THE EFFECTS OF DESMOS AND TI-83 PLUS GRAPHING CALCULATORS ON THE

PROBLEM-SOLVING CONFIDENCE OF MIDDLE AND HIGH SCHOOL MATHEMATICS

STUDENTS

by

Edwin Montijo

Liberty University

A Dissertation Presented in Partial Fulfillment

Of the Requirements for the Degree

Doctor of Education

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ABSTRACT

As technology in education continues to improve, research is necessary to assess the impact it is having on students' confidence in the way students solve mathematics problems. The purpose of this quasi-experimental, non-equivalent control-group comparison study is to examine the impact the Desmos graphing calculator has on the problem-solving confidence of middle school and high school students as compared to students who use a TI-83 Plus graphing calculator while controlling for students' math achievement scores. The students ($N = 146$) participating in this study were learning their respective mathematics material for an equivalent period of 12 weeks in order to determine whether students who used the Desmos calculator experienced a statistically significant difference in problem-solving confidence levels. Students in both groups took the assessment at the end of the 12-week period of learning and an Analysis of Covariance (ANCOVA) was used to test whether there was a significant difference in the scores of the Problem Solving Inventory (PSI). Results indicate that there was a statistically significant difference in problem-solving confidence scores between middle and high school students who used the Desmos graphing calculator as compared to students who used a TI-83 Plus graphing calculator, while controlling for student math achievement scores.

Keywords: graphing calculator, Desmos, TI-83 Plus, mathematics, Social Cognitive Theory, problem solving, confidence, Problem Solving Inventory

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Analysis of Covariance (ANCOVA)

English Language Learner (ELL)

Measures of Academic Progress (MAP)

Northwest Evaluation Association (NWEA)

Problem Solving Inventory (PSI)

CHAPTER ONE: INTRODUCTION

Background

Educational technology in mathematics has become dynamic and progressive. There has been a steady advance in the technology available for math teachers and students; namely, four function calculators, scientific calculators, computers, graphing calculators, and applications for mobile technology. As graphing calculators assimilate into the mathematics classroom, changes occur (Al Lily, 2013; Lee & McDougall, 2010). Currently, the TI-83 Plus, manufactured by Texas Instruments, has been the graphing calculator of choice for many high schools in the United States. It is familiar to teachers and integrated into many textbook activities, lesson plans, and teacher professional development. The graphing calculator is widely used on state tests and national examinations, such as the College Board's SAT and Advanced Placement Exams. The SAT and other standardized tests do not allow the newer online and downloadable calculator applications. This is due to the extra capabilities the devices have, such as a keyboard, cell phone service, and the fact that many are on laptops or hand held computers (The College Board, 2015).

The focus of this study is to examine the effects of the Desmos and TI-83 Plus calculators on students' problem-solving confidence, since the use of graphing calculators plays a role in student achievement. Laumakis and Herman's (2008) study of teacher training with graphing calculators showed an increase in student achievement. They concluded that student achievement increased with the implementation of graphing calculators by trained teachers. As students continue to interact with newer graphing calculators, researchers should investigate them further, as it may alter students' problem-solving confidence. This is in keeping with prior research patterns. For example, increases in technology literacy skills have led to reduced

anxiety for students and teachers (Sun & Pyzdrowski, 2009; Tatar, Zengin, & Kagizmanh, 2015). This is because students can feel anxiety over finding patterns and relationships and the additional help the graphing calculators provides can ease this anxiety. Since graphing calculators may ease anxiety, it is reasonable that researchers investigate them for their effect on problem-solving confidence.

Recent mathematical applications have kept up with current trends in mobile technology (Nadel, 2012; Wahl, 2015). Many types of calculators, including online graphing calculators and downloadable applications, are available free of charge or for a few dollars for those equipped with computers, tablets, phones, and other mobile devices. These online graphing calculators have interfaces that dramatically simplify the manipulation of data, equations, and graphs. As technology continues to make mathematics computations easier and more intuitive, further investigation should follow to measure its effect on the problem solving confidence of students as they engage in meaningful mathematics applications.

One model of an online graphing calculator is the Desmos calculator. It is downloadable without cost to mobile devices or used in its online application. Its developers have included built-in content such as a bank of equations, dual workspace that includes data and graph located on the same screen, and application anticipation features such as automatically displaying vital information about the graph (Desmos, 2015). By comparison, students need to access two separate screens to go from seeing the graph and table on the TI-83 Plus graphing calculator. There is a split screen option, but this makes both the graph and table smaller. On Desmos, students have access to the graph, table, and important points on the function in one screen. These factors make Desmos easier to manipulate and more intuitive in its approach to math, cutting down steps that interfere with the deep thinking required when solving math problems.

Intuitive features create a benefit to high school students because students can easily navigate difficult math concepts with programs found on the mobile technology (Freeman, 2012). Changing the screen dimensions of the graph involves multiple steps on the traditional graphing calculator, whereas on Desmos, zooming in and out requires pressing the plus/minus button on the screen or if it is a touch screen, squeezing one's fingers together or apart on the screen to zoom in or out. Finding the intersection of two lines, a difficult math concept, involves a series of learned steps on the older technology. On newer technology, it is a matter of clicking once on the intersection of the lines on the new calculator. Teaching the series of steps required to use the TI-83 could be a main objective in a 45-minute class period. With the new calculator, this now becomes a simple tool to allow the teacher to access more difficult problems within a matter of minutes of starting the lesson. Since the Desmos calculator is more intuitive and easier to use in certain aspects of math, this researcher believes that students who use this calculator may experience less stress when solving math problems. By easing students' anxiety, this researcher believes that the type of calculator may affect the problem-solving confidence of students. Hillman (2012) noted that one of the problems with technology is the inherent complexity within the device that hinders students from using it successfully.

Although implementation of online graphing calculators is becoming more accessible to teachers due to the increases in technology, not all schools have a mobile device for each student. This limits the exposure students nationwide have to the Desmos graphing calculator. Another consideration is that state assessments or college entrance exams do not currently allow test takers to use online graphing calculators for tests. This creates a barrier for students, teachers, and schools that consider using the more advanced graphing technologies. Additional research on the impact of this technology may help educators make informed decisions.

Problem Statement

Given the propensity towards the development of new technologies that aid academic achievement, the Office of Educational Technology recommended additional research to assist teachers so that they can adjust their teaching and educational technology practices (Office of Educational Technology, 2014). There is still a need for further research to determine if various types of graphing calculators lead to differing levels of problem-solving proficiency (Kenney, 2014). As such, middle school and high school teachers face the challenge of understanding the impact the type of calculator has on their students' perceptions of mathematical skills and problem-solving abilities. This information would aid them in making informed decisions concerning graphing calculator usage in their middle school or high school classroom.

Studies have not yet linked various graphing technologies to the effects on problem-solving confidence. There is a need to determine whether the Desmos graphing calculator has an impact on student problem-solving confidence because problem solving is a fundamental attribute in math related fields (Ozyurt, 2014). Understanding this gap in the research, Kaya, Izgiol, and Kesan (2014) have called for the advancement of problem-solving abilities of students with regard to the use of graphing calculators. Hillman (2012) made a similar proclamation, stating that problem-solving abilities are not as advanced as they could be. Hillman noted that one of the problems with technology is the inherent complexity within the device that hinders students from using it successfully. For these reasons, it is worth the effort to study the effects of graphing calculators on the problem-solving confidence of students.

The problem is there is a lack of research to determine if various types of graphing calculators lead to differing levels of problem-solving proficiency (Kenney, 2014). Problem solving improvement continues to be a foundational goal for mathematics teachers in secondary

education and newer calculators may influence student problem-solving confidence. Despite the call for education to keep up with the advances in technology due to its engaging qualities (Periathiruvadi & Rinn, 2012), the research is limited when it concerns the impact the type of device has on student problem-solving confidence. The void in the literature suggests that further research needs to occur for the verification and reflection of problem-solving skills of a wide range of students due to the cross-section of students who do not excel at problem solving (Allison, 2000).

Purpose Statement

The purpose of this nonequivalent control-group study is to examine the impact the Desmos graphing calculator has on the problem-solving confidence of high school and middle school students as compared to the impact the TI-83 Plus graphing calculator has on students. The independent variable was the type of calculator used and the dependent variable was problem-solving confidence as measured by the Problem Solving Inventory (PSI) (Heppner & Peterson, 1982). This study included a sample (*N*=146) of middle school and high school students. This sample was from one of the approximate 500 Pennsylvania school districts.

The dependent variable, confidence in problem-solving ability, is one's sense of assurance to be able to solve tasks. This confidence can be measured by the PSI created by Heppner and Peterson (1982). Confidence is rooted in self-efficacy, which Myers (2014) defined as one's impression of proficiency on a task or set of tasks. As such, Schwarzer and Jerusalem (1995) asserted that it facilitates goal setting, effort investment, and perseverance in the face of obstacles and drawbacks. This study recognizes problem solving as the interactions of cognitive, affective, and behavior processes with the aim of reconciling internal and external tasks (Heppner & Krauskopf, 1987).

