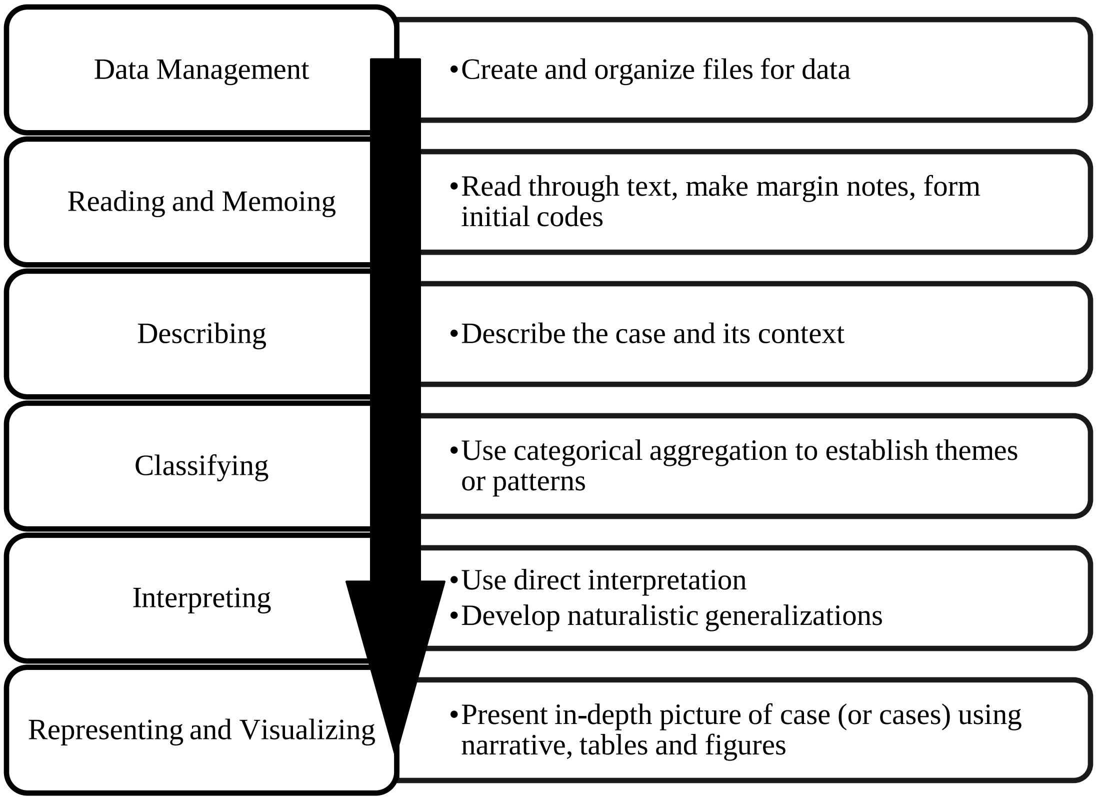

Figure 14. Data Analysis and Representation for the Qualitative Phase (Creswell, 2007)

Certain qualitative data were gathered by the General Technology Survey including the vignettes and additional comments by the participants. The vignette data that was collected was used to supplement and answer the research questions regarding how technology was being implemented into class preparation, classroom instruction, and student learning opportunities. This data were coded as qualitative data in the same manner as the semi-structured interviews. The coding cards were labeled to show that these pieces of data came from the vignettes or comments.

Ethical Considerations

Ethical issues that may have arisen during this study included variation in the instrument administration and confidentiality issues. The survey was electronic so participants completed them at their leisure, but the need was still present to make sure that little variation occurred. Contact information for participants was attached to the survey until after the semi-structured interview participants had been selected. At that point the contact information was removed and replaced with a participant code. For the semi-structured interview, the researcher took every effort to keep personal bias out of the data coding. Confidentiality issues were always important when working with the participants. Names of participants were changed for the write up of each individual case. Any data that was collected physically was placed in a locked filing cabinet which is behind a locked door and in a locked building. The data that was collected from the survey was secured within the Qualtrics database which is held behind the State University firewall.

Informed consent for the survey was based on whether or not someone filled out the survey. If the surveys were completed by the participants, they acknowledged that they consent to become involved in the study. This informed consent information was included on the first page of the general technology survey (Appendix B). An informed consent form was completed by all participants who were selected to participate in the semi-structured interviews (Appendix C).

Issues of Trustworthiness

Establishing the creditability or validity of the study is necessary to show that the participants' perceptions, including thinking, feelings, and actions were accurately represented by the researcher throughout the study. The researcher continually made a conscience effort to keep personal bias out of any of the data collection process and analysis. Audio recordings of the semi-structured interviews were continually available to ensure that the comments and opinions of the participants were included and interpreted in the study correctly. Clarification was made during the semi-structured interviews if the researcher did not understand a response from a participant. Member checks and peer debriefing was used to enhance the accuracy of the data collection process within the semi-structured interviews.

Dependability refers to “whether one can track the process and procedures used to collect and interpret the data” (Bloomberg & Volpe, 2008, p. 78). This can be achieved by providing a very detailed and complete explanation as to how the data was collected. Dependability for this study stemmed from the participants providing their true and honest opinions when completing the survey, completing the semi-structured interviews, and/or providing the descriptive vignette. The researcher had to assume that participants presented themselves and their technology usage as it was on a regular basis.

Although the results of this study cannot be generalized because of the low number of participants and the qualitative nature of the study, the findings may provide helpful insights in other situations. The data collection and analyses procedures were very detailed and allowed for other researchers to replicate the study. A detailed description of the data that data collected through the survey, semi-structured interviews, and vignettes provided a complete and realistic picture of how technology was used in higher education mathematics courses.

Impact of Researcher

A research study cannot be completed without the researcher having some impact on the study. The researcher has a vested interested in this study and considers herself an adopter of technology. Intention of the researcher was to allow the data to answer the research questions and bracket her own reflections and beliefs about the use of technology. To account for the bias that potentially existed toward the participants; the researcher kept an open mind to all data and was empathetic to concerns, and issues of training, time, experiences, and implementation of technology that came up during the semi-structured interviews. The researcher made sure to encourage more detailed responses to interview questions and was mindful of how she responded to answers given by the interviewees.

Limitations of the Study

Limitations for this study could include the low number of participants who responded to the survey. Since the respondents from the survey are the pool in which she sought to select the semi-structured interview participants, it was essential to obtain an appropriate number of responses. This was accomplished by reminding the participants to submit the survey via three reminder emails that were sent by the *Qualtrics* ™ system at strategic times. Reminders were sent every two weeks and finally the day before the survey closed. The reminders were only sent to individuals that had both started the survey and not completed it or to individuals that had not started the survey. With each reminder that was sent, the number of completers of the survey increased.

Another limitation was that the contact information for the participants was attached to the survey. This was necessary for the selection of participants asked to participate in the observations and semi-structured interviews. To account for this limitation, all identifying information was removed from the data before the final data analysis was completed. The only time the contact information was attached to the surveys was to choose the interviewees and during the actually semi-structured interviews. The interviewees were informed that their specific survey was being used for the interview, but then the contact information would be removed. The last limitation is in the trustworthiness of the participants. The researcher has to assume that those that complete the survey and were interviewed during the semi-structured interviews were honest and forthcoming in their responses.

Conclusion

In summary, this chapter provided a detailed account of how the study of technology usage in higher education mathematics courses was conducted and the theory that supported the methodology. The intent of the study was to provide a vivid description of how technology is being used and the characteristics of adopters and non-adopters of technology in higher education mathematics. This study followed a mixed methods research approach and utilized a survey, vignettes and semi-structured interviews to answer the research questions. The Social Cognitive Theory and the Technology Adoption Theory are the philosophical and theoretical framework behind the study. The sample of convenience consisted of faculty members from three types of higher education institutions that are housed across an entire Midwestern state. A general technology survey, semi-structured interviews, and descriptive vignettes were the data collection methods that answered what kinds of technology are being used in higher education mathematics courses, how technology is being incorporated, who is most likely to integrate technology into instruction, and challenges that were met by participants who chose to become adopters of technology. An explanatory sequential mixed methods research design allowed for qualitative data to be gathered which was followed by the qualitative data collection. The data was analyzed after each phase and the qualitative data was used to support and explain the quantitative data. The following chapter, Chapter 4, presents the results that were found during the data collection and analysis. Chapter 5 outlines the findings and conclusions of the study with regard to the research questions, as well as, provides future research that could be conducted based on the data and findings of the study.

CHAPTER IV

RESULTS

Technology is widely available in our society and is being included into the field of education. To understand if technology is playing a definitive role in higher education mathematics courses, it is necessary to understand the part technology plays in classroom preparation and instruction and who is incorporating the technology. This chapter includes the results from the data collection process of this study. Three types of data including an electronic survey, descriptive vignette responses, and semi-structured interviews, were collected to answer the following research questions.

1. What kinds of technology are being used in higher education mathematics content courses?
    a. How is the technology being used?
    b. What factors would encourage higher education mathematics faculty to incorporate technology into their classroom preparation, instructional opportunities, and classroom learning?

2. What is the description of an adopter of technology?
3. Who, adopters or non-adopters, are most likely to use technology to engage students in learning mathematics?
4. How have technology adopters overcome challenges of implementing technology into higher education mathematics content courses and enhance student learning?

This chapter is organized in the following manner. The first part of the chapter is an overview of how the data were analyzed for each instrument: General Technology Survey, vignette, and semi-structured interviews. Next, the overall demographics for each data collection instrument is presented using narratives, graphs, and diagrams. The heart of the chapter focuses on the findings as they relate to the individual research questions. The final section of Chapter 4 is an overall summary of the findings.

Data Analysis Overview

The data analysis for this study was based on an explanatory sequential mixed methods design. Both quantitative and qualitative data were gathered using an online survey sent to all participants and semi-structured interviews conducted with six selected individuals. The online survey contributed both quantitative and qualitative data, including the qualitative vignettes and open-ended comments. The qualitative data is used to support the quantitative data that was gathered. The data obtained through the survey was descriptively analyzed to detect general trends and were calculated using descriptive and inferential statistics. The qualitative data was coded and the analysis placed the responses into themes and subthemes to answer the research questions (Creswell, 2008).

The semi-structured interviews provided an abundance of qualitative data that came together to form a coding schema that sought to explain the data. This schema was developed by taking the qualitative data through numerous levels of coding. The interview data was managed within a spreadsheet. Phrases and statements from the transcribed interviews were placed on color-coded note cards and then the statements were classified into specific themes. All data that was gathered was transformed by the researcher through an analysis that was used to answer the research questions posed in this study.

General Technology Survey and Vignette

The General Technology Survey data was analyzed using both quantitative and qualitative methods. The quantitative methods included creating frequencies, determining percentages, as well as calculating confidence intervals for finding the differences in means between adopters and non-adopters. For questions that were answered by rankings, frequencies were found for the top rank and the bottom rank and these were turned into percentages. Questions that provided Likert-scale data were collapsed into a *strongly disagree/disagree* categories and a *strongly agree/agree* categories. Frequencies and percentages were then reported using these two categories. For data that were used to compare adopters and non-adopters of technology, a two-sample confidence interval for the difference between means was calculated. This inferential statistic was calculated using the mean, pooled variance, and sample size of each group. Statistical significance was determined at an alpha level of .05.

The vignette responses and additional comments from the surveys were treated as qualitative data. The vignettes data came from question #20 on the survey in which the participants were asked to describe and explain, in detail, how they utilized technology. Each participant's vignette was considered as one piece of data. Each piece of data was placed on its own note card and was coded with all the qualitative data. Additional comments that were gathered by the survey were also considered as one piece of data for each participant and placed on their own note card to be coded. Each note card for both the vignette responses and survey comments were labeled with the source of the data as well as whether the participant was perceived as an adopter or non-adopter of technology. Green note cards were used to denote the statements that came from the vignettes and yellow note cards were used to code the survey comments. Individual data that came from the vignettes and the survey comments were grouped with the semi-structured interview data note cards and coded as a group.

Semi-Structured Interviews

The semi-structured interviews were audio recorded and transcribed to provide another qualitative data set. The data analyses of the semi-structured interviews began with the researcher familiarizing herself with the transcribed data by reading the interview again to examine it more closely, looking for big ideas. As the re-reading occurred, the researcher highlighted statements and phrases that had a relationship to the research questions. The highlighted portions of the text were then placed on blue note cards and identified with the interviewee's name, type of institution, and whether they designated themselves as an adopter or non-adopter.

The green, yellow, and blue note cards that represented the vignettes, survey comments, and semi-structured interviews, respectively, were then read one-by-one and placed into broad themes. From those broad themes, the note cards were again sorted to ensure that they represented the appropriate themes in which they were placed. The broad themes were organized and then condensed into smaller subthemes to better represent the data. The analysis and coding of the data occurred based on a combination of two approaches supported by research: template and editing (Bloomberg & Volpe, 2008; Crabtree & Miller, 1992). The template approach used key codes that derive from the theory, research questions, or the preliminary reading of the data. The editing approach to coding depends less on the key codes listed above, is more flexible, and allows the codes to emerge from the data. The coding scheme that was created for the qualitative data came from the research questions. The following figure (Figure 15) shows the coding scheme the researcher developed from the qualitative data analysis.

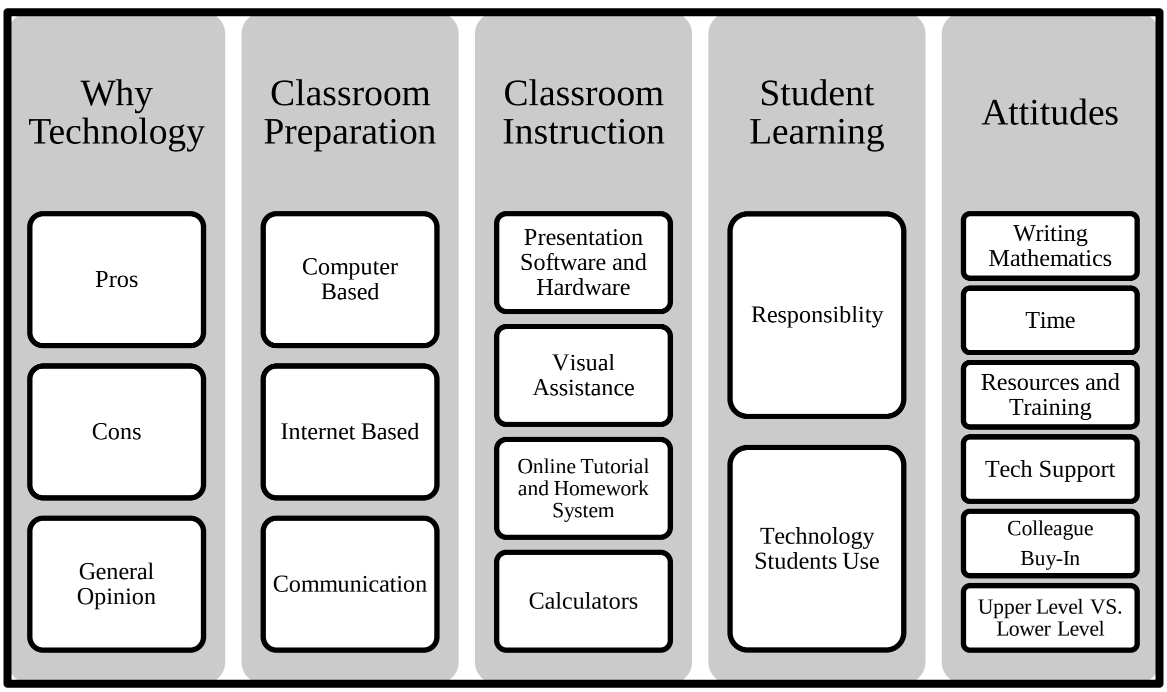

Figure 15: Coding Scheme for Qualitative Data

Five broad themes emerged from the qualitative data including (a) why use technology, (b) ways technology use impacts classroom preparation, (c) ways technology use impacts classroom instruction, (d) student learning, and (e) instructor attitudes. Each broad theme had two or more subthemes that filtered the data into smaller, more descriptive categories that supported the research questions. The broad themes and subthemes were used either as a whole category or in pieces to answer the research questions for this study. Not all themes and subthemes were used to answer the research questions. Data that was not used could be used for future research.

Demographics

The demographics for this study included gender, age, ethnicity, type of institution, position of faculty member, highest degree of faculty member, technology adopter preference, and highest degree of faculty member. Phase I began with the distribution of the General Technology Survey to 550 faculty members through an electronic, online format developed by *Qualtrics* ™. Of the 550 online surveys that were sent, 85 surveys were started, but only 68 surveys were fully completed and submitted for data analysis. This accounts for a 12.4 % survey return rate. The 68 individuals from the population that completed the survey are designated as the participants in the study. To insure that an adequate number of individuals completed the survey, reminder emails were sent through Qualtrics™ to those that had not completed the survey or had started the survey, but not yet completed it. The emails were sent four weeks after the survey was sent, one week before the survey end date, two days before the survey end date, and the day the survey ended. With each reminder that was sent, the number of completed surveys increased.

General Technology Survey and Vignette

Analyses of the General Technology Survey produced the following demographic information. Of the total 68 participants, 35 were male and 33 were female. The age of the participants ranged from age 20 to over 70 years old. Figure 16 below shows an overview of the age of the participants represented in this study.

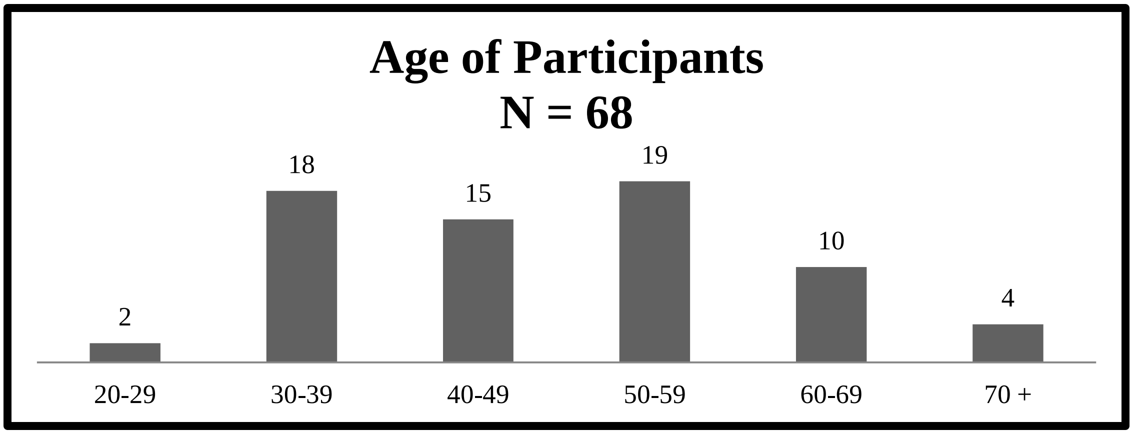

Figure 16: Age of Participants

Those participating in the study indicated their ethnicity based on the following categories: African American, Asian, Native American Indian, White/Caucasian, and prefer not to answer. Figure 17 shows the number of participants who self-identified in each category. The majority of participants in this study consider themselves to be white/Caucasian based on a percentage of 88%.