Significance of the Study

Effective use of graphing technology creates a practical way for teachers to provide their students with a framework that enables them to enhance their mathematical understanding (Lee & McDougall, 2010). Allison (2000) demonstrated that the graphing calculator can aid problem solving and that students can use a graphical approach to mathematical problem solving. The body of research associated with graphing calculators has demonstrated that these digital technologies are amplifiers that augment student learning (Barrera-Mora & Reyes-Rodriquez, 2013). In a meta-analysis of the use of graphing calculators, Nikolaou (2001) found that graphing calculators had a modest positive effect on achievement and problem solving, regardless of socio-economic level, location, and ability level.

The significance of this study is to focus on the calculator in order to see if one of the devices can cause an increased confidence in a student's ability to solve problems when provided one of two different graphing calculators. Problem solving uses four recognized steps that the problem solver uses to arrive at an answer effectively. Namely, (a) understanding the situation within the problem, (b) utilizing a plan that incorporates a problem-solving strategy, (c) executing the plan, and (d) checking the results (Musser, Burger, & Peterson, 2001). Educators and students use the calculator as an aid to assist them in attaining an answer. The significance is that there may be a measureable difference in confidence levels caused by the graphing calculators. Calculators, as educational tools, differ in the presentation of their data, difficulty level in inserting the appropriate information, and cost. As such, the experience of using one calculator versus another changes the experience the problem solver has when solving mathematical problems. One can state this because research in problem solving using calculators

has previously established a correlation between mathematical knowledge and proficiency in graphing calculator usage (Ocak, 2006).

Accordingly, teachers and other school personnel would be interested in knowing the impact different graphing calculators have on problem-solving confidence. Thomas and Hong (2013) support the introduction of graphing calculators because they sought to understand the implementation dynamics of graphing calculators among teachers. They noted that teacher perceptions of technology play a role in their graphing calculator implementation. As such, this study aims to contribute significantly to the body of literature on graphing calculators available to teachers by investigating the impact newer graphing technology has on perceptions of problem solving.

Research Question

RQ1: As measured by the Problem Solving Inventory (PSI) is there a significant difference in middle and high school students' problem-solving confidence when provided the use of the Desmos calculator as compared to students who use the TI-83 Plus calculator while controlling for student achievement math scores?

Null Hypothoses

$H_0 1$: As measured by the Problem Solving Inventory (PSI) there is not a significant difference in middle and high school students' problem-solving confidence when provided the use of the Desmos calculator as compared to students who use the TI-83 Plus calculator while controlling for student achievement math scores.

Definitions

1. *Desmos Calculator*: This downloadable online graphing calculator can readily graph various forms of equations, show their tables, and provide the user with information

regarding functions. A trait of the calculator is that the function form does not matter when graphing. Changing the screen dimensions on Desmos, or zooming in and out, involves pressing the plus/minus button on the screen, or if it is a touch screen, squeezing one's fingers together or apart on the screen. Difficult concepts, such as finding the intersection of two lines, involves clicking once on the intersection of the lines on the new calculator.

2. *Problem Solving*: Problem solving is a process that synthesizes internal and external resources and applies them to problems or challenges at hand. Problem solving is a dynamic interaction among cognitive, affective, and behavior processes with the aim of making changes due to internal and external challenges (Heppner & Krauskopf, 1987). Stages involved in problem solving include general orientation, definition of the problem, production of alternatives, decision-making and selection of strategies, and evaluation of outcomes and procedures (Heppner & Peterson, 1981). Similarly, Kaya, Izgiol, and Kesan (2014) declared that there are a fair number of concepts about problem-solving skills that include defining of the problem, generating possible solutions, persevering to find solutions, obtaining conclusions, and providing a decision.

3. *Problem-Solving Confidence:* Heppner and Baker (1997) defined problem-solving confidence as a student's self-assurance while actively dealing with a range of problem-solving activities and as a confidence in one's ability to problem solve.

4. *Social Cognitive Theory*: The social cognitive theory provides a framework concerning social and cognitive factors within an environment. According to Bandura (1997), these factors are in a state of perpetual reciprocal interactions, which provide humans the ability to determine their course of action, especially when solving a problem.

CHAPTER TWO: LITERATURE REVIEW

Introduction

The purpose of this chapter is to explore the technological and educational impact graphing calculators have on education and provide a framework to explore further the ramification of their use. The convenient nature of graphing calculators continues to evolve as an ongoing social innovation in its usability and ability to solve mathematical problems. In turn, this opens up new doors to explore as it relates to a student's ability to solve problems. The principles of social cognitive theory provide a platform to understand the applications of both usability and problem solving as it influences student learning.

Technology and Math

The impact of the graphing calculator is far reaching and its integration has shown that this technology allows students to reach better conclusions and improve performance on procedures (Abu-Naja, 2008; Ozel, Yetkiner, & Capraro, 2008). The key is the purposeful implementation of the technology into the classroom. Holubz (2008) added to the literature and claimed that student achievement via calculators stems from engaged student participation, vibrant interactive class discussions, and increased focus on instruction. Since achievement is increasing, students benefit from calculator usage during instruction.

The skill of the mathematics teacher matters when it concerns graphing calculators. Meagher, Ozgun-Koca, and Edwards (2011) claimed that teacher preparedness is an important aspect to integration of the graphing calculator in the classroom. There are many methods to ensure mastery of the graphing calculator. Depending on their available resources, teachers can find information within instructional books or textbooks, or ask college professors and each other to find out how to integrate the graphing calculator into the classroom. Teachers can also find a

host of online instructional materials, such as YouTube videos, that demonstrate to both teachers and students how to use the graphing calculator.

Preservice teachers are particularly influenced by the modeling of technology, as Meagher, Ozgun-Koca, and Edwards (2011) concluded in their study that the use of advanced digital technologies during field placements made a decisive impact on preservice teachers' attitudes regarding the use of the technology that would become their own teaching practice. This is especially true when the lesson's activity with technology includes open-ended questions and an inquiry-based approach. In these types of problems, modeling is especially effective when the material learned and taught is similar in cognitive difficulty, such as rate of change investigation problems that are in line with intercept and slope for Algebra 1, and non-linear patterns for the second year of algebra (Sinn, 2007). Students are empowered to believe that they can accomplish a task when teachers model how to use technology such as the graphing calculator.

Broad gains in student achievement have been associated with graphing technologies. When teachers received instructions in how to use the graphing calculator, there was a significant increase in the scores of their students (Laumakis & Herman, 2008). Laumakis and Herman's study (2008) examined statewide assessment scores for 328 students and found no significant gains for students taught by non-trained teachers, and furthermore concluded that teacher training was a critical factor in efficiently presenting and utilizing these technologies within the classroom. Three years later, Meagher, Ozgun-Koca, and Edwards (2011) concluded that teacher training was a key factor in implementing technology.

Mastery of the graphing calculator is not the only factor to consider for teacher preparedness. Teachers must also consider efficiency. For example, Table 1lists the number

steps required to solve a linear system of equations using Desmos and the TI–83 Plus graphing

calculators.

Table 1

Solving Linear Systems using the TI-83 Plus and Desmos Graphing Calculators

Number of Steps	Desmos	TI – 83 Plus
1	Go to desmos.com	Turn on calculator
2	Press *Start Graphing*	Press *y=*
3	Insert equation in line 1	Insert linear equation in Y_1
4	Insert equation in line 2	Insert linear equation in Y_2
5	Adjust the window	Press *GRAPH*
6	Press on the intersect	Adjust window as necessary
8		Press 2nd and *TRACE*
9		Select *intersect*
10		Press *ENTER* to choose the graph of the first equation
11		Press *ENTER* to choose the graph of the second equation
12		Press *ENTER* to take a guess of the intersect

According to Freeman (2012), solving equations efficiently with mobile technology is

upon us. One only needs to study the varying complexity found in the differences between the

TI-83 Plus and Desmos graphing calculators. Using the TI-83 Plus, there are approximately 12

steps required to find the intersection of two lines (solution to a linear system). Using Desmos,

there are half as many steps. Graphing calculators are currently undergoing major upgrades and

are available via mobile technology. Teachers and students must not overlook the importance of upgrades.

Effective use of graphing technology creates a practical way for teachers to provide their students with a setting that enables them to enhance their mathematical understanding (Lee & McDougall, 2010). Two factors that influence this finding include the level of proficiency with the calculator and the level of integration into the curriculum. This is especially important for at-risk students, since students who traditionally lag behind in achievement can make gains from incorporating graphing technology. Freeman (2012) found that English Language Learner (ELL) students, with frequent educational needs, benefitted from digital interventions in a coherent and purposeful student centered design. Hence, the results of Freeman's study demonstrated that purposeful digital interventions can improve students' math abilities and their perceived math self-efficacy.