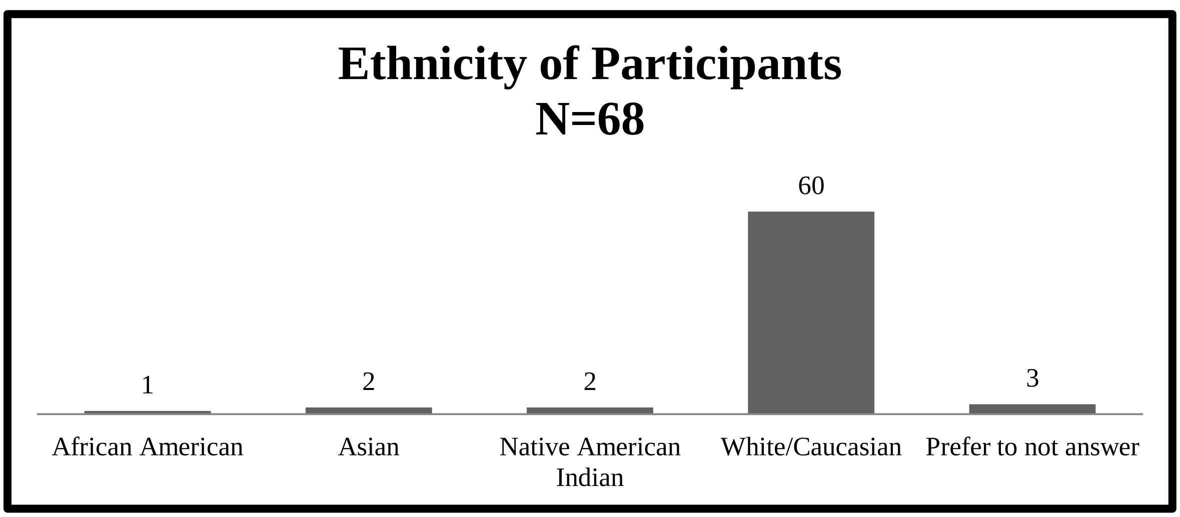

Figure 17: Ethnicity of Participants

Each participant that completed a survey indicated the type of institution with which he or she was affiliated. This data fell into four categories: research 4-year university, regional 4-year university, private 4-year university, community college/ 2-year college, and other. Figure 18 shows the number of participants who identified the type of institution in which they teach.

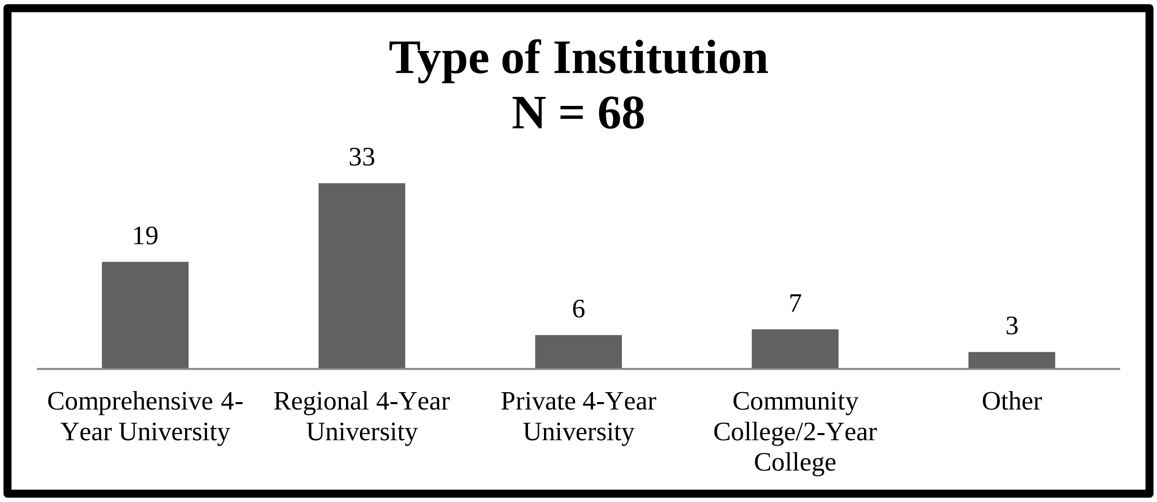

Figure 18: Type of Institution

The three individuals that marked *Other* were not specifically special cases, but apparently the participants did not know where to categorize themselves. Two of these individuals indicated they taught at a 4-year liberal arts public university. The other individual was a full-time professor at a private 4-year university, but also taught as an adjunct at a 4-year regional university.

For this study, the type of institutions were placed in three categories; research universities, regional universities, and community college. Research universities include the two major universities in the state. Regional universities include both public and private 4-year institutions. Community Colleges include institutions denoted as community colleges or 2-year colleges. Complete definitions for these terms were included in Chapter 1 under Key Terms. Because of these categories, regional 4-year universities and private 4-year universities were grouped together and labeled as regional universities. The three participants that selected *Other* were placed in the category of regional universities based on their given explanation in the survey. The categories used for the study are displayed in Figure 19. The data indicate that 62% of the participants are affiliated with a regional university, 28% are affiliated with a research university, and 10% of participants are from a community college.

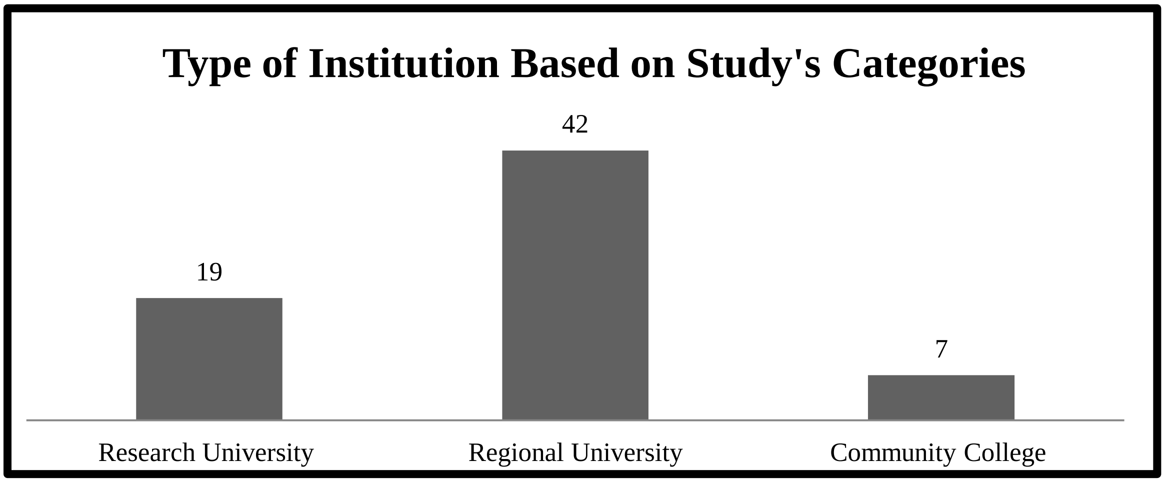

Figure 19: Type of Institution Based on Study's Categories

The faculty that completed their survey selected what their rank or position was at their selected type of institution. This question on the survey was left open ended and later categorized by the researcher. The following categories were present in the data: chair/assistant chair, full professor, associate professor, assistant professor, instructor, lecturer, teaching assistant, and adjunct instructor. Figure 20 shows the number of faculty participants separated by rank. The majority of those participating in the study held the position/rank of a Full Professor (26% [18]).

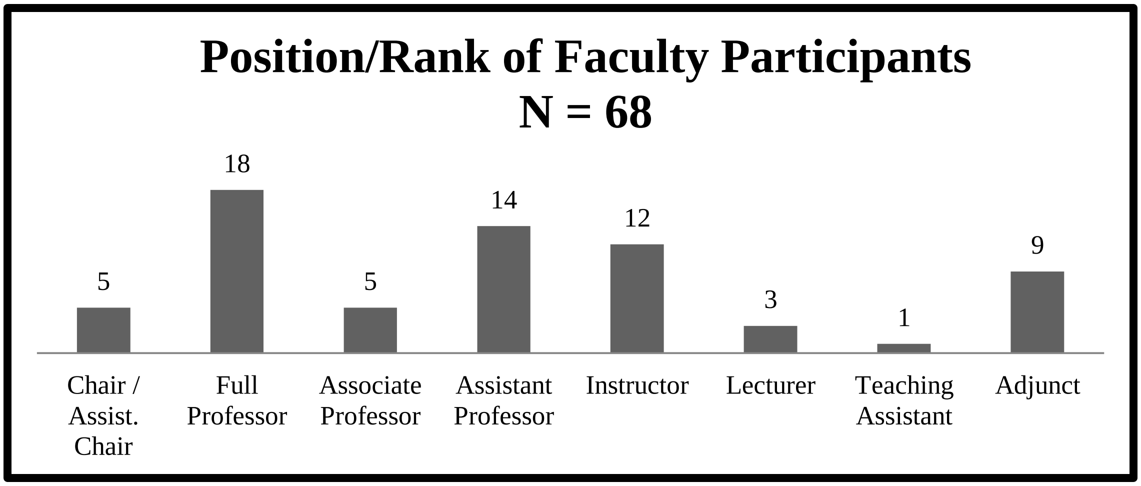

Figure 20: Position/Rank of Faculty Participants

Faculty members that choose to participate by completing the survey also indicated the highest degree that they had earned to date. The majority of respondents hold a doctorate, either a Doctorate of Philosophy or Doctorate of Education, which accounts for 65% of the participants. Figure 21 shows a full breakdown of the highest degree in which the participants had completed. In regard to the highest degree data, note that for accreditation purposes, the majority of higher education institutions must maintain a certain percentage of faculty members that hold a terminal degree.

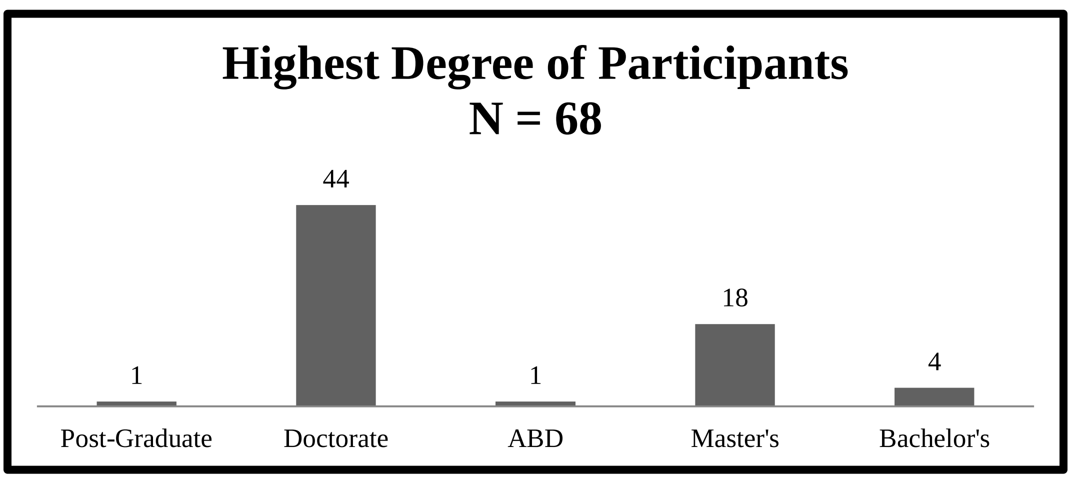

Figure 21: Highest Degree of Participants

The final demographic was technology adoption preference. Participants self-identified whether they were an *adopter* or *non-adopter* of technology.

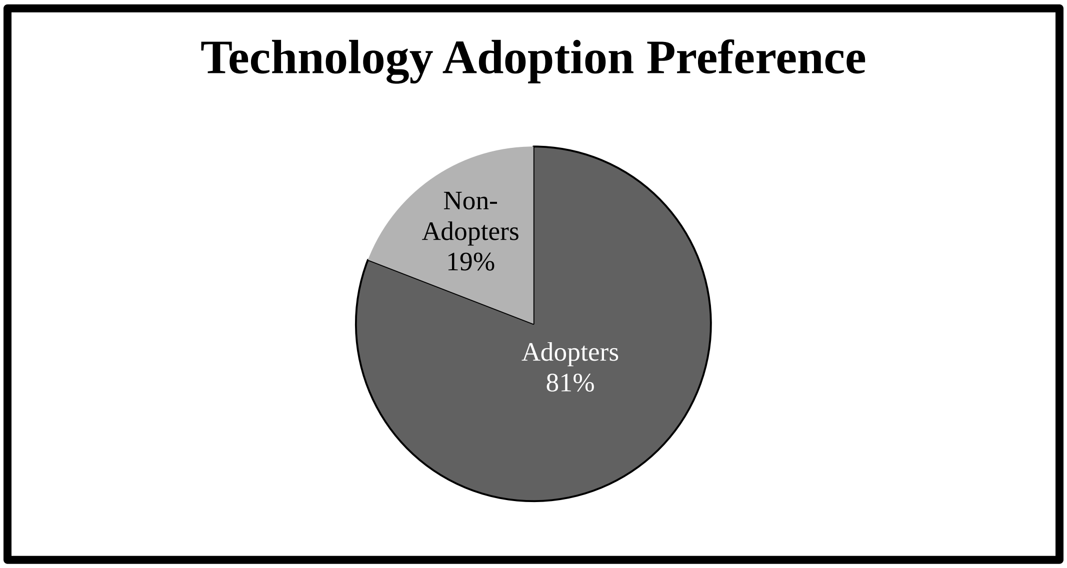

Figure 22: Technology Adoption Preference

The data from this survey question (Figure 22) indicated that the 55 participants (81%) considered themselves to be *adopters* of technology and thirteen individuals (19%) specified themselves as *non-adopters* of technology.

Semi-Structured Interviews

The semi-structured interviews were conducted with six participants that had originally completed the General Technology Survey. To be selected for the semi-structured interview process, the participant had to agree to be interviewed and have included contact information. Out of the 68 individuals that completed the survey, 43 indicated that they were willing to be interviewed during Phase II of the study. The breakdown of those agreeing to be interviewed included eight participants from research universities, 29 individuals that represented the regional universities and six individuals that were associated with community colleges.

The original intent of the study was to conduct semi-structured interviews with six individuals. This would have included an adopter and non-adopter of technology from each type of higher education institution. Because there were no non-adopters of technology from the community college level, a different selection process had to be used. The final group of interviewees included an adopter and non-adopter from a research university, an adopter and non-adopter of technology from a regional university, an adopter of technology from a community college, and an individual that changed their position from a non-adopter to an adopter of technology during the course of the survey.

A random name generator was used to determine who should be selected to be contacted for an interview. The random name generator was completed three different times, one time for each type of university. The researcher went down the list until a non-adopter and an adopter were found. For the community college, the first name was taken from the random name generator list. The six individuals selected to be interviewed were then contacted via email by the researcher and were asked to respond with a time to be interviewed as well as the preference for how the interview take place. Out of six interviews, one was completed using an online meeting forum with a web camera, four were phone interviews, and one was completed face-to-face. Throughout this chapter, when data from the interviews are referred to, a set of parentheses containing the type of university and their technology adoption preference will be used as the reference.

Table 2: Semi-Structured Interview Participant Demographics

Type of Institution	Research University			Regional University		Community College
No.	**#1**	**#2**	**#3**	**#4**	**#5**	**#6**
Gender	Male	Female	Male	Male	Male	Female
Age	40-49	30-39	30-39	50-59	40-49	50-59
Ethnicity	White / Caucasian	White / Caucasian	African American	White / Caucasian	White / Caucasian	White / Caucasian
Position	Professor	Clinical Instructor	Instructor	Instructor	Chair	Assistant Chair
Degree	Doctorate	Doctorate	Masters	Masters	Doctorate	Doctorate
Technology Adoption Preference	Non-Adopter	Adopter	Adopter	Non-Adopter	Non-Adopter to Adopter	Adopter

Table 2 shows the general demographics of the six individuals that completed the semi-structured interviews. Of the six participants, four are male and 2 are female. The age of the interviewees ranged from 30 to 60 years old and five of the six considered themselves to be white/Caucasian, with the other being African American. At their respective institution, four had completed doctorates. The four holding doctorates were a Chairman, an Assistant Chairman, Professor, and Clinical Instructor. The two individuals that had completed master’s degrees were both Instructors in their department. The last demographic is whether the participants considered themselves to be adopters or non-adopters of technology. Two individuals considered themselves to be non-adopters, three considered themselves to be adopters of technology, and one individual started the survey as a non-adopter, but switched to an adopter at the end of the survey.

Findings by Research Question

Research Question #1: What kinds of technology are being used in higher education mathematics content courses?

This research question was included to investigate what technology is actually being used in higher education mathematics courses and whether it is for classroom preparation or classroom instruction. The data necessary to answer this research question came from all three data sources, including the General Technology Survey, vignette, and semi-structured interviews.

The General Technology Survey included two questions concerning what technology was being used. Each question contained the same list of technology tools and allowed participants to add technologies that were not listed. The only difference between the two questions was that one was designed for technology used in relationship to classroom preparation and the other was in relationship to classroom instruction. The participants were asked to rank their frequency of use for each. Significance for this data was determined by adding together the *Often* and *All of the Time* categories and creating a percentage. If the technology was used at a rate of over 50%, the specific technology was deemed statistical significant.

For classroom preparation, seven primary technology tools were shown to be used over 50% of the time by the participants. Table 3 provides an account of the data showing the number of technology tools that were significant when used for classroom preparation. A full listing of technology tools used for classroom preparation and their percentages can be found in Appendix F. The technology tools that represent significant use included computers (82%), calculators (59%), word processing (64%), learning management systems (56%), email communication (66%), and the internet (58%).

Table 3: Significant Technology Used for Classroom Preparation

Question	Never	Rarely	Sometimes	Often	All of the Time	Total Responses
Computer	1% (1)	1% (1)	15% (10)	32% (22)	50% (34)	68
Calculators (basic, scientific, graphing)	7% (5)	15% (10)	19% (13)	46% (31)	13% (9)	68
Word Processing	3% (2)	9% (6)	24% (16)	33% (22)	31% (21)	67
Learning Management systems	21% (14)	8% (5)	15% (10)	29% (19)	27% (18)	66
E-mail Communication	1% (1)	9% (6)	24% (16)	33% (22)	33% (22)	67
Internet	1% (1)	9% (6)	31% (21)	27% (18)	21% (14)	67

Technology used during classroom instruction, as indicated by the participants, varied greatly. Only one piece of technology, the computer, met the 50% requirements for statistical significance. Other technology utilized by participants that was slightly below the significance level included the calculator (48%) and the projector (44%). An overview of these three technology tools is included in Table 4, but a full listing of technology tools used for classroom instruction and the respective percentages can be found in Appendix G.

Table 4: Significant Technology Used for Classroom Instruction

Question	Never	Rarely	Sometimes	Often	All of the Time	Total Responses
Computer	5% (3)	10% (6)	33% (21)	16% (10)	37% (23)	63
Calculators (basic, scientific, graphing)	11% (7)	11% (7)	29% (18)	29% (18)	20% (12)	62
Projector	20% (12)	13% (8)	25% (15)	22% (13)	20% (12)	60

Qualitative data also contributed to identifying what technology is used. The vignettes, survey comments, and semi-structured interview data provided an account of what technology was used in higher education mathematics. Based on the comments, the types of technology used were categorized into the four general roles of technology that were explained in Chapter 2 – tool, tutor, exploration, and communication (Means, 1994). Figure 23 displays the technology used in each category based on the general roles of technology. The types of technology that stemmed from the qualitative data were also visible in the quantitative data but not statistical significant. Technology used in the role of a tool included the majority of variation with ten different technologies. A few of the most used included calculators, document cameras, and interactive whiteboard technology. Technology that acted as a tutor for students included online homework systems, video software and Livescribe pens to create podcasts for student viewing. Interactive websites and premade internet videos were types of technology that were used by higher education mathematics faculty to promote exploration of knowledge.

Tool	Tutor	Exploration	Communication
• Calculator • Document Camera • Interactive Whiteboard Technology • Computer Algebra Systems (Mathematica) • Presentation Software • Dynamic Geometry Software • Spreadsheets • Word Processing • LaTex typesetting system • Graphing Software	• Online Homework System • Video Software • Livescribe Pen	• Interactive Websites • Internet Videos (Youtube) • Graphing Software • Dynamic Geometry Software	• Smartphone capabilities • E-Mail • Learning Management Systems

Figure 23: Technology Used Based on Qualitative Data

Technology used as a communication outlet included e-mail, learning management systems, and smartphone capabilities. Dynamic Geometry software and graphing software were included as technologies that are considered both a tool and for exploration, whether it was used by the faculty member or by the student.

Technology is also used in higher education mathematics courses as a tool, a tutor, and for exploration and communication. The technology that is integrated into the mathematics classroom has changed classroom preparation and instruction for some faculty members. Some faculty view technology as a “necessary evil,” but others view it as something that has made their preparation for classes and instruction of materials easier. The next section of this chapter discusses how the technology is used in higher education mathematics content courses.

Research Question #1.A: How is the technology being used?

Based on the previous data, there is evidence that technology is used in higher education mathematics content courses by faculty members, but how is each technology specifically being used? Data from the General Technology Survey, vignettes, and the semi-structured interviews provides a deeper look at exactly how technology is being integrated and utilized in mathematics courses.

Table 5: How Technology is used In Mathematics Content Courses

	Ranking #1	Ranking #5	Total Responses
Class Preparation	32% (21)	8% (5)	65
Class Instruction	48% (31)	2% (1)	65
Individualized Instruction (working with a single student while including technology)	2% (1)	35% (23)	65
Student Interaction (Collaborative work with students working with technology)	3% (2)	34% (22)	65
Assessment (Any aspect relating to assessing students or yourself)	15% (10)	26% (17)	65

The data in the first table in this section (Table 5) explain whether the technology is being used for class preparation, class instruction, individualized instruction, student interaction, or for assessment. This data was gathered from the General Technology Survey as part of a question asking participants to rank how they used technology from greatest (1) to least (5). Based on the results of the analysis of this data collection, technology is most used during classroom instruction (48%) followed by classroom preparation (32%), assessment (15%), student interaction (3%) and individualized instruction (2%). From these statistics, technology use is centered more on faculty use than on student use.

The semi-structured interviews, survey comments, and vignette responses also provided the purpose of technology and specific ways that technology is used. Through the qualitative data coding process, two major themes emerged; technology is used for classroom instruction and technology is used for preparation. These two themes that emerged are consistent with the analysis of the quantitative data in that participants used technology predominatently for classroom instruction and classroom preparation.

The purpose of technology in teaching college-level mathematics courses came through several comments found on the survey and through the vignettes. Participants explained that technology should be viewed as an instructional aide to extend students' knowledge. A non-adopter of technology indicated that he or she did not use technology because they did not "want the technology to become a substitute for understanding" (Vignette Response). An adopter of technology stressed in one vignette that "technology is a tool to enhance learning, rather than replace it" (Vignette Response). Another participant stated that "I am a firm believer that technology is an aid, not an end in itself" (Vignette Response). One particular survey comment from an adopter of technology stood out when stating that "my guiding principle in technology use is that mathematical technologies should be used to illustrate principles that would be difficult to envision or do in a standard blackboard environment" (Survey Comment). Technology implementation is best when it assists students as they learn mathematics content, but does not take over.

Classroom Instruction

- **Presentation Software and Hardware for Delivery**
  - Computers
  - Projectors
  - Interactive Whiteboard Technology
  - Document Camera
  - PowerPoint
- **Visual Assistance**
  - Pictures
  - Tables
  - Graphs
  - Interactive Videos
  - Mathematical Illustrations
- **Online Tutorial and Homework System**
  - MyMath Lab
  - WebAssign
  - ALEKS
  - EducoSoft
  - MathXL
- **Calculators**

Figure 24: Uses of Technology for Classroom Instruction

The participants provided numerous examples of how technology is used in classroom instruction. Figure 24 shows the uses for classroom instruction with examples given by the participants. The most common use was as a means to deliver instruction. Faculty members used presentation software and hardware to display mathematical content to students. The most commonly used presentation hardware was the computer and projector combination. With this combination, lecture notes and other visual aids could be projected for students to view on a large scale. The computer and projector combination could also be used in conjunction with interactive whiteboard technology. For those not using a computer and projector combination, with or without interactive whiteboard technology, document cameras were used to project information to students. Presentation software, such as PowerPoint or SMARTBoard Software, was the most commonly used software to create lecture notes to be projected for the students.

The next most prominent use of technology was for visual assistance during mathematics instruction. Several faculty members use visual aids to supplement information being taught or as an extension to lessons. Examples of technological visual aids that were supplied by the respondents include mathematics-related illustrations, diagrams, tables, graphs, and interactive video or simulations. Specific technology used includes: Mathematica ™ for illustrations, graphing, and animation, as well as Geometer's Sketchpad ™ to showcase geometric illustration. An adopter of technology wrote in his or her vignette that "technology, in many instances, provides a visual that many student need for comprehension" (Vignette Response). Another vignette stated that:

> I typically use the computer algebra system Mathematica ™ to illustrate mathematical ideas or concepts that would be difficult to do in a more static environment and to quickly do routine tasks. A few examples would be playing a sine wave as sound to explore the notion of frequency, showing the solution to a differential equations as the initial conditions change, or showing Reimann sums converging to an area as more and more rectangles are used. (Vignette Response)

Just like the presentation software and hardware used for delivery, technology used as visual aids assist students in making connections between concepts and reality.

Another piece of technology that was commonly used for classroom instruction was online tutorials and homework systems. In many cases, these systems are bundled with textbooks. Examples of these systems include MyMathLab™, WebAssign™, ALEKS™, Educosoft™, and MathXL™. Online tutorials and homework systems provide opportunities for students to progress through at their own pace, assisting students as they expand skill levels and build conceptual understanding. Once tutorials are completed, students can complete homework assignments within the program. An interviewee commented on online tutorials and homework systems stating that one class "uses ALEKS entirely, with very little lecturing in his remedial algebra classes" (Regional/Adopter Interview). Another interviewee explained that when his students are not doing well on their homework he can have them work through certain online tutorials. Once the students have completed the tutorial they can proceed to completing an assessment. The interviewee went on to say that "you can link tutorials to the assessment and force the students to use the tutorial and learn objectives before they are actually allowed to take the assessment" (Regional/Adopter Interview). Online tutorials and homework systems also allow students to complete homework in an online environment allowing for immediate feedback or additional help features.

The last use of technology for classroom instruction was with calculators. Although most faculty members are not teaching how to use a calculator in class, calculators can be used to "visualize and analyze graphs, create regression equations, and perform many, many statistical calculations that are otherwise cumbersome and time-consuming" (Vignette Response). Some faculty use calculators for specifically designed activities or exploration activities, but the majority just encourage the use of calculators for computation on lecture materials, homework assignments, and tests (Vignette Response). Faculty members that teach technology courses for mathematics and mathematics education students tend to go into further detail on calculator functions.

Not only is technology used for classroom instruction, but also as a classroom instruction preparation tool. Data from the vignettes and semi-structured interviews focused on three themes that represented how technology was used for classroom preparation. The themes are technology that is computer based, technology that is internet based, and communication technology. The categories are shown in Figure 25 along with example given by study participants.

Classroom Preparation

- **Computer Based**
  - Word Processing
  - Spreadsheets
  - Typesetting Software
  - Interactive Whiteboard Technology Software
- **Internet Based**
  - Educational Resources
  - Learning Management System
  - Course Webpage
- **Communication**
  - Email
  - Learning Management System
  - Remind 101

Figure 25: Uses of Technology for Classroom Preparation

The first type of technology used for classroom preparation is computer based. Computer based technology refers to using software that does not require an internet connection. Examples of this type of technology taken from survey comments and semi-structured interview transcripts include word processing software, spreadsheet software, dynamic geometry software, LaTex mathematical typesetting software, and the software that supports the interactive whiteboard technology. An adopter of technology from a research university stated in her interview that she tends to spend much time on her computer preparing for class (Research/Adopter Interview). Another interviewee explained the she uses the SMARTBoard software to prepare lessons so when her students are absent or need additional work, she can send them the lessons Community/Adopter Interview). A non-adopter of technology wrote in the vignette that

> Spreadsheet programs like Microsoft Excel are preferable for the use of gradebooks because they save you about a hour or two per semester by doing routine grade calculations for you. Word processing programs like Microsoft Word are good for writing a syllabus and okay at writing quizzes and tests, although LaTex is superior once you know how to use it. (Vignette Response)

Spreadsheets were also used by an interviewee to perform statistical operations in preparation for a statistics class (Regional/Adopter Interview).

Technology that requires the use of the internet is another type of technology used for classroom preparation. Examples of this include educational resources and websites, learning management systems, and faculty-developed course webpages. One vignette writer indicated that he uses "the internet heavily to get ideas and look up information while preparing my lectures" (Vignette Response). This information is used to add supplemental information or extension to lessons being prepared. Learning management systems offer a virtual place for faculty members to post lecture notes, homework assignments, videos, announcements, and conduct assessments that are available to all students from a remote locations via the internet. A non-adopter of technology who teaches at a research university explained in his semi-structured interview that instead of using a learning management system, he creates a course webpage for each course he teaches. He went on to say that

> It has basic information, the syllabus and I post all the homework that I assign on that and all the exams when they are done. It creates a record of the course. If a student misses a class, they can go back and look at the website. I could do this in D2L, but the thing about D2L is that it goes away. They delete the stuff after a few years. It is not a permanent record. (Research/Non-Adopter Interview)

Internet-based resources and technology used by faculty members for classroom preparation offer a wide variety of information and ideas that add to the mathematics content instruction, enhancing learning in the process.

The last way technology is used for classroom preparation is through communication outlets. Faculty members not only communicate with students face-to-face, but also through email, learning management systems, and text message applications. The three communication outlets that came from the data are able to communicate with students on an individual basis or as a whole. Two adopters of technology, one from a regional university and the other from a community college, indicated in their interviews that they use a text message application called Remind 101 that will send text messages to students (Regional/Adopter Interview, Community/Adopter Interview). One explained that he uses Remind 101 to “send my students text messages to remind them about upcoming test, quizzes, homework reminders or if I forgot to mention something in class” (Regional/Adopter Interview).

Communication is a major part of teaching and these technology tools offer faculty members a way to make it easy.

Technology used by higher education mathematics faculty is mainly used for classroom instruction and classroom preparation. Several examples have been provided by participants through the General Technology Survey, vignette, and semi-structured interviews. Used for deliver, visual assistances, tutorials, homework, resources, and communication, technology continues to play a major role in how higher education mathematics faculty teach today's students.

Research Question #1.B: What factors would encourage higher education mathematics faculty to incorporate technology into their classroom preparation, instructional opportunities, and classroom learning?

Many factors come into play when faculty make decisions to incorporate technology into higher education mathematics content courses. Instructors decide if they will use technology and then whether it will be used for classroom preparation, classroom instruction, both which influence student learning. The data to answer this research question was gathered from the General Technology Survey, semi-structured interview transcripts, vignette responses, and survey comments.

The quantitative data came from the General Technology Survey. Participants were asked rank a set of statements from one to eight based on the following statement: *I would be more willing to use technology if I had …* Table 6 lists the ten statements and the top and bottom rankings for both adopters of technology and non-adopters of technology. Percentages, along with the frequency for each category, were used to document the descriptive statistics from the survey question. Statistical significance was calculated using a 2-sample confidence interval comparing the means using a pooled variance. An alpha of .05 and 60 degrees of freedom were used to determine if each statement was significant. Although none of the statements were significant between adopters and non-adopters of technology there were a few important statements that stood out in analysis.

Table 6: Willingness to Use Technology

Ranking	Ranking #1		Ranking #8		Significance
Technology Preference	Adopter	Non-Adopter	Adopter	Non-Adopter	α = .05
I would be willing to use technology if I had specific technology training and/or professional development	29% (15)	38% (5)	4% (2)	0% (0)	Not Significant
I would be willing to use technology if I had more time to implement new technology	43% (22)	31% (4)	0% (0)	0% (0)	Not Significant
I would be willing to use technology if I had pre-made content lessons that include technology integration	4% (2)	23% (3)	6% (3)	0% (0)	Not Significant
I would be willing to use technology if I had been teaching lower level courses	0% (0)	0% (0)	31% (16)	15% (2)	Not Significant
I would be willing to use technology if I had technology integration lesson creation assistance	0% (0)	0% (0)	8% (4)	8% (1)	Not Significant
I would be willing to use technology if I had the newest technology available	12% (6)	0% (0)	10% (5)	23% (3)	Not Significant
I would be willing to use technology if I had updated hardware and equipment	4% (2)	8% (1)	16% (8)	15% (2)	Not Significant
I would be willing to use technology if I had colleagues that also embraced technology	8% (4)	0% (0)	25% (13)	38% (5)	Not Significant

Although not significant, the first statement that was interesting was *I would be more willing to use technology if I had pre-made content lessons that included technology integration*. Twenty-three percent of non-adopters agreed with this statement. Furthermore, in an interview with a non-adopter, he explained that

> I don't have a resource bank to go to where or know of that ways for a certain math topic use a certain technology application. I don't have a resource bank where there is good technology discussion on certain math topics. I wish I had a reliable, approved for quality, place to go that is effective and efficient source to link technology with math lessons. (Regional/Non-adopter Interview)

Pre-made content lessons resource banks could potentially be a factor that encourages an increased number of higher education mathematics faculty to incorporate additional technology into mathematics content courses.

Another statement that stood out was the statement *I would be more willing to use technology if I had more time to implement new technology*. The adopters of technology and non-adopters of technology, with 43% and 31% respectively, believed that they would use more technology if they had more time. An adopter of technology talked about the time issue during her interview:

> I sometimes have enough time in the day to teach my classes, eat lunch, and then go home. I don't even have time to grade papers; I don't have time to do anything else. When I get home often I do grade papers or make lesson using the technology that I do have. (Community/Adopter Interview)

She went on to explained that if she had "enough time in the day, [she] would sit and play with technology all day long" (Community/Adopter Interview). Just like most things we do in our life, time plays a factor. We must learn to prioritize what is most important, but also look to see what could make our classroom preparation and instruction better for student learning and engagement.

The last interesting piece of data that came from Table 7 was the statement *I would be more willing to use technology if I had specific technology training and/or professional development*. Non-adopters of technology (38%) ranked this statement higher than adopters of technology (29%). A survey comment from a non-adopter supported this fact stating “I am not adverse to technology, but I find I have little time to learn on a campus where training is offered on a limited basis” (Survey Comment). Adopters also support the idea for faculty to continue to integrate technology into mathematics instruction, training and/or professional development is necessary. An adopter of technology indicated in the survey comments that “more training is needed because technology changes so quickly” (Survey Comment). Although not significantly different between adopters and non-adopters of technology, both indicated that training and professional development would encourage faculty to use more technology in their courses.

Factors that encourage higher education mathematics faculty to integrate technology into classroom preparation and instruction are not necessarily different between adopters and non-adopters of technology. Both groups indicate that the need for pre-made content lessons or resource banks, more time, and an increase in training and professional development play a major role in instructors’ willingness to incorporate technology.

Research Question #2: What is the description of an adopter of technology?

An adopter of technology is defined for this study as someone that uses technology on a regular basis. Each participant who completed the General Technology Survey was asked whether they considered themselves to be an adopter or non-adopter of technology. The data from this survey question (Figure 26) indicated that the 55 participants (81%) revealed that they considered themselves to be adopters of technology. Thirteen individuals (19%) specified themselves as non-adopters of technology. Based on this data, the majority of the participants in the study identified themselves as adopters of technology.

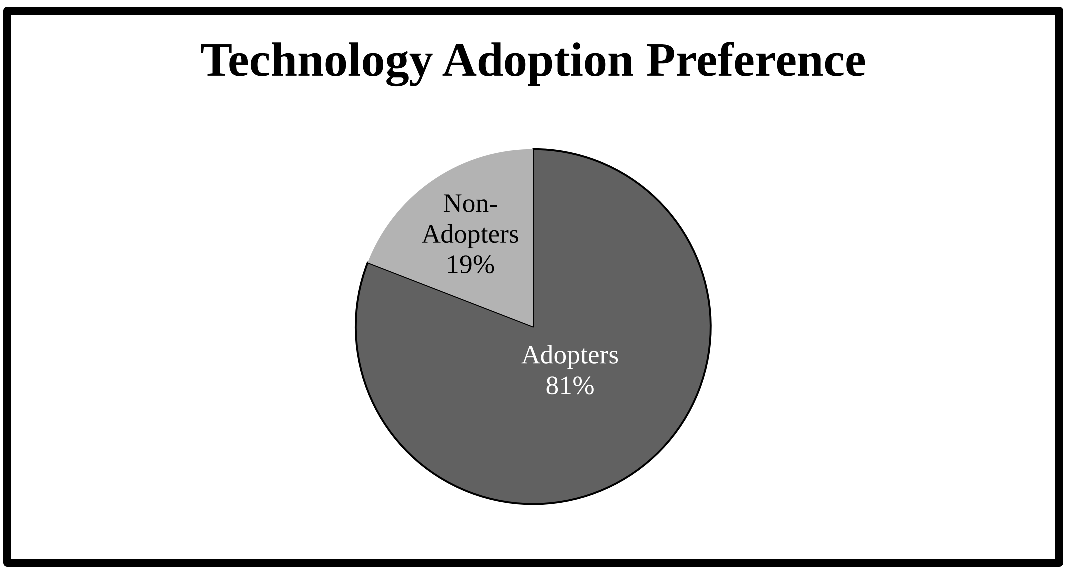

Figure 26: Technology Adoption Preference

To see if anyone switched their technology adoption preference, the same survey question, asking participants if they were an adopter or non-adopter of technology, was asked again at the end of the survey. Although the statistics stayed the same with 55 adopters and 13 non-adopters of technology, it was found that four individuals switched their adoption preference at the end of the survey. Two individuals started as non-adopters and switched to an adopter of technology, while two other individuals started as adopters of technology and indicated they were non-adopters at the end of the survey.

The demographic information from the General Technology Survey was compiled to form a description of an adopter of technology. Gender did not play a major role in whether participants were adopters or non-adopters of technology. Out of the 55 adopters of technology, twenty-eight (51%) were male and twenty-seven (49%) were female. The age of adopters of technology ranged from age 20 to over 70 years old. The majority of the adopters were between 30 years old and 59 years old based on the data in Figure 27.