A benefit of the newer graphing calculator Desmos is that it is a free calculator and can be readily found and downloaded to mobile devices. This technology aids students by reducing or eliminating complex graphing calculations that are prone to errors when computed by hand. With the reduction of steps involved in solving math problems, teachers can dramatically reduce the amount of verbal and written instruction to students. The new applications on mobile devices can be a significant upgrade for students when compared to popular graphing calculators such as the TI-83 Plus.

Graphing Calculators as a Societal Innovation

Graphing calculators have reduced educational boundaries much the same way other technologies, such as online learning, e-books, and social networks have reduced traditional spatial boundaries (Al Lily, 2013). As such, graphing calculators constitute a social innovation

that has affected the mathematics classroom across the United States. Bandura's (1998) (1998) social cognitive theory provides a framework that describes the impact on society by innovations and new ideas.

Bandura (1998) rationalized that the pattern of social diffusion begins with early adopters conveying information about the real and perceived benefits of a practice. If the practice gains momentum and is widespread, it does so at an accelerated rate. Eventually, the practice saturates a society and the acceleration levels off and begins its decline due to the lesser numbers that have not adopted the practice. In addition, it is also true that innovative practices face competition and are subject to alternate forms that take some of the participants away. Applying this principle to graphing calculators, the Texas Instrument family of graphing calculators has been the most widely distributed graphing calculator and is now seeing competition from online graphing calculators such as Desmos.

There is a difference between knowing about an innovation and applying that innovation into practice. Incentive factors influence the adoption of an innovation (Bandura, 1998). In mathematics, incentives exist when calculator users navigate difficult math concepts with ease with programs found on mobile technology (Freeman, 2012). To facilitate this, orientation to a graphing calculator can be entertaining for students. For instance, teachers can use scavenger hunts to get students to find and think about ideal locations in which calculator functions exist (Huizdos & Gosse, 2003). For example, on the TI-83 Plus, the yellow button opens access to all the functions in that particular color, providing an alternate function to every button. A scavenger hunt allows students to explore the calculator in a cognitively safe way and allows students the opportunity to learn how to exit out of functions they have entered.

Innovations need to satisfy a person's self-evaluation concerning their values, beliefs, and standards in order to lead to adaptive behaviors (Bandura, 1998). Teachers who value the innovations that a graphing calculator brings to mathematical learning will readily use the devices they value (Reeves, 2003). Conversely, teachers who believe that the use of graphing calculators hinders student academic growth will resist using the devices.

Moreover, adoption of innovations will often require financial resources, and this could hinder the disposition of people to obtain the innovations (Bandura, 1998). When it concerns affordability, Desmos has an advantage in that it is free to download, provided a school district has access to a platform that can run it, such as a computer, laptop, tablet, phone, or other similar device that connects to the Internet. Some schools can afford to provide these devices to every student, while others do not have these options.

New innovations face several obstacles such as additional time and effort, overcoming or facing insecurities, and learning new skills in order for people to release old habits to conform to new ones (Bandura, 1998). If a teacher works with a particular calculator and invests a large amount of energy into synchronizing their lessons with it, the teacher may have preferences regarding the implementation of the technology (Fleener, 1995). For instance, the teacher may know how to use a graphing calculator to find the vertex of a quadratic equation. The teacher may also know where in the curriculum this skill is useful. The teacher, however, may still question when the best time is to introduce the matching graphing calculator activity into the lesson, (i.e., before students can compute the vertex by hand, or after this skill is developed).

Furthermore, innovations have the potential to clash with the existing frameworks and practices already in place. For example, state testing requirements may only permit certain types of calculators in an exam room. Suppose a new calculator emerges that does not meet those

requirements; it could face resistance from teachers who deem such a calculator not worthy of the risk of using it, given the high stakes nature of state testing. Teachers would be slow to adapt this innovation due to the hindrances of the bureaucracy imposed on the system. Groups not encompassed by state testing mandates, such as private schools and home schooled students, would not face this aversion and therefore not be subject to the institutionalized barriers it creates.

In order to produce a socio-cultural change within a system, a diffusion program should select a favorable setting, meet the preconditions for change, effectively implement the program, and spread the innovation(s) elsewhere (Bandura, 1998). Calculators have long been a fixture in many schools (Dion, Jackson, Klag, Liu, & Wright, 2001); therefore, schools would be a reasonable place for innovative calculators to make their appearance. In order to continue to expand and upgrade the use of calculators, developers would have to convince teachers that the new calculators are useful in promoting critical thinking and innovative ways to solve problems, and are readily accessible. The main enhancement to Bandura's diffusion steps is that due to the Internet, schools that have access could implement new online-based calculators without having to wait for results from other schools. This allows a quicker saturation of a new technology and eliminates some of the early adopter role to convey information because explorers are now actively searching for helpful applications. Schools that have technology integration personnel serve as an example to demonstrate that new technologies are being developed at a quick enough rate that schools have designated personnel to investigate and implement them.

Individuals gain affective learning through direct experiences, which leads to likes and dislikes by individuals within a group (Bandura, 1998). Relating to mathematics, students have preferences on the calculators they use due to the aesthetics of the device, screen preference, and

complexity (Hanson, Brown, Levine, & Garcia, 2001). Although dated to the technology at the turn of the century, Hanson et al.'s (2001) study showed that students perceived that their personal calculators were more sophisticated than the one provided for standardized testing. This is a reason why studying the effects of newer calculators is important. When students have access to the newest technology, this may affect their preferences and thereby their confidence. The graphing calculators show favorable impact on student perceptions and their ability to find solutions (Allison, 2000). This is because they provide ready access to a level of mathematical speed and accuracy within scalable graphs and tables of values not possible by hand and pencil. Taking away this arduous aspect of mathematics allows the individual student to focus on reasoning and results.

The Usability of Graphing Calculators

Competition among devices spurs individuals and systems to examine the usability of the devices to determine which product best serves the needs of the users. When comparing graphing calculators, their usability is not a tangible attribute, but rather a measurable examination of the quality of suitability for the created purpose (Jordan, Thomas, Weerdmeester, & McClelland, 1996). Product usability is effective and successful when the product performs its technical function and its user(s) can get the product to work as intended (Kortum & Bangor, 2013). The concept of usability for graphing calculators is framed within the curriculum the school uses (parameters of the intended users); the ease by which functions and graphs can be accessed (task the artifact aims to perform); and the classroom (environment) in which it is used. It seeks to measure the effectiveness, efficiency, and satisfaction of the graphing calculator while using a measuring tool that is cost effective, quick, and able to compare accurately.

As such, the measurement of the graphing calculator's usability is beneficial to educators and administers (practitioners) because it provides an equitable method to compare the graphing calculators (specified product) (Bangor, Kortum, & Miller, 2008; Kortum & Bangor, 2013; Sauro, 2011). While both are proficient at graphing applications, the Desmos and TI-83+ calculators differ in their interfaces and by default, so do the procedures and length of steps required to assist students in their problem solving skills.

Theoretical Framework

The foundation and springboard to investigating graphing calculators' impact on problem solving can be found in Bandura's (1986) social cognitive theory due to the dynamic nature of student learning in a school setting.

Problem Solving and Social Cognitive Theory

Social cognitive theory provides a wide-ranging framework concerning social and cognitive factors within an environment. These cognitive and social factors are in a state of perpetual reciprocal interaction, which provide humans with the ability to determine their course of action, especially when solving a problem (Bandura, 1997). In addition, social cognitive theory is suited for the study of students in their school environment as it encompasses diverse cultural environments that differ in their values, traditions, and social practices (Bandura, 2002).

In mathematics, problem solving can involve highly structured routines, such as applying a formula or following the steps to solve an equation. Van Merriënboer (2013) referred to this process as the strong methods definition of problem solving and builds upon this definition to arrive at practical problem solving in real-life situations. Real-life problem solving involves a mix of non-structured and well-structured processes that require the student to integrate reasoning and decision making skills with strong methods to arrive at conclusions.

At the cognitive level, algebra students are learning a new language with its own set of rules and nuances that provide a way to apply relevant mathematical thoughts and insights to realistic problems (Abram, 1969). Whether on paper or on the graphing calculators, this ability for students to use symbols to represent real-life phenomena is explained within social cognitive theory as the capability humans have to symbolize aspects of their environment that allow problems to be solved symbolically before being applied in real life (Bandura, 1986). The use of graphing calculators in algebra provides another way or avenue for students to put symbols and equations into practical applications without eliminating their ability to interpret and formulate (Pierce, 2005).

Frameworks for dealing with symbols in calculator-assisted math classes exist. Relevant to this study are various student abilities, mainly: (a) linking verbal and symbolic representations together; (b) recognizing conventions and their properties; (c) making connections to symbols and their graphs; (d) linking symbols with their numeric representational (e.g., equations and tables); and (e) recognizing their meaning within the problem (Kenney, 2014; Pierce, 2005).

Verbal and symbolic representations in the form of equations allow students to model real-life situations as mathematical models and analyze interpretations (i.e., projections, estimations, and patterns). Calculators assist in these tasks by manipulating equations and making graphs and tables of data that can be both quickly generated and manipulated. Doing difficult problems by hand requires time, and long tedious problems take time away from other important curricula. Graphing calculators make these laborious problems more manageable and thus allow teachers to focus on parts of the curriculum that were previously inaccessible due to time limits (Pierce, 2005). An underlying assumption to Pierce's conclusion is that teachers are

not spending a large amount of time learning to operate the calculator, thus negating the time allowed for other important curricula.

Observational Learning and Problem Solving with Graphing Calculators

Social cognitive theory describes the ability individuals possess to learn by observation, which is relevant due to the visual aspect of graphing calculators. Bandura (1998) evoked the concept that learning can occur by observing behaviors and actions without experiencing them first hand. Research has shown that students in upper elementary math classrooms can observe how teachers and peers solve problems and benefit from the modeling that occurs (Ramdass, 2011; Ramdass & Zimmerman, 2011). Concerning secondary students, the use of teacher modeling with the employment of mistakes and error analysis leads to a favorable form of observation, as opposed to using mastery teaching without errors. Teachers use interactive white boards, such as the Smart boards used in Nejem and Muhanna's (2014) study, as a modeling tool that have a positive effect on middle school students' achievement and math retention. Teachers can use interactive white boards along with other projection tools to model the use of calculating devices to students. Generally, a teacher would need computer access with graphing software or Internet access to attach to the interactive white board. One benefit of using large displays is that students observe the sequences used to manipulate graphing calculators and can apply that information as they perform their tasks.

Observational research is important because it uses the vicarious capability of humans to acquire rules and patterns of behaviors without the tedious route of trial and error (Bandura, 1998). This is useful because students can learn graphing calculator procedures through observation. This is important because a classroom full of students with iPads connected to the Internet has an abundance of options if they were to download calculator apps from the Apple

store. These options may not need involve teacher modeling, as students may be using them without permission. Photomath is one example, because students can take a photo of the math problem and the answer comes up on the student's screen.

In the case of mathematics education, the teacher's personal values, attitudes, and behaviors can have an impact on his or her students. The power of observation extends past knowledge; it affects values, attitudes, and behaviors (Bandura, 1998). The level of attention and interest an individual demonstrates affects the depth of observation. Ardies, Maeyer, Gijbels, and Keulen (2015) found teachers who sustained interest in high school aged males (12-14 years) fostered a more positive view about a future career in technology. This suggests that the better a teacher can arouse student interest in the subject matter, including the use of graphing calculators, the better the level of attention and interest a student will display.

Observations, by their nature, need modeled events in order to take behavior from observation to matching patterns. According to Bandura (1998), modeled events are first observed or given attention, then retained; afterward, it goes through a production process, and finally through a motivational process, which can culminate in a matching pattern. As it relates to problem solving, it benefits students to observe problem solving events before teachers ask the student to duplicate the skill. Van Merriënboer (2013) argued that providing support to students is highly valuable in helping them expand their problem solving skills. Support in the use of calculator use can include help with skills such as graphing, reading tables, and solving equations.

Teachers can aid students in making the most of their observation skills. The goal is to make the students realize that they too can be good problem solvers and mathematicians. In an article describing a method on how to prepare students for problem solving, Hodges, Johnson

and Fandrich (2014) shared a strategy in which students reflected on other students' problem solving abilities and then internalized this information and applied it to themselves. In this strategy, the teacher focuses their students' attention on how others solve problems, how to address the issue of adversity, and where they go to find help. Afterwards, the teacher focuses the attention back to the student. The subsequent questions would ask the student where they could get help, what would you do if you got an incorrect answer, and how would you help someone who is struggling. By focusing on other student's good math solving qualities, the teacher is using that as a modeled event that may lead to a matching pattern.

Along with the power of observation, the ability to self-reflect is a human function that enables individuals to analyze past behaviors and muse over their thoughts (Bandura, 1998). This is important in problem solving because the multiplicity of answers students are capable of producing require a knowledgeable teacher who can identify, interpret, evaluate, and remediate answers when conducting error analysis work (Peng & Luo, 2009). Teachers can empower mathematics students by helping them identify the existence of their errors, assisting them to understand and interpret their work, encouraging self-evaluation of performance, and presenting teaching strategies to eliminate errors. Each of these problem-solving actions can help students resolve mathematical setbacks better.

In mathematics, correcting errors using self-reflection is a common occurrence that requires individuals to take into account past learning to reflect on whether a current answer is plausible or not. As students reflect on their ability and confidence to use the graphing calculator, they come to conclusions concerning their problem-solving abilities. Graham, Headlam, Honey, Sharp, and Smith (2003) concluded that familiarity with a graphing calculator was a deciding factor in its usage. Additionally, students need to decide whether the time spent

on a calculator is worth the effort to solve the problem. This is a critical area for further research

because different calculators have differing amounts of steps they use when solving a problem.

Attention is tuning into pertinent aspects of a modeled activity (Bandura, 1998). Factors

such as attraction, chunking information, and cognitive skills affect the level of attention. In

mathematics, the observed information sometimes comes too quickly for assimilation and

students need multiple examples to learn the presented material. This repeating strategy avoids

fragmentary observations and ensures the modeling is best suited for the cognitive capabilities of

the observer or student (Bullock, 1983). As applied to graphing calculators and problem solving,

teachers would do well to provide multiple layered examples.

In order for modeled activities to translate into matching behavior, retention is necessary

– since, as Bandura (1998) aptly noted, it would be impossible to perform a forgotten task. This

property of observation is effective when symbolic representation of an event occurs, facilitating

the remembrance of information in a format easily restored. The power of imagery, the symbolic

representation, should precede verbal representation when presenting to students new

unsolidified concepts. The purpose is to build a memory bank of information that aids the

student in future problem solving endeavors. Symbolic representations are relevant to

mathematics, specifically image representation. Image representation happens when a student

observes a process occurring and then visualizes the sequences of steps necessary to reproduce

the action. For example, the teacher displays a graphing calculator screen on the board and then

proceeds to explain how to graph a linear problem ($y = mx + b$). The student, relying on the

image representation, recreates the problem with another example provided by the teacher.

Similarly, verbal representations of observational learning are effective because the

processes that control behavior are predominantly conceptual (Bandura, 1998). The fact that

learning mathematics is similar to learning a new language makes verbal representation a vital part of teaching mathematics. Eighty years ago, students faced the same problem current students do, in that there are words whose meanings in English and in mathematics are very different (Moulton, 1946). Base, vertical, and degree are a few examples of mathematics vocabulary terms that have dual definitions with regular English definitions. A complete and thorough understanding of vocabulary words is an essential aspect in learning mathematics (Oldfield, 1996). One helpful piece to effective representation is that mathematical language should come as second nature to teachers. They should use correct terminology in fluid conversation and encourage students to do likewise. The downfall is that verbal representations can be more easily forgotten, thereby requiring rehearsal to store the information.

As representations or modeled events go from observation to practice, the production process becomes necessary because it provides the learner with a chance to see if the observed learning produces a faultless performance (Bandura, 1998). When mathematics teachers check for understanding in problem solving, they are checking to see if the observed learning produced work that is free from error. As teachers find errors, the next round of observational learning concentrates its efforts in those places to eliminate the error.

Motivational Factors Influencing Problem Solving

Motivational factors are relevant because students make judgments about whether they will even attempt to problem solve specific mathematics content. As such, researchers need to consider internal or external motivational influences that encourage behavior, which include problem-solving behavior.

Inherent within any environment are incentives and disincentives. Incentives play a role in education, and though extrinsic rewards lose their appeal over time, nevertheless, a variety of

incentives are helpful to keep students interested in a classroom (Haywood, Kuespert, Madecky, & Nor, 2008). The lack of incentives and presence of disincentives can have a detrimental effect on efficacy and play a role in education. When students perceive academic challenges as a threat instead of an opportunity to learn, this can serve as an overall disincentive that affects an individual's efficacy within the classroom (Schweinle, Turner, & Meyer, 2006). This previous study shows that many students have the knowledge, skills, and tools they need to be successful, yet lack the motivation to act upon their ability.

Shukla, Tombari, Toland, and Danner (2015) conducted a study of over 1,500 ninth-grade students of diverse backgrounds and found that students' perceptions of at-home support by the parent(s) was strongly associated with the student's personal mastery. In other words, within the relationship between parent and student, internal motivation for success within a mathematics classroom exists. Furthermore, parents are capable of building an academic schema developed outside the school walls that promotes academic ambitions. Garg, Melanson, and Levin's (2007) study on the effects of parenting on the educational aspirations of adolescents built a case that parental background, participation, and behavior provides an environment in which adolescents can develop an academic self-schema that influences educational aspirations. This is important because students do not come to school void of internal motivations and this impacts classroom engagement in problem solving activities.