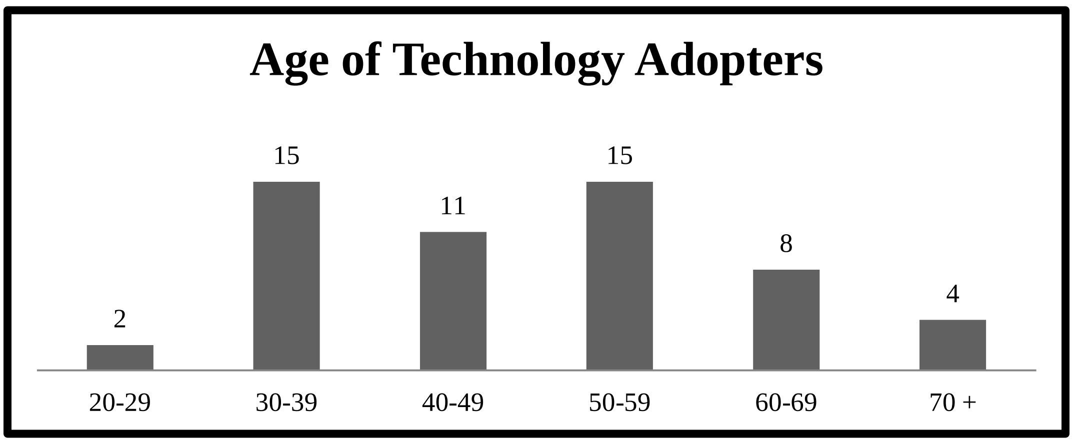

Figure 27: Age of Technology Adopters

The ethnicity of the participants that considered themselves to be adopters of technology were predominately white/Caucasian. The white/Caucasian ethnicity accounted for 49 of the 55 adopters (89%). Figure 28 displays the ethnicities represented by the adopters. One participant choose not to categorize their ethnicity.

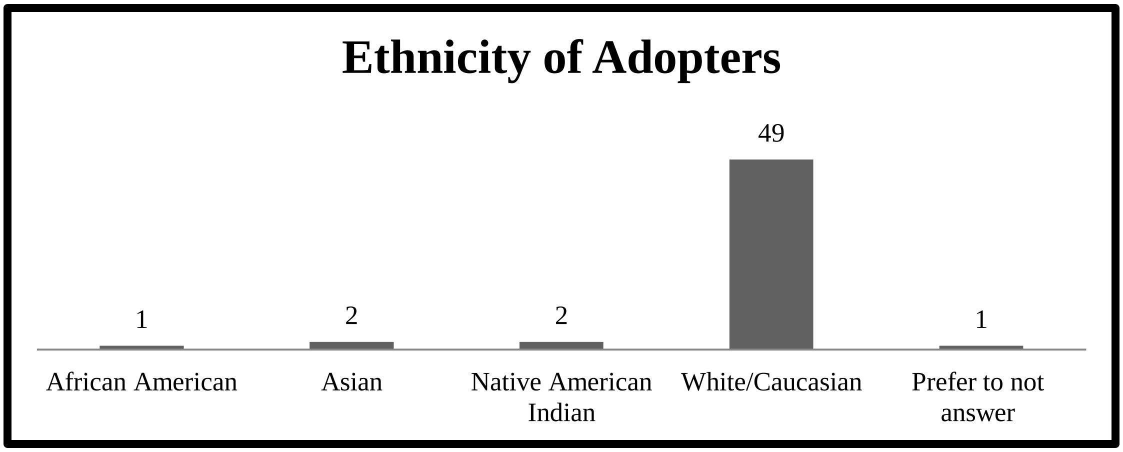

Figure 28: Ethnicity of Adopters

Adopters of technology can also be described by the characteristics of the higher education institution in which they are associated. Figure 29 shows that out of the 55 adopters of technology, 13 participants were associated with a research university, 35 participants with a regional university, and 7 were employed by a community college.

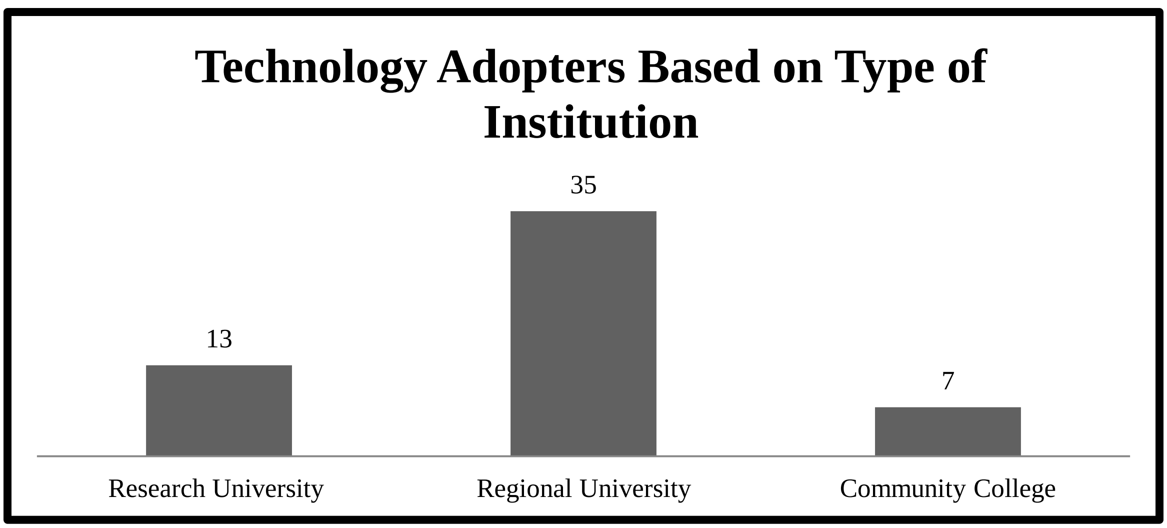

Figure 29: Technology Adopters Based on Type of Institution

This indicates that the majority of the individuals that adopt and utilize technology in higher education mathematics content courses are from regional universities. This category of regional universities represents 11 public universities, 10 private universities, and one public liberal arts university. The position and/or rank of these individuals were categorized into 8 categories which are exhibited in Figure 30. The figure shows that the majority of the adopters of technology are full professors (29%). The other two most common positions/or ranks are assistant professors and instructors of mathematics.

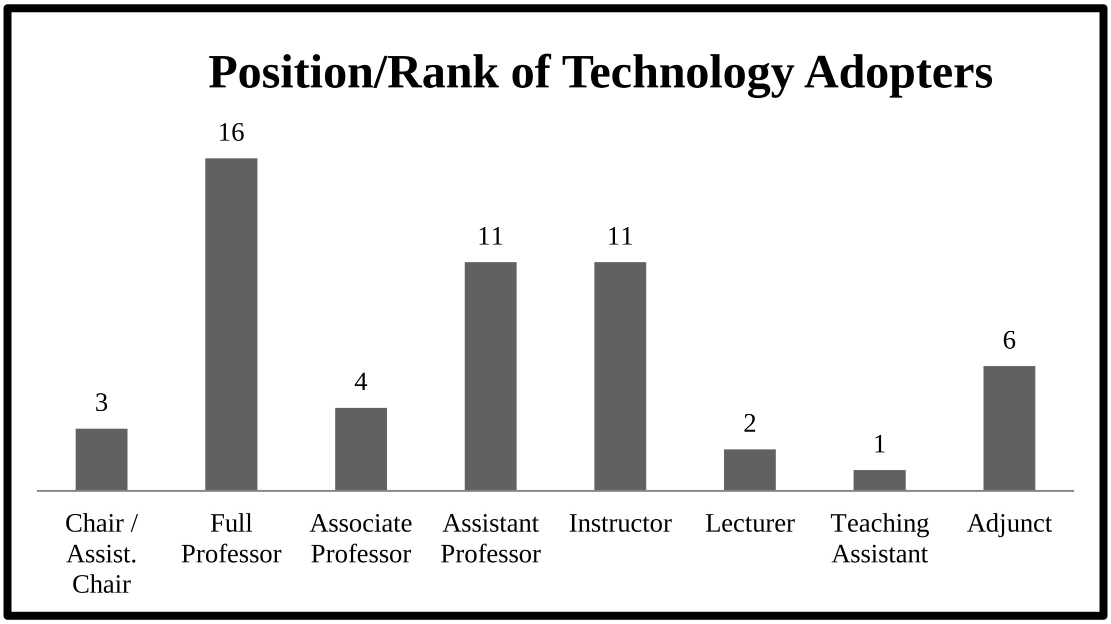

Figure 30: Position/Rank of Technology Adopters

The highest degree that technology adopters will most likely hold is a doctoral degree (65%). The other adopters are either ABD on their doctoral degree (1), hold a Master's degree (16), or a bachelor's degree (2). Within the 36 doctoral degrees, 20 (56%) adopters have completed a Ph.D. in Mathematics, 14 (39%) have completed either an Ed. D. or Ph.D. in Mathematics Education, one holds a Ph.D. in Statistics, and one has a Ed. D in Higher Education.

The adopters of technology could also be described by the number of years they have been employed by a higher education institution. As shown in Figure 31, the years of teaching experience in higher education ranged between one year and more than 36 years.

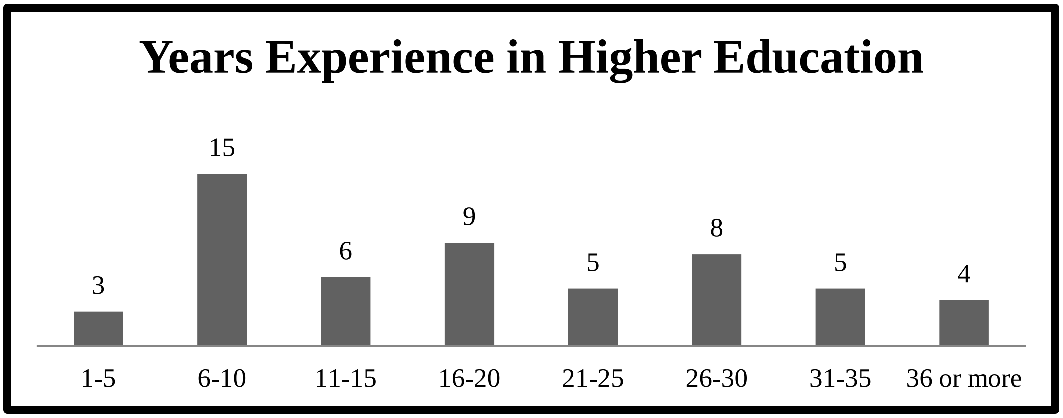

Figure 31: Years Experience in Higher Education

The majority of the adopters of technology had between six and ten years of teaching experience at a higher education institution. The last characteristic that can describe technology adopters based on their higher education institution is the level of the courses they teach (Figure 32). The majority of the technology adopters either taught lower division courses (49%) or taught both lower and upper division courses (47%). Some individuals that taught both lower and upper division courses also indicated they taught graduate level courses.

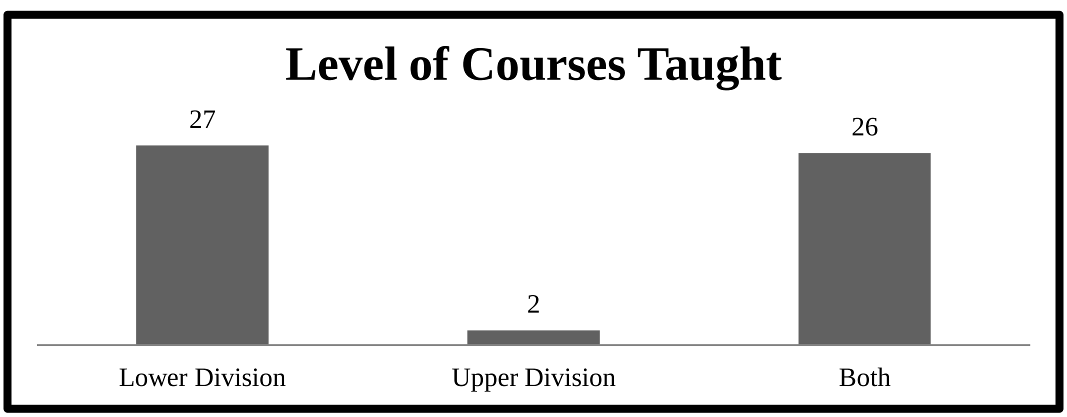

Figure 32: Level of Courses Taught

The last demographic that described the adopters of technology is whether a faculty member is certified to teach at a PK-12 institution. Being certified to teach at this level indicates that participants would have completed a teacher education program or alternative certification requirements. Of the 55 adopters of technology 31 (56%) participants indicated that they were certified to teach at the PK-12 level (Figure 33). The certified teachers went on to show that they were certified in some level of mathematics in their respective state. Twenty-one of the 31 certified teacher adopters had less than 10 years of teaching experience at the PK-12 level, while six had greater than 10 years experience at that level. Four adopters of technology held teacher certification, but had no teaching experience at the PK-12 level.

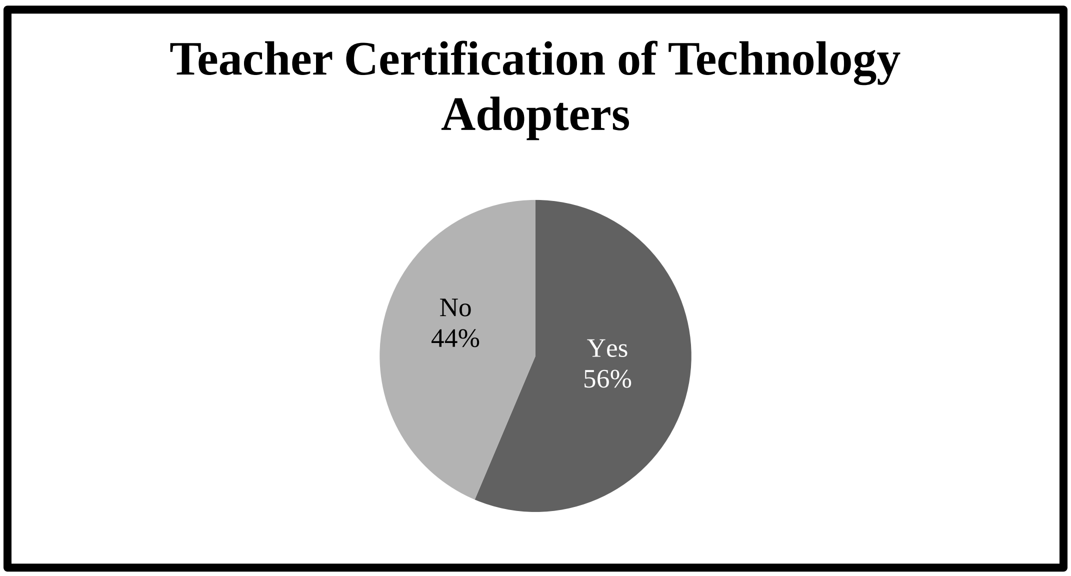

Figure 33: Teacher Certification of Technology Adopters

Therefore, in review and based on this study, an adopter of technology is equally likely to be either male or female, aged 30 to 59, and identified as white/Caucasian. An adopter of technology is most likely to be employed by a regional 4-year university as a full professor with a doctoral degree in the field. This group of individuals has been teaching in higher education between six and ten years and teaches only lower level mathematics content courses or all levels of mathematics content courses. In addition, the adopter of technology may also be certified to teach in a PK-12 educational institution, having completed a teacher education program or the alternative certification process.

Research Question #3: Who, adopters or non-adopters, are most likely to use technology to engage students in learning mathematics?

With more technology being introduced to today's students outside of the classroom, it is necessary to ask ourselves who on the faculty is most likely to engage students in learning by using technology. A specific question on the General Technology Survey asked participants to indicate their beliefs concerning different statements about the use of technology in regard to student learning. The response for these questions was a 5- point Likert-scale with *Strongly Disagree* starting at one and *Strongly Agree* at five. The data was separated first based on technology adoption preference and then the top two answers and the bottom two answers were combined to create a percentage for each category. Significance was determined by using a two sample confidence interval to determine if there is a difference between the means of adopters and non-adopters of technology. An alpha of .05 and 60 degrees of freedom were used to determine if each statement was significant.

Five different statements were given to survey participants concerning students and technology. Based on the data analysis, the beliefs indicated by the data of four of the five statements were significantly different between adopters and non-adopters of technology. Table 7 gives the five belief statements and the percentage of participants that indicated whether they *strongly disagree/disagree* or *agree/strongly agree* with each statement. The first statement that was significant was *I encourage students to use technology*. Eighty-eight percent of the adopters of technology believe they encouraged students to use technology as oppose to the 23% of non-adopters that agreed with the statement. This indicates that adopters are more likely to encourage students to use technology.

Table 7: Faculty Beliefs about Technology

	Strongly Disagree/Disagree		Agree/Strongly Agree		Significance
	Adopter	Non-Adopter	Adopter	Non-Adopter	α = .05
I encourage students to use technology.	4% (2)	23% (3)	83% (44)	23% (3)	Significant
Technology enhances content retention.	9% (5)	46% (6)	40% (21)	8% (1)	Significant
Technology increases student knowledge.	11% (6)	31% (4)	45% (24)	8% (1)	Significant
Technology functions as an effective tool for helping students master the content standards.	9% (5)	31% (4)	57% (30)	15% (2)	Significant
Students are more knowledgeable than I am when it comes to technology.	38% (20)	54% (7)	29% (15)	38% (5)	Not Significant

The next question referred to technology enhancing content retention. Eight percent of non-adopters *agree/strongly agree* that technology enhances content retention. Forty percent of adopters believe this to be true. This data indicates that the adopters believe that technology does enhance mathematics content retention. The next two statements in which the differences were statistically significant were *Technology increases student knowledge* and *Technology functions as an effective tool for helping students master the* *content standards*. Respectively, 45% and 57% of adopters of technology indicate that they *agree/strongly agree* with these two statements. These statistics as a group show that adopters of technology are more likely to see technology as benefit for student learning and encourage students to use technology than non-adopters.

The last statement, for which the difference was not statistically significant, was *Students are more knowledgeable than I am when it comes to technology*. There was not a significant difference between adopters and non-adopters of technology. Although not statistically significant, 54% of non-adopters *disagree/strongly disagree* with this statement. This potentially means that although some faculty members are encouraging students to use technology in higher education mathematics content courses, the faculty members still believe that they are just as knowledgeable about technology as their students.

The qualitative data from the semi-structured interviews and vignette responses indicated a great deal of student learning by using technology was the responsibility of the student. An interviewee explained that with her students she explains to them what is going on and "hopefully they will take the responsibility next time and figure it out" (Community/Adopter Interview). A non-adopter of technology indicates that he still uses a learning management system to upload information for students to have access too, but instead of calling or emailing the instructor, students need to use the technology offered and locate the information available. He went on to say that the materials are "posted there for them to know what we did or what is expected of them" (Regional/Non-adopter Interview). Instructors are also calling students to take responsibility for their learning using technology by changing the way students face situations that are difficult to navigate. A vignette responder wrote that "we have students who basically cannot solve multi-step problems because they do not have any persistence in the face of difficulties; they only want instant gratification" (Vignette Response). A non-adopter of technology indicated in his interview that if students put the time in, he could help students learn and enhance their learning through applying what they learned through the use of technology (Regional/Non-adopter Interview).

Faculty members also encourage student learning by integrating specific technology into instruction and practice. A vignette responder stated that the use of "technology encourages students to do their homework and be quizzed over the covered objectives" (Vignette Response). More instructors are incorporating online homework systems to appeal to this generation of technology users instead of relying on paper/pencil assignments. A vignette response from an adopter of technology uses online homework systems because they do a "pretty good job giving the students several choices as to the way they want to learn" (Vignette Response). One interviewee from a regional university stated for "those students that are logging on and doing those assignments, I can tell during the discussion how well they have mastered the concept. They tend to participant more and ask more questions, they tend to pose deeper questions than just is this the right way to do it or not" (Regional/Adopter Interview).

Another adopter laid out in her interview how she incorporates an automatic response system in her 300- student lecture course. The automatic response system, or clicker system, allowed her to

> Simulate being in a smaller classroom setting where I would do a lot of back and forth and asking questions during my lecture. Now I just incorporate those

questions into clicker questions and ask the class in that way. That way I can get feedback from the students and not just from the three people who are brave enough to talk in that big of a lecture. (Research/Adopter Interview)

One adopter explained in her semi-structured interview how she integrated video capabilities into her classroom. She is able to post videos of her lectures and the students can watch the videos later. Her reasoning behind this was that "they can back it up and hear the same thing over and over again and I don't have to repeat it 10 million times" (Community/Adopter Interview). She went on to say that the "benefits of technology are unbelievable as far as learning goes" (Community/Adopter Interview). Additional comments from the participants supporting the use of technology for student learning include:

- I am able to engage them more. (Regional/Adopter Interview)
- Besides using technology to explain mathematics concepts, I also use it to encourage students to succeed. I have many students who would not be successful without the technology available today. (Vignette Response)
- The technology gives them a sense of hope. (Regional/Adopter Interview)
- I appreciate the way that technology has been used in higher education to help students which enables them to learn. If I'm excited about something the student will be excited about it. (Community/Adopter Interview)
- I use technology for explaining mathematics concepts that are difficult to grasp. (Vignette Response)
- I can tell that my students actually learn more when technology is used in the classroom. (Vignette Response)

Technology has made its way into higher education mathematics classrooms and from the statements of the study's participants; instructors are seeing that students are using technology to assist in the learning process.

Research Question #4: How have technology adopters overcome challenges of implementing technology into higher education mathematics content courses and enhance student learning?

As with implementing any new idea, implementing technology into higher education mathematics content courses does not come without its challenges. Some challenges that faculty members have incurred are on a smaller scale, but other challenges have turned individuals totally away from utilizing technology for mathematics preparation and instruction. One adopter of technology that completed the semi-structured interview expressed these challenges by saying "I feel like each step along the way, each time I start to use a new technology there has been a hurdle that I have to jump over" (Research/Adopter Interview). A survey comment indicated that "I would be interested in trying new technology in the classroom if I was able to see its value. It is challenging to stay informed about the ever-changing field of technology for the classroom" (Survey Comment). Another participant's main challenge was that he had to teach himself how to use the technology before he could ever implement it into mathematics classroom preparation and instruction (Regional/Adopter Interview).

The General Technology Survey provided some insight into what challenges exist when faculty attempt implementing technology. Table 8 displays some potential challenges and the data explaining whether adopters and non-adopters agreed or disagreed. Using a two-sample confidence interval for the difference between means, it was determined that all the statements were not significantly different between the adopters and non-adopters. Although not statistical significant both non-adopters and adopters felt strongly that they would be more comfortable using technology if technology support was available.

Table 8: Challenges of Implementing Technology

	Strongly Disagree/Disagree		Agree/Strongly Agree		Significance
	Adopter	Non-Adopter	Adopter	Non-Adopter	α = .05
I would utilize more technology if I had more training.	24% (12)	31% (4)	41% (21)	38% (5)	Not Significant
Administrators expect us to learn new technologies without any formal training	35% (18)	62% (8)	27% (14)	15% (2)	Not Significant
There are too many technological changes coming too fast without enough support and training.	36% (18)	38% (5)	28% (14)	31% (4)	Not Significant
I am more comfortable using technology when technology support is available.	12% (6)	15% (2)	68% (34)	54% (7)	Not Significant

The survey comments and semi-structured interviews offered insight into the challenges that exist for higher education mathematics faculty. One interviewee believed that technology was a “big buzz word” in the education realm, especially with administrators (Regional/Adopter Interview). Several comments and interview data pieces indicated that they felt pressure from the administration to implement additional use of technology. A survey comment indicated that “sometimes administrators want us to use technology, but it either isn’t appropriate or doesn’t work” (Survey Comment). Another comment supports the previous statement saying there are other technologies that would be helpful, but they are not provided (Survey Comment). An interviewee, from a regional university that is an adopter of technology, explained that the push for technology did not necessarily come from the people in mathematics, but from

> Administrators that want to show off how flashy their school is. A lot of times the math people don’t want anything to do with it or they don’t want anything to do with it at the level that the administrators want it to happen. (Regional/Adopter Interview)

An interviewee from a research university also believed he was being pressured by administrators to revert to online instruction. He explained that

> Universities push online instruction pretty hard these days. It is all about money. We can fit more people into an online course. We can save some teachers’ time. They did some studies and it turned out that it is pedagogically unsound. It fell out of fashion a little bit. (Research/Non-Adopter Interview)

Administrators and university budgets were also seen as a challenge when it came to keeping adequate equipment. One adopter from a regional university explained in his interview that he had written a grant to construct a math lab. They started out with 50 computers six years ago, but now they are down to 20 because computers that were broken were not replaced by the university and the grant funding had been depleted. The faculty member commented that “when you have a class of 40 there is nothing you can do all together with 20 computers” (Regional/Adopter Interview). Other comments suggest that the faculty members are not necessarily asking for new technology, just working or adequate technology (Regional/Adopter Interview).

The need for additional time to implement technology and training opportunities were also determined by qualitative themes to be a challenge when faculty attempt to implement technology. One comment on the survey indicated that “administration must provide support for the maintenance and upgrade of technologies sanctioned by them. Training opportunities are also necessary and time off to learn to use the technology and monetary reward for creating classroom notes/courses” (Survey Comment). Time is a major factor when making the decision to implement something new into one’s classroom. Faculty members are asked to complete a certain amount of curriculum within a semester of time. One interviewee explained that

> There isn’t a lot of time for exploration. It (content instruction) is an inch deep and a mile wide. If you had less topics you could explore more in-depth and I think technology would be an awesome tool to apply more everyday to things. (Regional/Non-Adopter Interview)

He went on to say that “I see the potential for technology but not with the current set of topics you have to cover in a short period of time” (Regional/Non-Adopter Interview). Another interviewee from a research university explained that frustration sets in “when you see something you think that is kind of neat, but [you] don’t really have time to spend time to figure it out” (Research/Adopter Interview).

Technical issues with technology also come into play when implementing technology into mathematics content courses. A comment from the survey explained that

> More could be done if the technology consistently worked. There's a "smartboard" style of board in my classroom. I would use it, but soooooo often, the pens would not work. I spent a lot of time fighting it. (Survey Comment)

An adopter of technology from a community college explained that when technical issues arise in the classroom, specifically internet access, "sometimes I just let it go and just go on to the next thing. I come back later and see what went wrong. I don't have control over some of the things that go wrong and that is frustrating" (Community/Adopter Interview). Having students use technology requires the faculty member to know how to trouble shoot when there is a problem with the technology or when to send students to a help center for additional support. One faculty explained that she was constantly responding to students who could not get their online homework system to work correctly. She noted "there are just so many things they [students] either don't know or are not aware of that the way that they use computers can effect whether or not they can use the software that is on the computer or use the internet" (Community/Adopter Interview). Another interviewee explained that she has access to a help desk.

> Anytime I have problem with my clicker I have a phone number I can call and someone in another building across the street answers and helps me work through it. If I didn't have that support I would not use clickers. The same with D2L. D2L has faculty support as well. I can just call over there and ask them any questions. They can pull up my screen and figure it out. I call them all the time. (Research/Adopter Interview)

Knowing how to troubleshoot the technology integrated into instruction and having a help desk available are considerations when meeting the challenges of the presence of technology in the classroom.

The last challenge adopters of technology identified was that students do not seem to take responsibility for their own learning and the use of technology. One interviewee said it best in that higher education is being “held more accountable for their students and their success. That is a little bit hard to take at this level because the students really need to be responsible for themselves” (Community/Adopter Interview). This same educator questions “how do we teach them to be responsible for themselves and get to the point to where they are passing. Sometimes it takes a few hard knocks to realize they are not going to pass without working” (Community/Adopter Interview). There are also challenges when trying to get students to buy into using the technology. One comment stated that the problem is in trying to get students to “just try to think for themselves how are you going to use this, how are you going to do it” (Community/Adopter Interview).

Challenges exist when implementing technology into higher education mathematics content courses. Although some challenges are not statistically significant between adopters and non-adopters of technology, challenges will plague faculty members who try to adopter technology and integrate it into instruction. These challenges, including administrative demands at the faculty’s institution, time constraints of learning and implementing technology, lack of training opportunities, and how to overcome technical issues, place an additional burden on faculty. Most faculty generally look past the challenges and try to focus on the positive attributes that technology contributes to mathematics instruction and student learning.

Conclusion

This chapter presented the results of the data analyses as they related to the research questions based on the data that was collected. The report was organized with the design of the study summarized first. After the design, the demographics of the participants of the study were presented. Finally, the results of the data collection instruments and data analyses were presented and organized by each research question. For the most part, the quantitative data analyses results were presented first, followed by the qualitative data. Charts, tables, and figures provided a visual illustration of the quantitative data and numerous quotations were used to show the participants' beliefs and views on the use of technology in higher education mathematics content courses.

The primary results of the study indicate that eight pieces of technology are the most used technology either for classroom preparation or instruction. These technologies include computers, calculators, word processing software, learning management systems, e-mail communication, internet, and projector systems. Technology is predominately being used for classroom instruction as a tool, but also as a tutor, for exploration, and faculty-student communication. Many factors play a role in integrating technology into higher education mathematics including the need for pre-made content lessons and resource banks, more time, and specific training and/or professional development. The analyses also found that faculty who consider themselves to be adopters of technology are more likely to encourage students to use technology and believe that technology can enhance content retention and increase student knowledge. Through the data analyses, a profile of an adopter of technology was formed. The description was very broad and wasn't necessarily based on gender, age, and position. The challenges of faculty members implementing technology were also presented and included administration expectations, time element, technical support, and students taking responsibility for their own learning.

The next chapter, Chapter 5, brings the study to a close by providing a general overview of the findings and an interpretation analyzing the findings of the study. The chapter concludes with limitations that came about during the study and opportunities for future research.

CHAPTER V

CONCLUSION

The purpose of this study was to discover and describe to what extent technology is being used in higher education mathematics content courses, how and why technology is being used or not used, and challenges that faculty face during technology integration. In addition, the goal was to determine the characteristics of an adopter of technology. The report of this study consists of five chapters. The first chapter outlined the study providing the initial purpose, research questions, background information, research design overview, and key terms. Chapter 2 outlined the research by going into detail about the history of technology, technology usage in general, and how technology applied to the field of education, specifically higher education and the mathematics content area. The next chapter, Chapter 3, provided a detailed description of the research design and methodology that was carried out to answer the research questions. This chapter also contained the philosophical and theoretical framework that supported the study. Chapter 4 provided the findings from the data collection and analyzes, as well as the demographics of those individuals that participated in the study. The final chapter provides a summary of the study, interpretations of the findings, limitations of the study, and suggestions for future research.

Summary of Study

The intent of this study was to understand technology usage by faculty members that teach higher education mathematics content courses. This study included uncovering how technology was used within classroom preparation and planning, mathematics content instruction, and student learning and engagement. The following research questions were the driving force behind the study.

1. What kinds of technology are being used in higher education mathematics content courses?
    a. How is the technology being used?
    b. What factors would encourage higher education mathematics faculty to incorporate technology into their classroom preparation, instructional opportunities, and classroom learning?
2. What is the description of an adopter of technology?
3. Who, adopters or non-adopters, are most likely to use technology to engage students in learning mathematics?
4. How have technology adopters overcome challenges of implementing technology into higher education mathematics content courses and enhance student learning?

The theoretical framework that supported this study included Bandura’s Social Cognitive Theory and the Technology Adoption Theory. The Social Cognitive Theory was applicable to this study because of the focus on understanding change, the development of attitudes and beliefs about a concept, and self-reflection

(Bandura, 1977, 1986). The Technology Adoption Theory emphasized that new innovations require a changed perception that will inevitably alter environments and require new routines (Straub, 2009). These theories ultimately support the change that occurs when technology is adopted.

In reference to the Technology Adoption Theory and the Stages of Adoption of an Innovation (Figure 34) from Chapter 3, participants in the study showed they were represented various levels of adoption. Participants that self-identified as non-adopters of technology, although not implementing technology into mathematics content courses, were had *knowledge* or *awareness* of technology. Some non-adopters of technology were at the *decision* making level in that they knew they wanted to integrate technology, but did not possess the *familiarity and confidence* necessary for full adoption of technology. Adopters of technology were at the upper stages of the models in Figure 34, falling in the *implementation*, *adaption*, and *familiarity and confidence levels*. Based on the vignettes, survey comments, and the semi-structured interviews, very few adopters of technology had reached the top stages; *confirmation*, *invention*, *adaption to other contexts* and *creative application to new contexts*.

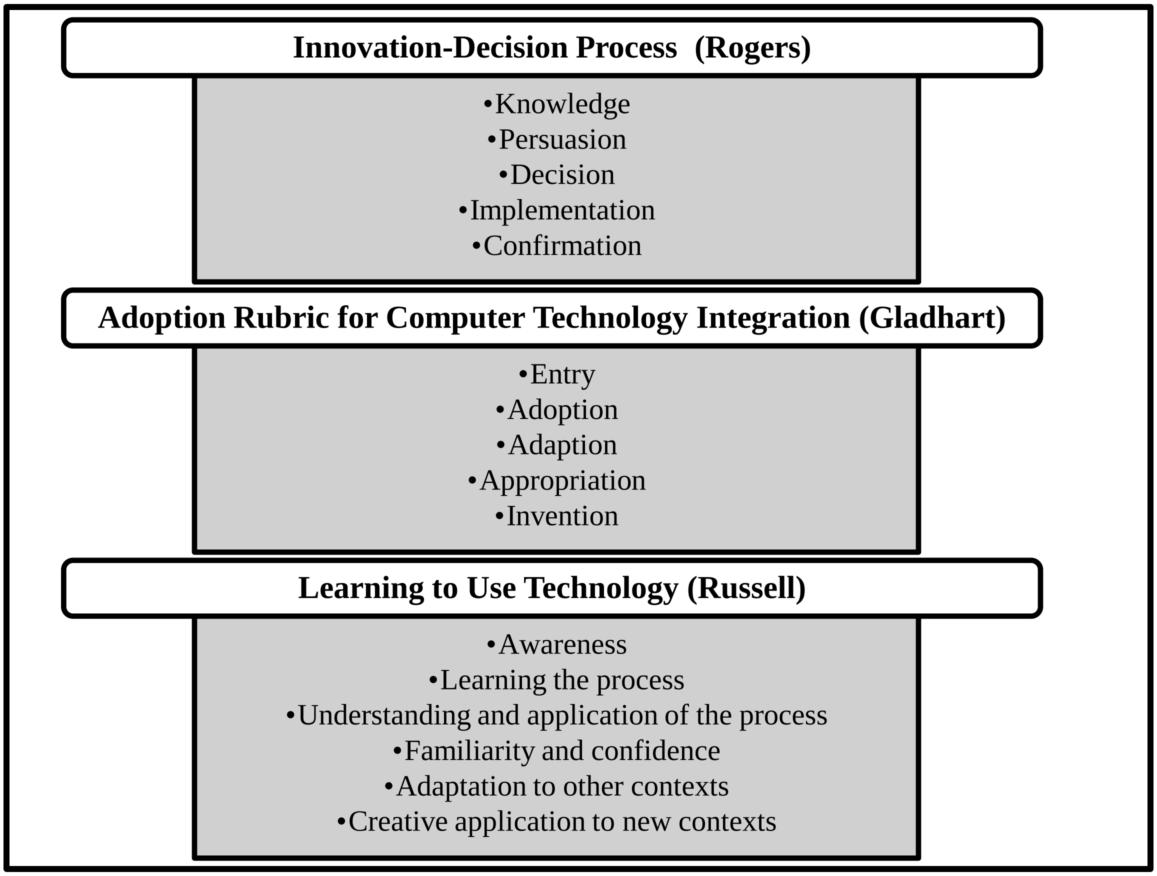

Figure 34: Summary of Models of Stages of Adoption of an Innovation (Toledo, 2005)

The overall design of the study was an explanatory sequential mixed methods design. The design first started with the quantitative data collection and data analysis. The quantitative analysis was then used to create semi-structured interview protocol and participant selection. The protocol included how the semi-structured interviews were carried out, what questions needed to be asked each participant to lead the discussion, and the necessary information needed to thoroughly answer the research questions. Once the protocol was developed and participants selected, the qualitative data collection and data analysis occurred. The final step of the explanatory sequential design was to integrate the quantitative and qualitative data and analyses, which allowed the qualitative findings to support the quantitative analyses and findings.

The sample population for this study was higher education mathematics faculty from a Midwestern state. These faculty members included all levels of professors, as well as instructors, lecturers, adjunct instructors, and teaching assistants. The faculty members included in the population were from research universities, regional public and private universities, and community colleges. The sample population contacted to participate in the study were contacted via electronic mail. A complete list of higher education institutions in this Midwestern state was provided by the state's Regents for Higher Education. Email addresses were secured through each higher education institution's public website and a database was created by the researcher.

Information and data used to answer the research questions was collected by three different instruments. The first instrument was an online survey, General Technology Survey (Appendix A), that was administered by *Qualtrics* ™. A link to the survey, which included an overview of the study, was sent to the sample population using the email address database that was created by the researcher. For this study, 85 individuals from the sample population started the survey, but only 68 completed the survey entire. This was a 12.4% return rate. Only those individuals who completed the survey were included in the data analysis, as well as the findings and results of the study. The General Technology Survey included demographic questions, ranking questions concerning willingness to use technology and attitudes toward technology, and a 5-point Likert-type scaled response questions related to frequencies of technology use for classroom preparation and instruction. Consent to participate in this part of the study was obtained through the use of an online consent form (Appendix B). The consent form for the

General Technology Survey was included on the first page of the survey and participants were informed that they were consenting to participate by completing the survey.

The General Technology Survey also gathered the second data collection instrument for this study, a vignette. The vignette was an open-ended description of how a faculty member used technology in his or her mathematics content course. These first-hand accounts of technology use were used as another source of qualitative data that was used to support the quantitative data gathered by the General Technology Survey. Because this data was gathered through the General Technology Survey, consent for this portion of the data collection process fell under the online consent that provided to survey participants.

The last data collection instrument used was the semi-structured interviews. Individuals who agreed to participate in the semi-structured interviews provided contact information on the online survey and were contacted a few weeks later after an initial review of the survey data. This list of contact information was they categorized based on whether they indicated they were an adopter or non-adopter of technology and into the three types of higher education institutions: research universities, regional universities, and community colleges. Six individuals were selected to participate in the semi-structured interviews. They included an adopter and non-adopter of technology from both a research university and regional university, an adopter of technology from a community college, and a participant from a regional university that switch from a non-adopter to an adopter of technology during the study. Semi-structured interviews for each of these individuals were conducted either by phone, video conferencing capabilities, or face-to-face. Audio recordings were transcribed as another qualitative data source. Consent for the semi-structured interviews was obtained through the Adult Consent Form (Appendix C). Interviewees were sent a copy of the consent form and they returned a signed form either by email or fax.