Interestingly, concerning the dual impact on math and technology, parents surveyed in Kansas and Missouri were quick to say that the United States lags behind other countries in math, but they were complacent in their perceptions, saying that math and technology are fine as they are (Kadlec & Friedman, 2007). These parental perceptions are important because of the changing reality of graphing technologies and its impact on education. Additionally, at the

parental level, Ing (2014) collected data from a nationally represented longitudinal survey and noted that simply informing parents on their child's progress is not enough to raise persistence and achievement levels. However, having students teach their parents the mathematics they are using in a project strikes closer to the goal of creating a situation that leads to greater involvement in science, technology, engineering, and mathematics careers.

Two additional sources of internal motivation are the pleasure of getting praise from others and the satisfaction provided by the need to engage in activities that promote self-esteem (Bandura, 1998). For example, praise can come from both teachers and parents as a response to attainment of a high grade on a test. System wide, a school can promote activities concerning self-esteem by incorporating interventions that target perceptions of justice, because within the school environment justice is of particular importance to students' global self-esteem (Morin, Marsh, Maiano, Nagengast, & Janosz, 2013). In adolescents, the perception of justice increases global self-esteem. Since classrooms make up the majority of the school's environment, it is important for mathematics teachers to establish classrooms that are equitable and fair to enhance the student's problem solving beliefs.

Both self-efficacy and self-esteem are important to academic success (Kandemir, 2014). In a study of seventh-grade students' self-efficacy concerning mathematics, Chiu et al. (2008) found that students compared themselves most frequently to other students that performed similarly to themselves. The external act of comparison to others, whether perceived to be greater or lower than them, had an effect on their self-esteem; consequently, those in a high academic track exhibited higher self-concepts than those in lower tracks. The multiplicity of sources that influence self-esteem present problems in identifying confounding variables that

contribute to the problem of measuring self-esteem, making the independent nature of self-efficacy a desired measurement for perceived mathematics abilities.

Intrinsic and extrinsic motivation affect incentives to behaviors. Intrinsic motivation is a desire to carry out a behavior for its own sake and extrinsic motivation is a desire to carry out a behavior in order to receive a set reward or avoid a threatened punishment (Myers, 2014). Intrinsic motivational studies concerning math have shown that students with lower levels of motivation also experienced lower achievement levels and less math course accomplishments (Gottfried, Marcoulides, Gottfried, & Oliver, 2013). Threats to intrinsic motivation cause students to shut down and Thompson (2014) asserted that teachers who create anticipation and curiosity cause students to be in a receptive mode of learning.

Extrinsic motivators such as a paycheck, approval, privileges and penalties are socially arranged phenomena that encourage certain behaviors in individuals. Parents are an important source of motivation and Fan, Williams, and Wolters (2012) discussed a negative correlation across ethnic groups, stating that frequent school/parent communication resulted in less confidence in school engagement and academic problems. The probable explanation for this, according to Fan et al. (2012), is that the parents were most likely providing discouraging and punitive feedback for the students. Bissell-Havran and Loken (2007) found that among adolescents, the tendency was to view intrinsic motivation as lower among peers. Students under-perceived their friends' actual value on academics.

The consequence of failing to establish a perception of justice in the school environment leads to lower levels of self-esteem. This has consequences that affect the outcomes of teaching because students who are not socially confident are more likely to avoid seeking help (Ryan & Pintrich, 1997). Therefore, internal motivation is important to consider. As a motivational

factor, students' ability to seek assistance during their struggles with problem solving influences learning within a classroom.

External influences that motivate behavior can take the form of rewards and tangible benefits, praise, and other positive or negative reinforcers (Iben, 1991; Kitsantas, 2002). Students who are slow in math computations may view the calculator as an external motivator to help them in their problem solving. In the mathematics classroom, external rewards can take the form of grades, report cards, praise from the teacher, status within the classroom, threats of punishment, and positive or negative phone calls home, among others. Concerning external rewards, Reeves and Taylor-Cox (2003) discussed a reward system that promoted good work habits among middle school students. The system worked when students did extra problems to earn stars for rewards.

External rewards are present in educational games that use badges to track progress, which are viewable to both the teacher and other students (Abramovich, Schunn, & Higashi, 2013). Steel and MacDonnell (2012) explained that the manner in which people receive rewards matters just as much as the reward itself, noting that effective rewards are transparent (without guile), clearly communicated, and easy to follow. One benefit is that extrinsic motivators have the capability to introduce intrinsic motivation, which causes the behavior to persist even after the removal of rewards. Teachers can use available online mathematics curricula, such as the Compass, Khan Academy, and Classzone.com curriculum, that has rewards systems built into the program and allows students to use their graphing technology to solve problems. In addition, Gasser (2011) encouraged teachers to use fun and interesting applications as a brain based approach to teaching because it spurs motivation.

Enactive Learning and the Graphing Calculator

Enactive learning is learning through the experiences or performances themselves (Bandura, 1986). Factors that govern how actions translate into learning include obtaining information from the actions that further guide individuals into achieving their purposes. For example, Hillman (2012) recorded the process of enactive learning using the graphing calculator as he observed a teacher providing time for students to complete an activity with the graphing calculator. Once the activity was completed, the teacher inquired of the students their solutions and the steps they took to arrive at their conclusion. The ensuing conversation allowed students to make connections between graphical (via the graphing calculator) and mathematical symbols (their equations).

A benefit to this approach to student learning and problem solving is that they can examine what went wrong and know what to fix in subsequent attempts. Likewise, a benefit to teachers in allowing the use of this enactive learning experience is that students can use the graphing calculators as a means to do arduous calculations, and they can verify their conjectures (Hillman, 2012).

Enactive learning with graphing calculators can be refined with immediate feedback that allows behavior patterns to adapt quickly (Bandura, 1998). Graphing calculators lend themselves readily to the refinement process of enactive learning since the feedback is immediate, predicative, and clear. The use of graphing calculators provides both predictable and clear observations in mathematics and allows students to draw conclusions. In McCulloch's (2008) research, the graphing calculator aided student decision-making schemas in solving a calculus problem. Of particular interest was the way the refinement process was marked by changes in displayed emotions. When students interpret the graphing calculators, they can

experience a set of emotions (confusion, comfort, guilt, relief, and happiness) that is a visual display of where they are in the problem. The sequence of functions performed on a graphing calculator may need to be refined through trial and error so that students achieve their desired outcome via the clear observation of the data.

Examination, testing, and implementation of new concepts show enactive learning in problem-solving (Cozza & Oreshkina, 2013). Interestingly, students across the globe used these three cognitive skills to problem solve in math and used the results to see if they needed to start the process over again as they refined their work. This shows that enactive learning can occur via steps that students go through in their problem solving experience.

Problem Solving

Students' perceptions of their problem-solving abilities are of great interest to educators, given the fact that social cognitive theory discusses how one's schemas and expectations can interact with one's environment to influence behavior (Myers, 2014). Heppner and Krauskopf (1987) described problem solving as the intricate weaving of cognitive, affective, and behavior processes with the aim of adapting to internal and external challenges. The National Council of Teachers (2015) views problem solving as mathematical tasks that potentially provide intellectual challenges aimed to enhance student understanding and development.

Heppner and Baker (1997) further defined problem solving as self-assurance while engaged in a diverse range of problem-solving tasks. Liu (2011) likened problem solving not as a science, but rather an art; requiring practice and sustained effort for progress. This is very similar to self-efficacy. Self-efficacy is a personal reflection of the ability or capability a person holds to concerning the control of a specific task by use of sustained effort and resourceful use of their skills (Bandura, 1993, 1997). The mathematics classroom challenges students with daily

problem-solving demands that require constant monitoring. A fundamental element to the human experience is the desire to control the events that surround an individual or group.

Controlling the events surrounding the problematic nature of mathematics is not always easy, as the nature of mathematics involves a person searching for and finding patterns and relationships within concepts, which produces a natural state of uncertainty within the mind (Lovin et al., 2012). Cognitively speaking, uncertainty is a disagreeable state of mind that produces anxiety and numerous other negative feelings, including apprehension and apathy, among others (Bandura, 1997). To counter such uncertainty, technology literacy skills have increased and found their way into the mathematics classroom, reducing the anxiety students and teachers experience (Sun & Pyzdrowski, 2009; Tatar, Zengin, & Kagizmanh, 2015). Technology can ease the anxiety that students feel when searching for patterns and relationships within mathematical concepts.

There exists a strong correlation between problem-solving confidence and efficacy. In a study of preservice teachers, Memnun, Akkaya, and Haciomeroglu (2012) found that a significant relationship existed between mathematical problem solving and self-efficacy. In other words, teachers' beliefs concerning their grasp of mathematical reasoning skills required for problem solving affected their self-efficacy concepts.

The connection between problem-solving benefits and efficacy is relevant in that, according to Bandura (1997), efficacy is an effective tool for predicting the outcomes of behaviors of repetitive nature. This is central to the mathematics and graphing calculator experience because every student has both efficacy beliefs and mathematics performances; each of which can be positive or negative. Although efficacy was not the focus of this study, its effects on problem solving are relevant. When efficacy beliefs and outcome expectancies are

both positive, a person often experiences productive engagement, aspiration, and personal satisfaction. In the case of positive efficacy but negative outcomes of performance, the resulting experience can lead to grievance, protest, and even social activism. When both efficacy and outcomes are negative, the results can be resignation or apathy. Lastly, when the efficacy is negative and the outcome performance positive, it can produce despondency and self-devaluation.