Data analysis for the three data collection instruments were completed using both quantitative and qualitative methods. The analyses were linked together to answer the research questions. For each research question, the quantitative data that answer the question was explained first, followed by the qualitative data that supported the quantitative data. Conclusions based on the data were then made by the researcher. The quantitative data source was the General Technology Survey. The qualitative data sources included the vignette responses, survey comments, and semi-structured interviews. The quantitative data from the General Technology Survey was first exported into a Microsoft Excel ™ spreadsheet. Descriptive statistics including frequencies and percentages were used for certain survey questions. Questions that were comparing characteristics of adopters and non-adopters of technology used the mean and pooled variance to calculate a two-sample confidence interval to find if a difference occurred between means. Statistical significance based on the inferential statistics was determined using an alpha level of .05 and 60 degrees of freedom.

The qualitative data came from the vignette responses, survey comments, and semi-structured interviews. The three data sets were broken into phrases and placed on color-coded note cards. The phrases were then coded into themes and sub-themes that represented the research questions and based on the previously read theory. Major themes included why technology, classroom preparation, classroom instruction, student learning, and attitudes. Phrases on the cards were used to answer the research questions and support the quantitative findings.

Demographics that came from the General Technology Survey and the semi-structured interviews were also represented within the analysis. The data that came from the demographics included gender, age, ethnicity, type of institution, position of faculty member, highest degree of faculty member, technology adoption preference, and highest degree of faculty member. The data was represented by narratives, figures, and tables.

Findings that came from the study indicated that technology is being used in higher education mathematics content course. Although only a few select pieces of technology are being used, some faculty members are using them quite abundantly within their classroom preparation and instruction. Technology was found to be used predominately for classroom instruction, either with the instructor as the user of the technology or the students as the user of the technology. Although very broad, the findings also created a description of an adopter of technology. The last major findings were the challenges that faculty encounter when integrating technology and how they overcome and adopt. The next section provides an overview of the finds and the researcher's interpretation of the findings in relationship to the research questions.

Interpretation of Findings

Several major trends were found in relation to the research questions. The findings for each research question were drawn from both the qualitative and quantitative data analyses. The demographic information that was gathered during the study shows that the majority of respondents identified themselves as adopters of technology. This was an initial assumption of the researcher. Since this study focused on the use of technology, it would be logical to assume adopters of technology are more likely to complete an online survey. Another reason that the majority of participants identified themselves as adopters of technology is based on the technology they use themselves. However, they may not have considered using technology in connection with student learning and instruction.

Another characteristic that appeared to differentiate the participants was the type of institution in which the mathematics faculty members were employed. Participants from a regional university made up 62% of the respondents. At the beginning of the study, the researcher predicted that faculty at the regional universities would be responders. Faculty members from regional universities are more likely to be an adopter of technology for preparation, instruction, and learning, because the focus of regional universities is normally more geared toward teaching rather than research. This is also somewhat based on the class sizes at these institutions. Regional universities generally keep their class sizes to between 30-40 students. Class sizes are smaller because the regional universities usually have smaller student populations and a higher student-to-teacher ratio. Smaller class sizes allow for an environment that is more conducive to integrating technology because generally each student is able to have their own piece of technology to use and the faculty member is able to assist students with the technology on a one-on-one basis.

The next interpretations of the analyses are organized by research question. The findings for each research question will be summarized and then followed by an interpretation of how the findings answer the research questions.

RQ 1: What kinds of technology are being used in higher education mathematics content courses?

Mathematics faculty utilized technology for classroom preparation or classroom instruction over 50% of the time. The information provided by the General Technology Survey described the use of eight pieces of technology, which can be broken down into two categories, hardware and software. The hardware technology included computers, projector systems, and calculators. The software that was used by faculty included word processing software, learning management systems, e-mail communication, and the internet. An interesting note about these eight pieces of technology is that they are not mathematics-specific technology, other than the calculator. This would indicate that the majority of technology used by faculty members is technology that is available to most instructors by the institution. The used technology is not content specific or anything that would require special training other than for general use.

RQ 1A: How is the technology being used?

The statistics from the quantitative data indicated that technology was used predominately for classroom instruction and then for classroom planning and preparation. Very few participants indicated that they used technology when working directly with students. Most faculty members indicated that the best use of technology was as an aid to instruction, not a tool that takes over instruction. Analysis of the data from General Technology Survey suggested that technology was also primarily used during classroom instruction for delivery of content. This could be a result of higher education institutions moving from basic chalkboard writing surfaces to integrating ceiling-mounted projectors that can be used in conjunction with multiple pieces of hardware and software and might include document cameras and interactive whiteboard technology.

Other technologies were used as visual aids and resources to enhance the presentation and learning of mathematics content. Technology has provided a way for faculty to integrate pictures, tables, graphs, animations, and illustrations into lectures, assisting students as they make connections between the mathematics learned and real-world applications. Technology used as a resource includes several types of communication technology. Communication technology connected faculty with students through email, learning management systems, and text message applications. Keeping the communication lines open between faculty and students is vital for student success to occur in higher education mathematics content courses. The results from this study support the idea that faculty use technology as a cognitive tool to support students as learners and in preparing materials for class.

RQ 1B: What factors would encourage higher education mathematics faculty to incorporate technology into their classroom preparation, instructional opportunities, and classroom learning?

Although analysis of the quantitative data did not show statistically significant results between the adopters and non-adopters of technology, several interesting trends emerged regarding factors that would encourage higher education mathematics faculty to integrate additional technology into classroom preparation, instructional opportunities designed for students, and to enhance classroom learning. The two factors that were most prevalent were having access to a technology resource bank and having more time to learn to use the technology. Participants said they would be more willing to integrate technology if they had a resource bank which included pre-made lessons, examples, and assessment resources. Participants also expressed a need for a resource that could be used to connect mathematics content with an appropriate technology-based activity. Although the internet contains a plethora of resources, faculty indicated that it takes so much time to find appropriate and high-quality resources that have been tried and proven.

The other factor that would encourage faculty to use technology is *time*. With only so many hours in a day, faculty members expressed having a hard time making *time* to implement new technology. Many participants wanted to include technology, but it took so much time to learn the technology, to write curriculum utilizing the technology, to make sure all students had access to the technology, and to reflect on the success of a technology-rich lesson activity. Technology is not something that can be used in a classroom without some sort of pre-planning. Some participants indicated that they would be willing to try one new piece of technology each semester, but would not necessarily use it in all their classes. Faculty indicated they would try the technology in one class to decide if using technology was helpful and then build from there. Having both time and effective resources are problems that faculty face every day, but these two factor seem to have the greatest impact on whether faculty willingly integrate new technologies into their mathematics instruction.

RQ 2: What is the description of an adopter of technology?

Based on the information gathered through this study, a very broad description of an adopter of technology can be drawn. As the researcher reviewed the data provided by the participants, several characteristics emerged. In this current study, an adopter of technology has an equally likely chance of being male or female, would be between the ages of 30 and 59, and of white/Caucasian ethnicity. An adopter of technology would have been employed for six to ten years in a regional university as a professor and hold a doctoral degree. Technology adopters either teach only lower level courses or a balance of both lower and upper level courses. The last characteristic that separates the adopter from the non-adopter is that he or she has been certified as K-12 teacher.

Since 81% of the participants considered themselves to be adopters of technology, reviewing the self-reported demographic information was important. The concern is that with the high percentage of adopters of technology, the description of an adopter of technology would practically be the description of the demographics of the study. Further analyses of the survey data from the adopters technology and previous research could potentially create a thorough description of an adopter of technology in higher education. Because of the small sample size, this description cannot necessarily be generalized across all higher education mathematics faculty members. However, in conversations with the interviewees during the semi-structured interviews, the participants identified as adopters of technology expressed the idea that the desire to use technology was a personal decision. The adopters of technology explored the technology to see how it could assist them on a personal level first and then they integrated the technology into the classroom where applicable. The adopters of technology possessed a willing attitude to try something new, were willing to add it to classroom instruction, and were willing to adapt as the technology changes.

RQ 3: Who, adopters or non-adopters, are most likely to use technology to engage students in learning mathematics?

The analysis of the data gathered on the survey indicates that adopters of technology are more likely to encourage students to use technology. The results, statistically significant at the .05 level, showed adopters of technology believe technology increases student knowledge, enhances content retention, and functions as an effective tool for helping students master the mathematics content standards. Faculty members went on to explain that to encourage students to engage in the learning process, they would integrate a specific piece of technology into the lesson activities. With so many new pieces of technology available for classroom use, including applications for smartphones and tablets, faculty members are eager to try anything that would encourage students to get involved in the learning process. Some faculty members voiced their concern that students were not taking on responsibility for their own learning and the use of technology might provide an outlet for students to become more engaged in the learning process and become more involved in classroom instruction. Adopters of technology are more likely to try out the new technologies in their classrooms in an attempt to actively engage students in the learning process.

RQ 4: How have technology adopters overcome challenges of implementing technology into higher education mathematics content courses and enhance student learning?

The findings from the data analysis indicated the greatest challenges higher education mathematics faculty encounter when implementing technology are complying with demands made by the administration, creating time to explore with the technology and working to implement activities into the courses, the availability of training opportunities, and lack of support to solve technical difficulties. Although none of the quantitative data was determined to be statistically different between adopters and non-adopters of technology, many comments gleaned from the vignette responses, survey comments, and semi-structured interviews indicated which concerns influenced the decisions no to integrate technology regularly. Adopters of technology indicated that they are able to overcome challenges by perseverance and seeking out assistance from qualified individuals. Faculty persevere through the challenges because they see the benefits of integrating technology into mathematics content courses. Qualified technology assistants are becoming more readily available to faculty when challenges arise, hence lessening the frustration that can potentially push faculty away from continuing to integrate technology into mathematics content courses.

Conclusions

Conclusions based on the data analyses can be made for each of the research questions. Higher education mathematics faculty have indicated that they are using technology for classroom preparation and instruction. These technologies, including computers, projectors, calculators, word processing programs, learning management systems, electronic mail and the Internet, support the definition of technology as a "tool" that was used in the study. The definition is "all forms of electronic devices, including computers, calculators, and other handheld devices, telecommunications equipment, and the multitude of multimedia hardware, including the software application associated with their use" (Masalski & Elliott, 2005, p. ix). The technologies that faculty utilize also fall into the categories presented by Dirk and Hollebrand (2011), which include action technology and conveyance technology. Figure 35 categorizes the technology used by higher education faculty in mathematics content courses.

Action Technology

- Computer
- Calculator
- Word Processing Software

Conveyance Technology

- Projectors
- Learning Mangement Systems
- Electronic Mail
- Internet

Figure 35: Technology Used by Higher Education Mathematics Faculty

Previous research shows that technology can be used within mathematics content courses as management tools, communication tools, evaluation tools, motivational, tools, and/or cognitive tools (Peressini & Knuth, 2005). The data analysis from the study indicates that higher education mathematics faculty are using technology primarily as cognitive tools and tools for communication. Cognitive tools are being used extensively for content delivery as visual aids, allowing for the integration of pictures, tables, graphs, animations, and illustrations. The communication tools include electronic mail, learning management systems, and text message applications. These tools are used by faculty to not only communicate with students, but also other colleagues around the world.

This study found two major factors that could potentially encourage higher education mathematics faculty to incorporate technology into mathematics content courses; the need for a technology resource bank and *time*. One of these factors, *time*, was also a barrier for integrating technology in a previous study by Pierce and Ball (2009). Although the technology was viewed as beneficial, the barriers, including *time*, kept faculty from integrating technology into their classrooms. The other factor that the current study highlighted was the need for a technology resource bank that included high-quality resources. Many textbook companies are meeting this need by providing resources electronically that aligns with the curriculum. There resources include lecture notes, video tutorials, a bank of images, and specifically technology activities that correspond with each content section. Other resources are always available on the Internet, but the need still exist to ensure they are appropriate and of sound quality.

Creating a profile of an adopter of technology was also a priority of this study. No clear definition, within the researched literature, was found by the researcher that fully described the characteristics of an adopter of technology. The researcher attempted to find the description of an adopter of technology in this study, but ended up with a set of descriptors that mimicked the demographics of the study. Through self-identification on the General Technology Survey, 81% of participants claimed to be an adopter of technology. In an attempt to fully answer the research question, the researcher looked deeper at the General Technology Survey to determine if specific questions could be combined together to form a better description of an adopter of technology. Based on prior literature and the readings of the researcher, the following survey questions were combined together to form a preliminary description of an adopter.

- Use of a computer at a frequency of Sometimes, Often, or All the Time
- Use of a calculator at a frequency of Sometimes, Often, or All the Time
- Use of a learning management system at a frequency of Sometimes, Often, or All the Time
- Somewhat Agree, Agree or Strongly Agree to “I encourage students to use technology.”
- Somewhat Agree, Agree or Strongly Agree to “Technology enhances content retention.”

- Somewhat Agree, Agree or Strongly Agree to “Technology improves the effectiveness of my teaching.”
- Somewhat Agree, Agree or Strongly Agree to “I am effectively implementing technology in my classroom.”
- Somewhat Agree, Agree or Strongly Agree to “Technology has changed the way I teach.”

The survey questions were then analyzed in each completed survey (Table 9). Based on these questions, a different number of participants were found to be adopters of technology, as well as three self-identified non-adopters of technology were categorized as adopters of technology. Additionally one individual who had initial claimed to be a non-adopter and then switched to become an adopter of technology was deemed a non-adopter of technology by the above description.

Table 9: Technology Preference Based on Researcher’s Preliminary Description

Self-Identification	Preliminary Description	Percentage (N)
Adopter	Adopter	44% (30)
Adopter	Non-Adopter	37% (25)
Non-Adopter	Adopter	5% (3)
Non-Adopter	Non-Adopter	13% (9)
Non-Adopter to Adopter	Non-Adopter	1% (1)

The data analysis using the researcher’s preliminary description shows that instead of 81% being adopters of technology, only 48% of participants are adopters of technology.

The interesting outcomes include the three non-adopters actually becoming adopters of technology and the non-adopter staying as a non-adopter of technology. There is a need for future research using the researcher's preliminary descriptions to fully know if her assumptions and specific survey questions truly describe an adopter of technology.

In addition to the specific survey questions participants completed identifying themselves as *adopters* or *non-adopters,* several major themes evolved through the data analyses of the survey data. Combining the analyses of these components, a set of descriptors of adopters of technology emerged. Adopters of technology consider the best use of technology to be an aid to instruction, not a tool that takes over instruction. They also use technology as a cognitive tool to support students as learners as well as use the technology to encourage students to use technology to solve problems and present solutions. Adopters of technology involve the students in the learning process by demonstrating how to incorporate the technology to support student understanding. Technology adopters also push for additional resources, including a technology resource bank, more time to experiment with the technology to discover ways to utilize technology within the mathematics content courses, and as tool to enhance learning.

Attitude toward technology plays a major role in who chooses to become an adopter of technology and those who do not. The analyses of the data showed that technology adoption by mathematics faculty is a personal decision and cannot be influenced by others. Adopters of technology are also willing to persevere through challenges because the benefits of using the technology in mathematics content courses overshadow the difficulties. Lastly, adopters of technology possess a willingness to try new technology, individually and within a classroom, to draw on the power of the technology to achieve student success.

The researcher believes there also may be some connection between faculty members who completed teacher certification requirements and technology adopters. Of the 55 participants who original self-identified themselves as adopters of technology 56% hold a teaching certificate. The researcher believes the connection to be strong because teacher education programs have placed great emphasis on technology in the classroom as well as pre-service teachers being introduced to how technology can be used in the classroom. Teacher certification may also play an integral part in the description of an adopter.

Another conclusion that can be made from this study is who is most likely to use technology to engage students in learning mathematics. This study found that adopters of technology are more willing to use to technology to engage students. Adopters of technology are more likely to use technology during classroom instruction in conjunction with students. A study by Raines and Clark (2011) confirms these thoughts stating that when technology is incorporated into mathematics instruction, students become active participants in the classroom. Another study also confirms the goal of faculty should be to create a technology-rich learning environment (Sivin-Kachala, 1998). These learning environments are found to influence learning and ultimately increased achievement.

The final conclusion for this study is for higher education mathematics faculty to become adopters of technology and integrate technology into classroom instruction, challenges must be kept to a minimum. Roberts (2008) supports this idea in her study which explains that the factors that play a role in the speed and degree in which faculty integrate technology include resources, culture, readiness, training, time commitments, and academic freedom. All of these factors can be alleviated if the idea of integrating technology is viewed by faculty as a positive step toward assisting students through the learning process.

Recommendations

Based on the interpretations of the results of this study, it is quite evident that faculty face many challenges when integrating technology into mathematics content courses. The following recommendations provide suggestions for effective implementation of technology. The greatest challenge higher education mathematics faculty face when considering the implementation of technology is the demands that the higher education institution's administration places on the faculty to integrate technology throughout the mathematics program. Many times administrators will attend a conference or visit with another university's administration and discuss the new technologies available being used in the other programs. The administrator comes back and tells the mathematics department faculty that they will begin integrating this new piece of technology or bit of software immediately in their courses. In most cases, this change is either not appropriate to use in most of the mathematics courses or there is a limited time in which to learn the new technology. Higher education administrators make decisions without consulting with their mathematics faculty regarding the technology and software that would be most appropriate to use in mathematics courses and for working with students to enhance their skills and knowledge. Another challenge faculty face is when mathematics faculty have requested specific technology and software, but their requests have been denied by the administration. Most administrators blame lack of funding for new projects, budget restrictions, or lack of available resources to meet these requests. It is in the best interest of the faculty to make a presentation to the administrators when they are requesting new technology. These presentations allow the faculty to explain ways the technology would improve instruction or student learning allowing the administrators to have a first-hand interaction with the technology and observe how the technology can benefit both the teacher and the student. Students could demonstrate how the technology works and how the technology can help them. These hands-on demonstrations might be helpful for faculty to secure funding for additional technology. A key to alleviating the conflict between administration and faculty is too maintain open lines of communication so both sides can listen to each other and reach a compromise. Integration of technology, with both hardware and software, will benefit both the students and the mathematics faculty.

The second challenge to implementing technology that faculty alluded to was *time*, *time* to explore the capabilities of the technology, *time* to structure the best student interactions, and *time* to develop materials. As this was an initial assumption made by the researcher, the lack of *time* to study, to explore, and to element various aspects of technology was a common response from participants as a reason they do not integrate technology into their instruction. Faculty are overwhelmed by the normal tasks that are required for maintaining effective classroom lessons, but when faculty are asked to voluntarily adapt their lessons using more technology, they will most likely push those changes to the bottom of their to-do list. There will always be faculty requirements, including committee work, continued research, and student advisement, that will overshadow the adaptation of technology into the mathematics curriculum and courses.

Unless faculty make it a priority, there will never be enough time to implement technology. Every teacher has a different view of how a mathematics classroom should be run and, with that, opinions on the integration of technology will always be a point for discussion. For educators who are truly willing to make a commitment to improved student learning, they will have to reevaluate their teaching style, make the conscience effort to successfully incorporate technology, and acknowledge the benefits it offers both students and faculty. It is not quantity of the technology that matters, but the quality of the technology integration into the mathematics classroom that may account for improvement. If technology is made a priority by the faculty, the time will be available to slowly implement it into classroom instruction and student learning opportunities.