Heppner and Baker (1997) stressed that educators should be interested in increasing both content knowledge and students' problem-solving abilities. Educational technology influences problem-solving abilities and performance (Tajuddin, Tarmizi, Konting, & Ali, 2009). Heppner and Baker's study found that increased availability and use of calculator technology in the mathematics classroom improved the ways students can efficiently solve math problems. Specifically, the graphing calculator decreased the number of steps it took to solve problems, thereby increasing the accuracy and precision by which students solved problems. This alone did not account for better problem-solving abilities, since the students' meta-cognitive awareness, as measured by student self-checking, was significantly higher than the control group. This implied that the graphing calculator, as it assisted students' writing of linear equations, helped with the problem-solving abilities of the students and increased their academic achievement. The framework of the Social Cognition theory encompasses the graphing calculator, since it affects both a person's cognitive and social environment.

Concerning confidence in problem solving, Huebner (2009) noted the difference in male and female involvement in the physical sciences. To counter the male dominated careers stemming from math and science, the author proposed that teachers remind their students that intellectual abilities are not rigid and that specific informational feedback is important in

building confidence. This includes formative feedback, which provides timely feedback to students by targeting desired academic goals and informing students of their progress towards it. To aid in the confidence building responsibility of the teacher, Ayodele (2011) recommended that teachers provide a collaborative environment in which male and female students work cooperatively so that they maintain mathematical equity in performance. Ayodele concluded that performance in mathematics moderately resulted from student self-concept and that teachers should pay more attention to problem-solving skills in order to produce better results in mathematics. Better attention to the problem-solving approach improved the academic outcomes of girls in a study conducted by Perveen (2010). In Perveen's problem-solving approach, versus the expository strategy, the girls who were taught using a problem-solving approach performed better on the posttest and led the author to believe that problem solving is a means to enhance the teaching of mathematics at the secondary level.

Literature Review

In math, a problem differs from an exercise in the following manner. According to Musser, Burger, and Peterson (2001), an exercise involves a routine procedure to arrive at a response, while a problem is one that requires thought, reflection, and ingenuity to derive the answer. There are several stages involved in problem solving, including general orientation, definition of the problem, production of alternatives, decision-making, and evaluation (Heppner & Peterson, 1981). According to Liu (2011), of the stages involved in problem solving, getting started (orientation) appears to be the most difficult step.

Polya (1957) posited that teachers who use only drills hamper the intellectual development of mathematics students as problem solvers. He argued that independent thinking results from students solving problems that are proportionate to their knowledge base. In his

authoritative book on problem solving, Polya delineated four steps that educators can use, namely, (a) understanding the problem, (b) devising a plan, (c) carrying out the plan, and (d) looking back.

Understanding the problem involves the consideration of what is the unknown, and understanding the data and the conditions to the problem (Polya, 1957). A person demonstrates understanding of the problem when they can eliminate redundant information, accurately assess insufficient data, and understand the various parts of the conditions to the problem. Musser et al. (1957) added to the discussion by encouraging the problem solver to paraphrase the problem.

Devising a plan requires a strategy that purposefully makes a connection between the data and the unknown (Polya, 1957). The plan compares the problem with a previous solved example and seeks to either solve the problem at once or breaks it down to manageable chunks. Musser et al. (2001) listed strategies that are employed in this step. They include (a) use guess and check, (b) use a variable, (c) draw a picture, (d) use a pattern, (e) use a list, (f) reduce the problem, (g) use direct and indirect reasoning, (h) use properties of numbers, (i) work backwards, (j) use cases, (k) use formulas or equations, (l) use a model, (m) use dimensional analysis, (n) use sub-goals, and (m) graph it. Examples of how the graphing calculator aids in these strategies are discussed in the following section.

After a problem solver makes a purposeful connection, s/he needs to carry out the plan and check the completed work at each stage (Polya, 1957). Sometimes a change of direction and strategy is required (Musser et al., 2001). Staying with a problem, or allocating an appropriate time to complete the problem, is necessary for success in problem solving.

Lastly, checking the results or the argument allows the problem solver to examine the correctness of the solution. One benefit of checking the solution is that it allows the solver a

chance to see if there was an easier or different way to solve the problem (Musser et al., 2001; Polya, 1957). An additional benefit is that extensions to the problem can be found that could aid in future problems.

Problem Solving Strategies Using the Graphing Calculator

The graphing calculator can aid students in taking a guess and testing the answer in various ways. For example, if a situation arises in which the student needs to find the answer to a system of equations, the student can graph the function and see the approximate location. The student can then take an educated guess on the location of the intersection and try to solve the equations in this manner. This method is useful for taking educated guesses, but other situations are present in which the student uses random answers. One goal in using this strategy is to improve and refine consecutive guesses until the correct answer is tested and found. This strategy has positive effects on test taking when there are a limited number of possibilities. This is because the student can systematically rule out answers such as the distracters (Hong, Sas, & Sas, 2006).

Graphing calculators are convenient for manipulating variables, expressions, and equations. In mathematics, students face situations for which they could guess an infinite number of times. When this is the case, it is better to use a variable and set up equations that solve the appropriate mathematics. This strategy is effective when the problem employs an unknown number or set of numbers. It is also useful when a person needs a general rule.

Draw a picture or diagram of the situation can be helpful in problem solving (Musser et al., 2001). When the problem involves a physical situation, drawing a picture usually leads to a better understanding of the problem. The TI-83 Plus graphing calculator can do this well in

statistics lessons in which using scatterplots and other visual representations are useful. Students can enter their data and then examine various graphs to aid them in their study.

When a person generates a pattern within a problem, a systematic listing of the cases can lead directly to the answer, often long before other strategies can generate the solution (Musser et al., 2001). This strategy is helpful when a sequence of data is given. As it relates to generating lists of data, the graphing calculator can generate a list of data from equations by having the student type in the equation(s) and looking at the table of values. This is especially useful when students have to find the zeros on an equation and can readily look at a list of values to find the answer. A list can reveal numerical patterns that lead to solutions. A clue in using this strategy is when the problem asks the reader to list the number of solutions.

One benefit of the graphing calculator is the ability to see many functions simultaneously on the screen. This allows the students to compare and contrast functions by relating the problem to a simpler form. For example, students may study the function $y = (x+2)^2$ by graphing it together with its simplest form of $y = x^2$. Students use this strategy by reducing complex problems to their vital information. The student then studies the relationship with the simpler problem and uses this information to extrapolate the results of the original problem.

The properties of numbers strategy are appropriate when using special groups of numbers such as odds, evens, primes, and others (Musser at al., 2001). The goal is to employ this strategy when students need to reduce or factor the problem. An example of this strategy is when students need to find the greatest common factor when attempting to find the solution of an equation. The Ti-83 Plus understands that this is vital information and has a way for students to find the greatest common factor of numbers (Texas Instrument Guidebooks, 2016).

One can use the strategy of working backwards with the graphing calculator to solve problems (Musser et al., 2001). For example, if a student knows two points and needs to figure out the equation, the student can enter this information and instruct the calculator on how to solve the problem. This strategy is useful in mathematics when results are clear and the initial portion of the problem is unclear. When this occurs, the problem solver can work backwards from the starting point to solve the problem for what is unknown.

Students use graphing calculators to solve equations by either setting up a matrix or graphically (Texas Instrument Guidebooks, 2016). Solving an equation requires a variable to be present as well as an equality statement. To have the calculator solve an equation, say $3x + 20 = 2x - 4$, one could graph each side separately and find the point of intersection. The x value of this point of intersection is the solution to the equation. Effectively using this strategy requires a functional understanding of solving equations.

There are times when problems contain the necessary information and what remains is for the problem solver to find and use a formula (Musser et al., 2001). Formulas serve a variety of mathematical applications including geometry, percent, rate, distance, among a host of other uses. In order to solve a formula without the necessity of using the order of operations, students can program the value of the variable(s) into the Ti-83 Plus and simply type in the equation (Texas Instrument Guidebooks, 2016). The calculator then substitutes the values and solves the expression, eliminating possible errors in using the order of operations.

The graphing calculator can model real-life situations and allows students a way to visualize their information (Musser et al., 2001). For example, if a student bounces a ball and gathers information regarding its path, a graphing calculator can model the situation (Swingle & Pachnowski, 2003). With the use of this strategy, students can employ the use of physical

objects to enhance the visualization aspects of the problem and enhance their understanding of the problem.

In order to solve certain problems in mathematics, it is sometimes necessary to subdivide the problem into its individual factors and address each factor to solve the problem (Musser et al., 2001). This strategy is helpful, for example, when the problem solver needs to solve an intermediate step that leads to the solution of the original problem. In graphing functions, it is often necessary for the student to use intermediate steps, such as setting the window to the right scale, zooming in to pertinent parts of the graph, looking at the table of values, setting the table of values, and shading parts of the graphs (Texas Instruments Guidebooks, 2016). Each of these components can be helpful to the student's success in graphing and understanding the problem. Furthermore, the strategy of using coordinates is appropriate when the problem involves the use of independent and dependent variables. By using the graphing calculator, students can investigate and solve problems involving slope, rate of change, intersects, and others (Nichols, 2012).

In mathematics, the ability to project the future is applicable when students engage in self-regulating strategic planning that enables them to accomplish their goals (Kitsantas, 2002). This includes devising organizational strategies, rewriting notes, highlighting main ideas, outlining, rehearsing, using mnemonics, and employing other strategies. In Kitsantas' study, students who employed self-regulating strategic planning earned higher test scores than those who did not. In a similar study, Appelhans and Schmeck (2002) found that academic interest, effort, personal responsibility, organization, and critical thinking skills led to better exam preparation.

Barriers to Problem Solving

Anxiety is a barrier that people need to remove in order to improve their beliefs in accomplishing a mathematical task. Mathematics brings anxiety to many people and part of this is attributable to achievement and social comparison to others (Erdogan, Sesici, & Sahin, 2011). In such cases, teachers can respond by offering students constructive feedback and avoiding using upward social comparison that compares students to others within the classroom. Instead, teachers can use spoken and behavioral feedback to develop student personalities in a positive direction. When viewed with a positive perspective, the difficult nature of math provides a conducive environment for growth in self-efficacy because coping modeling is likely to enhance personal efficacy in circumstances full of impediments (Bandura, 1997). In early elementary students, as well as students with mental challenges, coping models benefited individuals as they saw and observed others rise above their obstacles (Kazdin, 1973).

The amount of pressure a student experiences can affect their problem-solving strategies (Beilock & DeCaro, 2007). In their study, these researchers placed students into low pressure and high pressure groups. Students in the high pressure group received instructions aimed at producing feelings of performance stress and anxiety and students in the low pressure group did not experience these stressors. The researchers found that low-pressure conditions led to students more likely using computationally demanding algorithms to solve problems, and the high-pressure conditions led to simpler problem-solving strategies that resulted in accuracy setbacks. The added stress in the study had a negative effect on students' problem-solving abilities. As Bandura (1997) stated, it is better for the well-being of a person when motivation stems from a positive, unwavering belief in one's ability, rather than when it comes from fear of coming across as anything less than intelligent.

Student mistakes can be a barrier to problem solving in mathematics, and to counter this, teachers can frame their message by telling the students that mistakes are a signal for them to try the problem a different way (Medoff, 2013). Framing the feedback in this form can motivate students to try again instead of discouraging them to give up. Additionally, feedback attained from formative assessments assists students in developing a mindful awareness through self-regulation, which reduces the number of students who are not successful (Davis, 2007). Even in an arbitrary or trite situation, when a person receives feedback that they performed well or poorly, these statements can influence a person's self-efficacy even if the statements contradict past experiences (Bandura, 1997).

Feedback can take on various forms, including the praise of effort, mistake interpretation, empathy, solidifying understanding, supports, and respectful responses to questions (Medoff, 2013). Ozdemir and Pape (2013) noticed students in a sixth-grade class who reported higher levels of self-efficacy participated more in class discussions, showed greater effort and persistence, and accomplished more than students with lower levels of self-efficacy.

Feedback and verbal persuasion are effective when they come from knowledgeable individuals who account for when the level of difficulty of the task is beyond the skill of an individual (Bandura, 1997). These types of persuasions are important because there exists a group of individuals who possess the skills necessary for a task, yet are persistent underachievers. In a study of 197 gifted secondary students, Abu-Hamour and Al-Hmouz (2013) identified underachievers by three characteristics: lower levels of intrinsic and extrinsic motivation, poor self-regulatory strategies, and negative attitudes towards the school system. According to Stein (2010), highly effective teachers can counter underachievement by creating a positive, motivating, and highly ethical classroom environment. These teachers can persuade

students to study for tests, complete homework to reinforce class concepts, establish teamwork, and discover students' strengths and weaknesses. A healthy classroom environment fosters positive moods that play a vital role in how individuals process sources of self-efficacy. Moods affect self-efficacy due to the impact they have on a person's functions; happy individuals, as compared to sad ones, benefit from greater perceived self-efficacy (Bandura, 1997). The value in this for education is that the higher the perceived self-efficacy, the higher the goals people strive to achieve (Bandura & Wood, 1989).

Not all feedback is beneficial, however. Watrous (2003) pointed out that just like false praise, the effects of constant criticism are unproductive due to the consistently negative message that students receive. Likewise, repeated positive feedback for arduous tasks can send a message that only difficult and hard efforts produce desired results (Schunk & Rice, 1986). Without these strategies, teachers may risk artificially boosting their students' personal beliefs and self-efficacy, only to have them perform poorly on a task, thus producing feelings of disappointment and discouragement (Bandura, 1997). Effective criticism, referred to as constructive suggestions, turns the negative stigma of criticism into action points that the evaluated person can use to improve a situation (Lukaszewski, 2008). Applied to problem solving, a student's level of prior knowledge was a factor when providing feedback (Fyfe, Rittle-Johnson & DeCaro, 2012). In essence, Fyfe et al. found that when students knew how to use various strategies to solve algebraic problems, feedback was unnecessary.

In mathematics, students may find demanding work difficult to sustain due to inappropriate placement or the lack of perseverance (Schwartz, 2006). To counter these challenges, students can employ skills such as listening for relevant information, taking notes,

talking to the instructor, and completing their homework. Teachers can help the process by promoting student interest while staying true to the curriculum (Gasser, 2011).

Negative past experiences can be a barrier to problem solving in mathematics (Bandura, 1989; Skaalvik & Skaalvik, 2011). Past experiences impact efficacy beliefs due to a variety of affective factors stemming from successes and failures (Bandura, 1989). In a study of middle school and high school mathematics students, Skaalvik and Skaalvik (2011) demonstrated that efficacy beliefs have the strong ability to out-predict past experiences, such as grades. Some plausible reasons for this change in students is that they receive new classes with different classmates, student roles become less static, teacher expectations are different, and new opportunities are presented. Smith (2006) refined this idea in his study with university students. Smith found that failure negatively affected an individual's task-specific self-efficacy and ensuing task performance, but not one's general self-efficacy.

In mathematics, prior successes build a person's confidence and efficacy, because they paint an accurate picture of what an individual is capable of doing. Wheland, Konet, and Butler (2003) found that college students who took an intermediate algebra class and received high grades went on to take an additional math class the following semester; whereas students who performed poorly stopped taking math classes during the next term at a high rate. This confirms the idea that students would continue to take classes in those areas in which they have had prior success. Bandura (1997) agreed with this and asserted that prior knowledge and skill provide the self-schemata that affects people's personal efficacy judgments as it relates to retrieving information from their memory via master experiences. Interestingly enough, in Wheland, et al.'s study, students who performed poorly contributed their performance to factors outside their

control such as whether or not the professor spoke fluent English. This suggests that in order for students to preserve their self-efficacy, they may blame their failure on outside factors.

Poor modeling is not profitable for problem solving (Latif, 2014; Lubowsky, 2011). Teachers who model the use of graphing calculators facilitate students' visualization and understanding of equations and systems, real-life examples, and precalculus problems involving the composition of functions, which may also be found in the first year of algebra (Lubowsky, 2011). In addition to poor modeling, requiring students to examine their solution and detect errors helps students to solve problems (Latif, 2014). Latif also explained that modeling multiple ways to solve problems helps students when they become stuck with one method of solving the problem.

In order for vicarious experiences to lead to behavior changes, individuals need to consider several phases (Bandura, 1997). First, a person's selective attention needs to tune in to learn the aspects of the modeling experience. Next, the person needs to remember the behavior(s) that have occurred so that the next step, production and imitation, can occur. For an individual to produce a modeled behavior, the person's motivation either curtails or enhances these processes. In the mathematics classroom, students who are motivated to be able to reproduce similar problems modeled for them can take down notes to aid their memory and be more likely to reproduce the modeled behavior (Schwartz, 2006). Latif (2014) found that student learning was enhanced when they learned from the modeling they received from their peers. Therefore, it is important to teach students how to work cooperatively, model good helping behaviors, and lend each other strong academic and social support within the classroom.

Another source of modeling implemented within the classroom can be self-modeling. Teachers can structure self-modeling so that progressive mastery can occur (Bandura, 1997). A

general definition of self-modeling is the observation of oneself via images engaged in adaptive

behaviors (Hitchcock, Dowrick, & Prater, 2003). In Hitchcock et al.'s meta-analysis concerning

self-modeling, they found that self-modeling strategies brought about decreases in inappropriate

student behaviors and increases in desired classroom behaviors. In the case of the mathematics

classroom, self-efficacy and achievement increase in those who have overcome mathematical

difficulties because of the rehearsal effect on mental skills when observing a self-modeled

recording (Schunk & Hanson, 1989). An added benefit is that a performance well done leads to

greater effort and persistence for school age students who have difficulties in mathematics.