A third challenge that could be overcome is for colleges and universities to provide additional training and professional development regarding technology. Throughout the process of learning and implementing new technology, educators often experience great frustration when they have not received proper training. The research literature reiterates what is commonsense to most faculty that “the lack of practical and methodological training can impede and frustrate” the initial attempt of using the technology (Smith, et al., 2005, p. 98). Waits and Demana argue that professional development training “cannot be done in several afternoons or one day workshops,” but must be a length of time that allows to have complete training on new technology, exercises to practice the new knowledge, and adequate follow-up (1998, p. 5). Technology professional development training is readily available for educators, but they have to be willing to take time out of their already busy schedule and learn the new techniques. Attending professional development training is usually on a volunteer basis, and those who choose to participate demonstrate their willingness to learn, to change their teaching with technology, and to try something new (Lawless & Pellegrino, 2007). Professional development training must be focused on supporting faculty who are willing to develop new knowledge and change the way they use technology in mathematics education. Training for basic technology use, specifically computers and corresponding software, should not be overlooked. Non-adopters of technology are more likely to become adopters of technology if they can begin with the technology they already have in their office and with which they are familiar.

The final challenge that faculty encountered when integrated technology was the lack of technical support and assistance. Anytime faculty try to integrate technology there has to be someone available to troubleshoot, fix problems that occur, and answer questions. Most faculty members expressed that they do not get upset when something happens with the technology they cannot fix; they have met the difficulties by moving on in the lesson and finish it using alternative methods. When plans are made to implement new technology into mathematics content courses, these plans should include technology support that can be called upon at a moment’s notice. Participants were more willing to use technology within their mathematics courses when they had technology support available to answer questions and save problems.

Suggestions for Future Research

The results of this study imply several suggestions for future research. When the results from a study are reviewed, there are often several new research paths that can be considered. Based on the interpretations of the results of this study, these new research paths might include:

- Completing a case study on higher education mathematics faculty who adopt technology for use in their classes;
- Investigating the attitudes and beliefs that are identified with adopters of technology; and
- Confirming the researcher's preliminary definition of the characteristics of an adopter of technology.

The first suggestion for future research would be to use the existing set of participants that were willing to be interviewed for this study and conduct an in-depth case study with several of those individuals. This could include conducting additional semi-structured interviews, as well as observations of technology use during classroom preparation and classroom instruction. The observations of the technology use could provide a truer picture of how technology is being utilized in higher education mathematics content courses. Interviews with students would also provide a perception of how technology is used in the particular classroom in comparison to the interview with the faculty and the observations.

The next suggestion for future research would be to look at the attitudes and beliefs that can be identified with adopters of technology. The attitudes and beliefs of higher education mathematics faculty play a major role in their decisions to use technology in mathematics. In some of the later data analyses of the current data set, the questions concerning willingness to use technology and beliefs about technology provided a deeper look at the adopters and non-adopters of technology. These findings could be used further to develop the description of the adopter of technology that was formed from this study.

The last project for future research would be to confirm the researcher's preliminary definition of an adopter of technology. As stated in the conclusion of the interpretations, a better way to identify adopters of technology is through a set of specific survey questions instead of self-identification. As found earlier, the number of adopters of technology dropped when the technology preference of the participants was determined by the researcher's preliminary definition instead of by the results of self-identification.

Limitations of the Study

There are several limitations to this study. These exist mostly in the data collection and data analysis portion of the study. These limitations include:

- Limited data were available (Low number of respondents)
- Inconsistencies in the researcher developed General Technology Survey
- The notion that *technology adopters* may have been more receptive to completing the survey so there is a basis in the data.

The first limitation of this study was low number of completed surveys. The online survey was sent electronically to 550 higher education mathematics faculty members in a Midwestern state. Of those 550 surveys, only 68 individuals completed the entire survey. This represents a 12.4% response rate. The preferred response rate based on the literature review is approximately 30%. The researcher anticipated there might be a problem encouraging faculty to complete the survey at the beginning of the study and attempted to increase the number of returned surveys by including four reminder emails throughout the time the survey was open. The reminders were sent using the *Qualtrics*™ system and were only sent to those individuals that had not opened the survey or had started the survey, but had not submitted the completed survey. The first reminder was sent a month after the survey was opened, available initially sent to the sample population. Another reminder was sent two weeks later. The last two reminders were sent during the last week the survey was open approximately six weeks after the initial email was sent, one a week before it closed and one the day before it closed. With each reminder that was sent to the population, additional surveys were completed and the response rate increased. Other than providing compensation for completing the survey, which was not an option, the researcher believes that sending the reminders was the only option for increasing the response rate.

The next limitation to the study was the design and development of the General Technology Survey. The survey was created by the researcher to meet the needs of this particular study. The researcher had field tested the survey before it was sent to the population. To establish the reliability and validity of the survey, the survey was sent to experts in the field of mathematics. Although they approved of the survey with no major changes, there were some questions concerning the ranking questions and open response options that could have enhanced the survey, as well as provided for more trustworthy responses from participants. At the time these comments were acquired from the experts, the survey had already been sent to the population and responses had been received. No adjustments were made to the survey during the data collection and data analysis portion of the study. When the survey is used again, adjustments will be made that correspond to the information received from the experts in the field. Additionally, both the reliability and validity will be examined statistically.

The final limitation is the notion that "technology adopters" may have been more receptive to completing the survey due to the online format. The survey was sent through survey software called *Qualtrics™.* The system sent the General Technology Survey to the email address of each higher education mathematics faculty member in the Midwestern state. The limitation occurs here because it is less likely for a non-adopter of technology to open the email and actually complete the survey in the online format. This limitation could have been lessened if the researcher had sent a postcard through the postal service to each member of the sample indicating that an email was coming that would include an online survey and encourage their participation. A paper copy of the survey could have also been made available to those who wished to fill it out in a non-electronic format. The method in which the survey was distributed could have played a role in the number of participants as well as the number of non-adopters of technology that responded to the survey. Of concern to the researcher is her perceived limited background and experience in the field of mixed methods research. Although she had previously taken a graduate course in this type of research, she was concerned that perhaps her skills were not as strong as she would like then to be. To accommodate for the inexperience and build her confidence, she referred to numerous resources including previous textbooks used during her doctoral coursework. Through these resources the researcher gained confidence and helpful guidance along the way. Among the resources the researcher included are:

- *Destination Dissertation* (2007) Sonja K. Foss and William Waters
- *Designing and Conducting Mixed Methods Research* (2011) J.W. Creswell and
- *Completing Your Qualitative Dissertation: A Roadmap From Beginning to End* (2008) L.D. Bloomberg and M. Volpe

Although these limitations could have very well affected the study, most were taken into account early in the study to ensure that the study would be as valid as possible.

Summary

Technology will continue to play a major role in education. As new technologies continue to be designed and presented to society, questions will be raised as to whether they are appropriate for use in mathematics content courses. This study took a small snapshot into the world of technology as it relates to teaching higher education. The previous chapters described the technology that is being used by higher education mathematics faculty as well as offered insight on engaging students using technology, challenges that faculty face with technology integration, and a basic description of an adopter of technology. Many faculty are still searching for the best technology to integrate and how to incorporate the technology in conjunction with the mathematics content. There is still much to learn about how technology adoption or non-adoption is affected by the attitudes and beliefs of higher education mathematics faculty who teach content courses. The key idea to remember is that there are no specific directions on how to successfully integrate technology into mathematics content courses, but faculty can be willing to try new or old technology and see what works best for them, their classroom, and enhances the learning of their students. When the faculty member is confident and comfortable with the technology, it is easier to integrate technology into their mathematics courses.

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APPENDICES

Appendix A. General Technology Survey

(The format of this survey will look different on the *Qualtric*™ software.)
General Technology Survey

PARTICIPANT INFORMATION
Oklahoma State University

Q1 Consent Form:

Title: Technology in Higher Education Mathematics: A Mixed Methods Study

Investigator(s): Dena E. Walker, M.Ed. and Patricia Lamphere Jordan, Ed.D.

Purpose: The purpose of the research study is to identify what technology is being used and the role that the technology plays in learning and assessment in higher education mathematics classrooms.

What to Expect: Phase 1 of this research study is administered online. Participation in this research phase will involve the completion of one questionnaire. The questionnaire will ask for demographic information, types of technology used in class preparation and instruction, beliefs about technology, and how the technology is used. You may skip any questions that you do not wish to answer, but may not backtrack to the previous question.

You will be expected to complete the questionnaire once. It should take you about 10-15 minutes to complete.

This study also has a Phase 2 which will consist of semi-structured interviews. If you are willing to be contacted by the researcher and complete a face-to-face interview, you will be asked for your contact information. Only those willing to participate in Phase 2 will provide contact information.

Risks: There are no risks associated with this project which are expected to be greater than those ordinarily encountered in daily life.

Benefits: You may gain an appreciation and understanding of how research is conducted.

Compensation: You will not receive any compensation for participation in this study.

Your Rights and Confidentiality: Your participation in this research is voluntary. There is no penalty for refusal to participate, and you are free to withdraw your consent and participation in this project at any time, without penalty.

Confidentiality: All personal information and responses to the questionnaire will be kept confidential and will not be released. Research records will be stored securely within the *Qualtrics Survey Software* and only the researchers and individuals responsible for research oversight will have access to the records. The *Qualtrics* account is password protected and supported by Oklahoma State University.

Contacts: You may contact any of the researchers at the following addresses and phone numbers, should you desire to discuss your participation in the study and/or request information about the results of the study:
Dena E. Walker, M.Ed. (Ph.D Candidate), 816 8th Street, Alva, OK 73717, (580)327-2191
-or-
Patricia Lamphere Jordan , Ed.D., (Doctoral Adviser), 247 Willard Hall, College of Education, Oklahoma State University, Stillwater, OK 74078, (405)744-8142.
If you have questions about your rights as a research volunteer, you may contact Dr. Shelia Kennison, IRB Chair, 219 Cordell North, Stillwater, OK 74078, 405-744-3377 or irb@okstate.edu

If you choose to participate:. By clicking NEXT, you are indicating that you freely and voluntarily agreeing to participate in this study and you also acknowledge that you are at least 18 years of age. Your completion of this survey will serve as your consent to participate in this study.
It is recommended that you print a copy of this consent page for your records before you begin the survey by clicking below.
Please, click NEXT if you choose to participate.

Q2 Gender:

- ❍ Male
- ❍ Female

Q3 Age:

- ❍ Age 20-29
- ❍ Age 30-39
- ❍ Age 40-49
- ❍ Age 50-59
- ❍ Age 60-69
- ❍ Age 70+

Q4 Ethnicity:

- ❍ African American
- ❍ Asian
- ❍ Native American Indian
- ❍ Hispanic/Latino
- ❍ Pacific Islander
- ❍ White/Caucasian
- ❍ Other
- ❍ Prefer to not answer

Q5 Describe the type of institution in which you are employed

- ❍ Research 4-Year University (Research Institution)
- ❍ Regional 4-Year University
- ❍ Private 4-Year University
- ❍ Community College/2-Year College
- ❍ Other ____________________

Q6 Title of the position you hold at your teaching institution.

Q7 Number of years teaching mathematics content courses in a higher education setting

Q8 What courses do you currently teach or have taught at the college and/or university level? Please list by course title.

Q9 What is the highest degree you have earned?

- Associates Degree
- Bachelor's Degree
- Masters Degree
- Doctorate
- Post-Graduate
- Other ____________________
- None of the above

Q10 Please indicate the content of your degree(s). (ie. PhD in Mathematics or Masters in Science Education)

Associates Degree
Bachelor's Degree
Master's Degree
Doctorate - Ed.D.
Doctorate - Ph.D.

Q11 Are or have you been certified to teach in a PK-12 school? (any state, any level)

- Yes
- No

Q12 List areas in which you have been certified to teach in PK-12 schools.

Q13 Number of years teaching in the PK-12 schools.

Q14 Would you consider yourself an adopter or non-adopter of technology?

- Adopter (Faculty member that uses technology on a regular basis.)
- Non-Adopter (Faculty member who does not use technology.)

Q15 Rank the following activities in which you use technology. Click on each activity and rank by dragging the activity to the appropriate position. (The activity in which you utilize the most technology should be ranked #1.)

_______ Class Preparation
_______ Classroom Instruction
_______ Individualized Instruction (working with a single student while including technology)
_______ Student Interaction (Collaborative work with students working with technology)
_______ Assessment (Any aspect relating to assessing students or yourself.)

Q16 Please read the following list of technology tools and indicate your frequency of use in relation to CLASS PREPARATION.

	Never	Rarely	Sometimes	Often	All of the Time
Computer	❍	❍	❍	❍	❍
Calculators (basic, scientific, graphing)	❍	❍	❍	❍	❍
Word Processing	❍	❍	❍	❍	❍
Presentation Software (ie. Powerpoint, Prezi, etc)	❍	❍	❍	❍	❍
Desktop Publishing	❍	❍	❍	❍	❍
Spreadsheets	❍	❍	❍	❍	❍
Test Preparation Software	❍	❍	❍	❍	❍
Web Design	❍	❍	❍	❍	❍
Management programs for student data	❍	❍	❍	❍	❍
Interactive Whiteboard SOFTWARE	❍	❍	❍	❍	❍
Interactive Whiteboard SURFACE (ie. SMARTBoard, Promethean, Mimeos, etc)	❍	❍	❍	❍	❍
Computer Algebra Systems (ie. Mathematica, Derive, Maple)	❍	❍	❍	❍	❍
Content-specific	❍	❍	❍	❍	❍

simulation software					
Dynamic Geometry Software (ie. Sketchpad)	❍	❍	❍	❍	❍
Statistical Software (ie. SAS, SPSS, Fathom, Tinkerplots)	❍	❍	❍	❍	❍
Learning Management systems (ie. Blackboard, D2L, Moodle)	❍	❍	❍	❍	❍
Interactive Virtual Worlds	❍	❍	❍	❍	❍
Instructional online gaming	❍	❍	❍	❍	❍
Web 2.0 tools (ie. blogs, wikis, social media)	❍	❍	❍	❍	❍
E-mail Communication	❍	❍	❍	❍	❍
E-Portfolio Tools (ie. Livetext)	❍	❍	❍	❍	❍
Internet	❍	❍	❍	❍	❍
Internet Search Engines	❍	❍	❍	❍	❍
Internet for school website	❍	❍	❍	❍	❍
Internet for developing lesson plans	❍	❍	❍	❍	❍
Internet for Research	❍	❍	❍	❍	❍
Smart Phones	❍	❍	❍	❍	❍
I-Pod	❍	❍	❍	❍	❍

Tablet technology (i.e. iPad, Surface PRO, Kindle)	❍	❍	❍	❍	❍
Tablet Applications	❍	❍	❍	❍	❍
Student Response Systems (ie. clickers, iTouch)	❍	❍	❍	❍	❍
Television	❍	❍	❍	❍	❍
VCR/VHS tapes	❍	❍	❍	❍	❍
Projector	❍	❍	❍	❍	❍
Digital Camera (still)	❍	❍	❍	❍	❍
Digital video camera	❍	❍	❍	❍	❍
Other	❍	❍	❍	❍	❍
Other	❍	❍	❍	❍	❍

Q17 Please read the following list of technology tools and indicate your frequency of use in relation to CLASSROOM INSTRUCTION.

	Never	Rarely	Sometimes	Often	All of the Time
Computer	❍	❍	❍	❍	❍
Calculators (basic, scientific, graphing)	❍	❍	❍	❍	❍
Word Processing	❍	❍	❍	❍	❍
Presentation Software (ie. Powerpoint, Prezi, etc)	❍	❍	❍	❍	❍
Desktop Publishing	❍	❍	❍	❍	❍
Spreadsheets	❍	❍	❍	❍	❍
Test Preparation Software	❍	❍	❍	❍	❍
Web Design	❍	❍	❍	❍	❍
Management programs for student data	❍	❍	❍	❍	❍
Interactive Whiteboard SOFTWARE	❍	❍	❍	❍	❍
Interactive Whiteboard SURFACE (ie. SMARTBoard, Promethean, Mimeos, etc)	❍	❍	❍	❍	❍
Computer Algebra Systems (ie. Mathematica, Derive, Maple)	❍	❍	❍	❍	❍
Content-specific	❍	❍	❍	❍	❍

simulation software					
Dynamic Geometry Software (ie. Sketchpad)	❍	❍	❍	❍	❍
Statistical Software (ie. SAS, SPSS, Fathom, Tinkerplots)	❍	❍	❍	❍	❍
Learning Management systems (ie. Blackboard, D2L, Moodle)	❍	❍	❍	❍	❍
Interactive Virtual Worlds	❍	❍	❍	❍	❍
Instructional online gaming	❍	❍	❍	❍	❍
Web 2.0 tools (ie. blogs, wikis, social media)	❍	❍	❍	❍	❍
E-mail Communication	❍	❍	❍	❍	❍
E-Portfolio Tools (ie. Livetext)	❍	❍	❍	❍	❍
Internet	❍	❍	❍	❍	❍
Internet Search Engines	❍	❍	❍	❍	❍
Internet for school website	❍	❍	❍	❍	❍
Internet for developing lesson plans	❍	❍	❍	❍	❍
Internet for Research	❍	❍	❍	❍	❍
Smart Phones	❍	❍	❍	❍	❍
I-Pod	❍	❍	❍	❍	❍

Tablet technology (i.e. iPad, Surface PRO, Kindle)	❍	❍	❍	❍	❍
Tablet Applications	❍	❍	❍	❍	❍
Student Response Systems (ie. clickers, iTouch)	❍	❍	❍	❍	❍
Television	❍	❍	❍	❍	❍
VCR/VHS tapes	❍	❍	❍	❍	❍
Projector	❍	❍	❍	❍	❍
Digital Camera (still)	❍	❍	❍	❍	❍
Digital video camera	❍	❍	❍	❍	❍
Other	❍	❍	❍	❍	❍
Other	❍	❍	❍	❍	❍

Q18 Rank the following items based on the following statement. I would be more willing to use technology if I had... Click on each item and rank by dragging the activity to the appropriate position. (The item that would make you more willing to use technology should be ranked #1).

______ specific technology training and/or professional development
______ more time to implement new technology
______ pre-made content lessons that include technology integration
______ been teaching lower level courses
______ technology integration lesson creation assistance
______ the newest technology available
______ updated hardware and equipment
______ colleagues that also embraced technology

Q19 Respond to the following statements concerning your integration of technology for student learning.

	Strongly Disagree	Disagree	Somewhat Agree	Agree	Strongly Agree
I encourage students to use technology.	❍	❍	❍	❍	❍
Technology enhances content retention.	❍	❍	❍	❍	❍
Technology increases student knowledge.	❍	❍	❍	❍	❍
Technology functions as an effective tool for helping students master the content standards.	❍	❍	❍	❍	❍
The use of technology saves me time on routine tasks.	❍	❍	❍	❍	❍
Technology improves the effectiveness of my teaching.	❍	❍	❍	❍	❍
Technology would do little to improve my ability to teach.	❍	❍	❍	❍	❍
I would utilize more technology if I had more training.	❍	❍	❍	❍	❍
Students are more knowledgeable than I am when it comes to technology.	❍	❍	❍	❍	❍
Administrators expect us to learn	❍	❍	❍	❍	❍

new technologies without any formal training					
There are too many technological changes coming too fast without enough support and training.	❍	❍	❍	❍	❍
Technology is an effective tool for collaboration with other faculty/instructors.	❍	❍	❍	❍	❍
I am effectively implementing technology in my classroom.	❍	❍	❍	❍	❍
I am more comfortable using technology when technology support is available.	❍	❍	❍	❍	❍
Technology has changed the way I teach.	❍	❍	❍	❍	❍

Q20 Write a statement that describes how you utilize technology in your classroom. Note: This could be a detailed account of a specific activity using technology or your use of technology in general.

Q21 Based on the survey answers that you just selected, please reanswer the following question. Would you consider yourself an adopter or non-adopter of technology?

❍ Adopter
❍ Non-Adopter

Q22 Additional comments you would like included concerning technology usage in higher education mathematics.

Q23 Are you willing to participate in a face-to-face interview with the researcher?

- ❍ Yes
- ❍ No

Q24 Contact Information for participants willing to be interviewed

Name
Higher Education Institution
E-mail Address
Phone Number

Q25 Thank you for your participation in this survey. Press NEXT to submit your responses.

Appendix B. Online Survey Consent Form

PARTICIPANT INFORMATION
OKLAHOMA STATE UNIVERSITY

Title: Technology in Higher Education Mathematics: A Mixed Methods Study

Investigator(s): Dena E. Walker, M.Ed. and Patricia Lamphere Jordan, Ed.D.

Purpose: The purpose of the research study is to identify what technology is being used and the role that the technology plays in learning and assessment in higher education mathematics classrooms.

What to Expect: Phase 1 of this research study is administered online. Participation in this research phase will involve the completion of one questionnaire. The questionnaire will ask for demographic information, types of technology used in class preparation and instruction, beliefs about technology, and how the technology is used. You may skip any questions that you do not wish to answer, but may not backtrack to the previous question. You will be expected to complete the questionnaire once. It should take you about 10-15 minutes to complete.
This study also has a Phase 2 which will consist of semi-structured interviews. If you are willing to be contacted by the researcher and complete a face-to-face interview, you will be asked for your contact information. Only those willing to participate in Phase 2 will provide contact information.

Risks: There are no risks associated with this project which are expected to be greater than those ordinarily encountered in daily life.

Benefits: You may gain an appreciation and understanding of how research is conducted.

Compensation: You will not receive any compensation for participation in this study.

Your Rights and Confidentiality: Your participation in this research is voluntary. There is no penalty for refusal to participate, and you are free to withdraw your consent and participation in this project at any time, without penalty.

Confidentiality: All personal information and responses to the questionnaire will be kept confidential and will not be released. Research records will be stored securely within the *Qualtrics Survey Software* and only the researchers and individuals responsible for research oversight will have access to the records. The *Qualtrics* account is password protected and supported by Oklahoma State University.

Contacts: You may contact any of the researchers at the following addresses and phone numbers, should you desire to discuss your participation in the study and/or request information about the results of the study:

Dena E. Walker, M.Ed. (Ph.D Candidate), 816 8th Street, Alva, OK 73717, (580)327-2191

-or-

Patricia Lamphere Jordan , Ed.D., (Doctoral Adviser), 247 Willard Hall, College of Education, Oklahoma State University, Stillwater, OK 74078, (405)744-8142.

If you have questions about your rights as a research volunteer, you may contact Dr. Shelia Kennison, IRB Chair, 219 Cordell North, Stillwater, OK 74078, 405-744-3377 or irb@okstate.edu

If you choose to participate:. By clicking NEXT, you are indicating that you freely and voluntarily agreeing to participate in this study and you also acknowledge that you are at least 18 years of age. Your completion of this survey will serve as your consent to participate in this study.

It is recommended that you print a copy of this consent page for your records before you begin the survey by clicking below.

Please, click NEXT if you choose to participate.

Appendix C. Semi-structured Interview Consent Form

ADULT CONSENT FORM – Semi-Structured Interview

OKLAHOMA STATE UNIVERSITY

TITLE:
Technology in Higher Education Mathematics: A Mixed Methods Study

INVESTIGATOR(S):
Dena E. Walker, M.Ed. and Patricia Lamphere Jordan, Ed.D.

PURPOSE:
The purpose of the research study is to identify what technology is being used and the role that the technology plays in learning and assessment in higher education mathematics classrooms.

PROCEDURES:
Phase 1 of this research study was administered through an online survey. You indicated on your technology survey that you were willing to participate in phase 2 of this study which includes a semi-structured interview. You will be asked questions concerning your use or non-use of technology for class preparation, instructional methods, and student learning. The semi-structured interview will be audio recorded to ensure that your responses and their meanings are accurately transcribed by the researcher. The semi-structured interview will last approximately an hour.

RISKS OF PARTICIPATION:
There are no known risks associated with this project which are greater than those ordinarily encountered in daily life.

BENEFITS OF PARTICIPATION:
Participation in this semi-structured interview may bring to light how you as a faculty member are actually utilizing technology in a positive manner.

CONFIDENTIALITY:
The records of this study will be kept private. Any written results will discuss group findings and will not include information that will identify you. Research records will be stored securely and only researchers and individuals responsible for research oversight will have access to the records. It is possible that the consent process and data collection will be observed by research oversight staff responsible for safeguarding the rights and wellbeing of people who participate in research.

COMPENSATION:
You will not receive any compensation for participation in this study.

CONTACTS :
You may contact any of the researchers at the following addresses and phone numbers, should you desire to discuss your participation in the study and/or request information about the results of the study:
Dena E. Walker, M.Ed. (Ph.D Candidate), 816 8th Street, Alva, OK 73717, (580)327-2191
-or-
Patricia Lamphere Jordan , Ed.D., (Doctoral Adviser), 247 Willard Hall, College of Education, Oklahoma State University, Stillwater, OK 74078, (405)744-8142.
If you have questions about your rights as a research volunteer, you may contact Dr. Shelia Kennison, IRB Chair, 219 Cordell North, Stillwater, OK 74078, 405-744-3377 or irb@okstate.edu

PARTICIPANT RIGHTS:
I understand that my participation is voluntary, that there is no penalty for refusal to participate, and that I am free to withdraw my consent and participation in this project at any time, without penalty.

CONSENT DOCUMENTATION:
I have been fully informed about the procedures listed here. I am aware of what I will be asked to do and of the benefits of my participation. I also understand the following statements:
I affirm that I am 18 years of age or older.
I have read and fully understand this consent form. I sign it freely and voluntarily. A copy of this form will be given to me. I hereby give permission for my participation in this study.

______________________________________ ____________________
Signature of Participant Date
I certify that I have personally explained this document before requesting that the participant sign it.

______________________________________ ____________________
Signature of Researcher Date

Appendix D. Email to Faculty Members to Participate in Study

Attention *Mathematics Faculty Member,*
Dena Walker, a Ph.D Candidate at Oklahoma State University, is conducting a research study with *mathematics faculty members at higher education institutions across the state of Oklahoma* in an effort to identify what *technology* is being used and the *role* that the technology plays in learning and assessment in *higher education* mathematics classrooms. Your input can assist in this research and is greatly appreciated.

Below you will find a link to a General Technology Survey. It is estimated that the electronic survey will take you approximately 10-15 minutes to complete the survey. More complete details about the study can be found below the link in this email. Simply click on the link below, or cut and paste the entire URL into your browser to access the survey:
Survey link
I would appreciate your response by ***October 1st, 2013***.
Thank you for your time. Your input is very important to us and will be kept strictly confidential (used only for the purposes of research for this project).

Research Study Details

Title: Technology in Higher Education Mathematics: A Mixed Methods Study

Investigator(s): Dena E. Walker, M.Ed. and Patricia Lamphere Jordan, Ed.D.

Purpose: The purpose of the research study is to identify what technology is being used and the role that the technology plays in learning and assessment in higher education mathematics classrooms.

What to Expect: Phase 1 of this research study is administered online. Participation in this research phase will involve the completion of one questionnaire. The questionnaire will ask for demographic information, types of technology used in class preparation and instruction, beliefs about technology, and how the technology is used. You may skip any questions that you do not wish to answer, but may not backtrack to the previous question. You will be expected to complete the questionnaire once. It should take you about 10-15 minutes to complete.

This study also has a Phase 2 which will consist of semi-structured interviews. Those indicating that they are will to be interviewed will participate in this portion of the study. Individuals will be asked questions concerning the use or non-use of technology for class preparation, instructional methods, and student learning. The semi-structured interview will be audio recorded to ensure that your responses and their meanings are accurately transcribed by the researcher. The semi-structured interview will last approximately an hour.

Risks: There are no risks associated with this project which are expected to be greater than those ordinarily encountered in daily life.

Benefits: You may gain an appreciation and understanding of how research is conducted.

Compensation: You will not receive any compensation for participation in this study.

Your Rights and Confidentiality: Your participation in this research is voluntary. There is no penalty for refusal to participate, and you are free to withdraw your consent and participation in this project at any time, without penalty.

Confidentiality: All personal information and responses to the questionnaire and semi-structured interviews will be kept confidential and will not be released. Research records will be stored securely and only the researchers and individuals responsible for research oversight will have access to the records.

Contacts: You may contact any of the researchers at the following addresses and phone numbers, should you desire to discuss your participation in the study and/or request information about the results of the study:
Dena E. Walker, M.Ed. (Ph.D Candidate), 816 8th Street, Alva, OK 73717, (580)327-2191
-or-
Patricia Lamphere Jordan , Ed.D., (Doctoral Advisor), 247 Willard Hall, College of Education, Oklahoma State University, Stillwater, OK 74078, (405)744-8142.
If you have questions about your rights as a research volunteer, you may contact Dr. Shelia Kennison, IRB Chair, 219 Cordell North, Stillwater, OK 74078, 405-744-3377 or irb@okstate.edu

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Simply click on the link below, or cut and paste the entire URL into your browser to access the survey:
Survey link
I would appreciate your response by ***October 1, 2013***.
Thank you for your time. Your input is very important to us and will be kept strictly confidential (used only for the purposes of research for this project).

Appendix E. Institutional Review Board Approval

Oklahoma State University Institutional Review Board

Date:	Thursday, June 27, 2013
IRB Application No	ED13121
Proposal Title:	Technology in Higher Education Mathematics: From Pencil to Stylus and Everything in Between
Reviewed and Processed as:	Exempt

Status Recommended by Reviewer(s): Approved   Protocol Expires: 6/26/2014

Principal Investigator(s):

Dena E Walker	Patricia Lamphere Jordan
816 8th Street	247 Willard
Alva, OK 73717	Stillwater, OK 74078

The IRB application referenced above has been approved. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46.

☒ The final versions of any printed recruitment, consent and assent documents bearing the IRB approval stamp are attached to this letter. These are the versions that must be used during the study.

As Principal Investigator, it is your responsibility to do the following:

1. Conduct this study exactly as it has been approved. Any modifications to the research protocol must be submitted with the appropriate signatures for IRB approval. Protocol modifications requiring approval may include changes to the title, PI, advisor, funding status or sponsor, subject population composition or size, recruitment, inclusion/exclusion criteria, research site, research procedures and consent/assent process or forms.
2. Submit a request for continuation if the study extends beyond the approval period of one calendar year. This continuation must receive IRB review and approval before the research can continue.
3. Report any adverse events to the IRB Chair promptly. Adverse events are those which are unanticipated and impact the subjects during the course of this research; and
4. Notify the IRB office in writing when your research project is complete.

Please note that approved protocols are subject to monitoring by the IRB and that the IRB office has the authority to inspect research records associated with this protocol at any time. If you have questions about the IRB procedures or need any assistance from the Board, please contact Dawnett Watkins 219 Cordell North (phone: 405-744-5700, dawnett.watkins@okstate.edu).

Sincerely,

Shelia M. Kennison

Shelia Kennison, Chair
Institutional Review Board

Appendix F. Technology Used for Classroom Preparation

Question	Never	Rarely	Sometimes	Often	All of the Time	Total Responses
Computer	1% (1)	1% (1)	15% (10)	32% (22)	50% (34)	68
Calculators (basic, scientific, graphing)	7% (5)	15% (10)	19% (13)	46% (31)	13% (9)	68
Word Processing	3% (2)	9% (6)	24% (16)	32% (22)	31% (21)	67
Presentation Software	21% (14)	26% (18)	25% (17)	19% (13)	9% (6)	68
Desktop Publishing	60% (40)	16% (11)	16% (11)	7% (5)	0% (0)	67
Spreadsheets	24% (16)	15% (10)	34% (23)	22% (15)	4% (3)	67
Test Preparation Software	56% (37)	6% (4)	20% (13)	11% (7)	8% (5)	66
Web Design	62% (41)	23% (15)	14% (9)	2% (1)	0% (0)	66
Management programs for student data	29% (19)	24% (16)	21% (14)	12% (8)	14% (9)	66
Interactive Whiteboard SOFTWARE	55% (36)	17% (11)	9% (6)	6% (4)	14% (9)	66
Interactive Whiteboard SURFACE	56% (37)	15% (10)	12% (8)	3% (2)	14% (9)	66
Computer Algebra Systems	34% (23)	25% (17)	21% (14)	12% (8)	7% (5)	67
Content-specific simulation software	48% (32)	18% (12)	26% (17)	5% (3)	3% (2)	66
Dynamic Geometry Software	50% (33)	26% (17)	18% (12)	6% (4)	0% (0)	66
Statistical Software	59% (39)	24% (16)	9% (6)	5% (3)	3% (2)	66

Learning Management systems	21% (14)	8% (5)	15% (10)	29% (19)	27% (18)	66
Interactive Virtual Worlds	97% (64)	0% (0)	2% (1)	0% (0)	2% (1)	66
Instructional on-line gaming	91% (60)	5% (3)	3% (2)	0% (0)	2% (1)	66
Web 2.0 tools	73% (49)	18% (12)	4% (3)	1% (1)	3% (2)	67
E-mail Communication	1% (1)	9% (6)	24% (16)	33% (22)	33% (22)	67
E-Portfolio Tools	86% (57)	9% (6)	3% (2)	0% (0)	2% (1)	66
Internet	1% (1)	9% (6)	31% (21)	27% (18)	31% (21)	67
Internet Search Engines	4% (3)	13% (9)	36% (24)	27% (18)	19% (13)	67
Internet for school website	23% (15)	17% (11)	26% (17)	17% (11)	18% (12)	66
Internet for developing lesson plans	29% (19)	20% (13)	38% (25)	9% (6)	5% (3)	66
Internet for Research	3% (2)	18% (12)	45% (30)	24% (16)	9% (6)	66
Smart Phones	64% (42)	17% (11)	18% (12)	3% (2)	5% (3)	66
I-Pod	89% (59)	6% (4)	3% (2)	0% (0)	2% (1)	66
Tablet technology	70% (46)	12% (8)	11% (7)	5% (3)	3% (2)	66
Tablet Applications	74% (49)	12% (8)	8% (5)	3% (2)	3% (2)	66
Student Response Systems	87% (58)	6% (4)	3% (2)	3% (2)	1% (1)	67
Television	77% (51)	17% (11)	5% (3)	0% (0)	2% (1)	66
VCR/VHS tapes	85% (56)	14% (9)	0% (0)	0% (0)	2% (1)	66

Projector	29% (19)	21% (14)	27% (18)	12% (8)	11% (7)	66
Digital Camera (still)	71% (47)	15% (10)	9% (6)	2% (1)	3% (2)	66
Digital video camera	73% (49)	18% (12)	7% (5)	0% (0)	1% (1)	67

Appendix G. Technology Used for Classroom Instruction

Question	Never	Rarely	Sometimes	Often	All of the Time	Total Responses
Computer	5% (3)	10% (6)	33% (21)	16% (10)	37% (23)	63
Calculators (basic, scientific, graphing)	11% (7)	11% (7)	29% (18)	29% (18)	19% (12)	62
Word Processing	25% (15)	27% (16)	28% (17)	12% (7)	8% (5)	60
Presentation Software	24% (15)	24% (15)	32% (20)	15% (9)	5% (3)	62
Desktop Publishing	78% (47)	13% (8)	5% (3)	3% (2)	0% (0)	60
Spreadsheets	43% (26)	23% (14)	25% (15)	8% (5)	2% (1)	61
Test Preparation Software	65% (39)	10% (6)	15% (9)	5% (3)	5% (3)	60
Web Design	92% (55)	2% (1)	3% (2)	3% (2)	0% (0)	60
Management programs for student data	72% (43)	10% (6)	8% (5)	5% (3)	5% (3)	60
Interactive Whiteboard SOFTWARE	57% (37)	10% (6)	11% (7)	2% (1)	20% (12)	61
Interactive Whiteboard SURFACE	52% (32)	11% (7)	13% (8)	3% (2)	21% (13)	62
Computer Algebra Systems	41% (25)	28% (17)	16% (10)	11% (7)	3% (2)	61
Content-specific simulation software	58% (35)	20% (12)	12% (7)	5% (3)	5% (3)	60
Dynamic Geometry Software	63% (38)	12% (7)	22% (13)	3% (2)	0% (0)	60
Statistical Software	77% (46)	12% (7)	8% (5)	2% (1)	2% (1)	60

Learning Management systems	34% (21)	10% (6)	30% (18)	16% (10)	10% (6)	61
Interactive Virtual Worlds	97% (57)	0% (0)	2% (1)	0% (0)	2% (1)	59
Instructional on-line gaming	97% (54)	3% (2)	2% (1)	2% (1)	2% (1)	59
Web 2.0 tools	87% (52)	7% (4)	5% (3)	0% (0)	2% (1)	60
E-mail Communication	40% (24)	13% (8)	18% (11)	15% (9)	13% (8)	60
E-Portfolio Tools	95% (55)	2% (1)	2% (1)	0% (0)	2% (1)	58
Internet	12% (7)	25% (15)	35% (21)	17% (10)	12% (7)	60
Internet Search Engines	27% (16)	27% (16)	33% (20)	7% (4)	7% (4)	60
Internet for school website	34% (20)	20% (12)	27% (16)	14% (8)	5% (3)	59
Internet for developing lesson plans	46% (27)	24% (14)	22% (13)	2% (1)	7% (4)	59
Internet for Research	38% (23)	22% (13)	28% (17)	8% (5)	3% (2)	60
Smart Phones	71% (42)	15% (9)	12% (7)	0% (0)	2% (1)	59
I-Pod	97% (57)	0% (0)	2% (1)	0% (0)	2% (1)	59
Tablet technology	85% (50)	8% (5)	3% (2)	2% (1)	2% (1)	59
Tablet Applications	88% (52)	5% (3)	3% (2)	2% (1)	2% (1)	59
Student Response Systems	86% (51)	2% (1)	8% (5)	2% (1)	2% (1)	59
Television	83% (49)	10% (6)	5% (3)	0% (0)	2% (1)	59
VCR/VHS tapes	85% (50)	15% (9)	0% (0)	0% (0)	0% (0)	59

Projector	83% (12)	13% (8)	25% (15)	22% (13)	20% (12)	60
Digital Camera (still)	20% (46)	12% (7)	5% (3)	3% (2)	2% (1)	59
Digital video camera	79% (45)	12% (7)	10% (6)	0% (0)	0% (0)	58

VITA

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