Additionally, students can record themselves while using their graphing calculators to solve a

familiar problem. Student self-efficacy improves as they see themselves succeeding, even

though they acquire no new knowledge.

Overlooked Difficulties in Problem Solving

Difficulties arise in enactive learning when problem-solving techniques produce wrong

outcomes that go unnoticed by individuals (Bandura, 1998). For example, common errors made

by students involve sign errors (negative signs), errors in solving equations, inequality mistakes,

inaccuracies in properties of numbers and variables, fractions, and arithmetic errors (Booth,

Barbieri, Eyer, & Paré-Blagoev, 2014).

When teachers stress the importance of checking for errors, students are more likely to

find careless errors, such as typing the wrong information into the graphing calculator and

checking the constraints of the graphing calculator (McCulloch, Kenney, & Keene, 2013). Some

mistakes are more complicated to detect than others. For example, suppose a student graphs a

problem on a device and copies the graph onto a provided coordinate plane, but fails to realize

that the scales of the two graphs are different. This can occur when the scale of one graph uses

intervals of ones and the other graph uses intervals of twos, for example. Left unchecked, the student will believe the enactive learning experience was a successful experience needing no refinement when in fact it was not.

An example of error analysis is demonstrating to students that they are misunderstanding a particular step in a problem solving activity. This partial knowledge, however, benefit students when instructors use and manipulate error analysis (Lorenzet, Salas, & Tannenbaum, 2005). In Lorenzet et al.'s study involving college students learning a technology program, they found that if instructors corrected and guided errors, it resulted in greater confidence and gains in student performance, as measured by speed and accuracy.

Bandura (1997) added that poorly defined directions may create a sense of over assurance or under assurance in the mind of an individual. Teachers can examine their instructions to make sure there are no ambiguities in the directions that would cause confusion to their students.

Another source of student stress occurs when teachers place difficult cognitive tasks within apparently easy assignments (Bandura & Schunk, 1981). This misleads individuals to overestimate their abilities when assessing whether or not they have the skill set to complete the task. Mathematics presents numerous opportunities to humble a person's perceptions concerning his or her abilities to solve problems. Egodawatte's (2009) study on algebra found common errors related to intuitive assumptions and algebraic syntax. In addition, rules in algebra must frequently be carried out in sequence and often require multiple skills in order to solve, which may not have full cognitive comprehension on the part of the student. For example, students may be required to use order of operations for a problem. Yet, within the problem is an imbedded double negative that needs resolved before completing the task. Such dynamic nuances are examples in math of what Bandura and Schunk (1981) referred to when they

discussed difficulties embedded within easy assignments that can lead to misleading

measurements of self-efficacy.

CHAPTER THREE: METHODS

Design

The purpose of this quasi-experimental, nonequivalent control group design was to examine the impact the Desmos graphing calculator has on middle and high school students' problem-solving confidence as compared to students who use a TI-83 Plus calculator. This design was appropriate because a posttest was used to measure confidence once students were exposed to the Desmos or TI-83 Plus graphing calculators and the students were not randomly assigned to groups (Gall, Gall, & Borg, 2007).

Middle and high school students in this study took a math achievement test and a posttest to determine their levels of problem-solving confidence, as measured by the Problem-Solving Inventory (PSI). The independent variable for this study was the type of graphing calculator used and the dependent variables were confidence in problem-solving abilities and usability perceptions. The scores of the MAP test measured the covariate in this study, which was math achievement.

The type of calculator used in this study was the independent variable and participants in the study had access to both the Desmos and TI-83 Plus calculators. Desmos describes their graphing calculator as the "next generation of graphing calculator" and users can use it either as an online graphing calculator or as a free downloadable application for an iPad or other mobile devices (Desmos, 2015). Its developers have professed an intention to promote math literacy and equipped this browser-based with in-built content such as a bank of equations, dual workspace that includes data and graph located on the same screen, and application anticipation features that display vital information pertinent to the graph. Information concerning the graphs of functions (such as x- and y-intercepts, vertices, maximums, and minimums) is instantly accessible. Other

factors tend to make Desmos easy to use and intuitive in its approach to math. Specifically, the calculator provides lists of formulas, essential points on graphs and allows the user to write and graph many different types of equations. One drawback is that it does not compute statistical data.

The TI-83 Plus graphing calculator is a 50-button calculator designed by Texas Instruments that graphs functions, performs statistical tests, is programmable, and includes various other functions (Nash & Olsen, 1998). The size of the screen is approximately six centimeters by four centimeters (or less than 1/10th the size of the iPad 2 screen) and Nash and Olsen (1998) noted that the viewing window can be cluttered, but that it does well in graphing functions. One of the benefits of this calculator is its connectivity to computers to assist with programming. The memory in this device allows users to store notes in it.

The dependent variable (confidence in problem-solving ability) is the interactions of cognitive, affective, and behavior processes with the aim of reconciling internal and external tasks (Heppner & Krauskopf, 1987). In addition, for the purpose of this study, confidence in problem-solving ability is a sense of confidence on tasks (Heppner & Peterson, 1982). Heppner and Peterson created the PSI to measure problem-solving confidence.

Finally, the covariate is math achievement, as measured by the Measures of Academic Progress math test. Merriam-Webster defines achievement as the act of achieving something or a result gained by effort (Achievement, n.d.). In a review of achievement that was broad and comprehensive, Wigfield and Cambria (2009), stated that achievement values, goal orientations, and interest(s) are reasons for individuals to achieve in their activities. Concerning this study, Holubz (2008) associated student achievement to calculators and engaged students. Gottfried,

Marcoulides, Gottfried, and Oliver (2013) made a connection between intrinsic motivation and achievement, noting that lower levels of motivation led to less math course accomplishments.

Research Question

RQ1: As measured by the Problem Solving Inventory (PSI) is there a significant difference in middle and high school students' problem-solving confidence when provided the use of the Desmos calculator as compared to students who used the TI-83 Plus calculator while controlling for student achievement math scores?

Null Hypothesis

$H_0 1$: As measured by the Problem Solving Inventory (PSI) there is not a significant difference in middle and high school students' problem-solving confidence when provided the use of the Desmos calculator as compared to students who used the TI-83 Plus calculator while controlling for student achievement math scores.

Participants and Setting

The participants for this study came from a convenience sample of middle and high school students selected from an urban high school located in south central Pennsylvania. The researcher selected this urban school district due to the high investment of technology, especially the fact that students had one to one access to technology (i.e., an iPad for each middle school and high school student), and convenience. Of principle interest, this school district had ready access to both the Desmos and TI-83 Plus calculators. The Desmos calculator was accessible on the iPad via a free download and every teacher has a suitcase of TI-83 Plus calculators. The case contains padding on the inside and has enough slots to hold 30 calculators. Teachers also have a classroom set of TI-30 calculators intended for everyday use in their classes.

Concerning the school's demographics, at the time of the study the population exceeded 1,000 students and were approximately 56% Hispanic, 35% White (non-Hispanic), 7% Black, and 1% Asian/Pacific (Pennsylvania Department of Education, 2015). In addition, about 76% of the students at this school came from low-income families. This school is located in a community in which 36% of the citizens are from out of state (Areavibes, 2017). The household income distribution is (a) 55% of households had income below $40,000, (b) 39% of households had income between $40,000 and $100,000, and (c) 9% of households had income above $100,000. Data collected from 2002 until 2014 reveal that thefts outpace other crimes in this community, followed by burglaries (City-Data, 2017).

While the researcher taught in this school district during the collection of data, he did not use any of his classes for the study. The convenience sample of 146 secondary students used in this study was appropriate for a statistical power of .7, at the .05 alpha level (Gall et al., 2007). Five highly qualified teachers taught the students in this study arranged in at least a pair of similar classes. This was set up this way so that teachers could teach the same lesson to both pairs of classes, with one class using Desmos on the iPad and the other using TI-83 Plus graphing calculators. The sample included 34 eighth graders and 112 ninth graders. The age range for the students was 13 to 16 years old.

The instructional setting for the study included five separate classrooms within the math department of the study's school district. Teachers taught students using the McDougal Littell Algebra 1 (2007) curriculum textbook and corresponding curriculum material. All classrooms were fitted with interactive Smartboards and white boards. Each room was set up wirelessly for the iPad, meaning the teacher could control what was projected on the interactive white board while walking around the room and manipulating the iPad. All the classrooms had a set of

graphing calculators. Teachers also had a graphing calculator emulator on their laptop that

mimics the handheld version and enables connectivity to the interactive smart board. Each room

had its own sound system built into the ceiling tiles that teachers used and incorporated in a

lesson involving an online game.

The seating arrangement was set up with individual desks and chairs arranged in three

groups. The students rotated within the groups during a lesson. These groups were comprised of

a direct teaching station, a cooperative learning station, and an independent learning station.

Throughout any given lesson, the students rotated from one group to another – receiving either

direct teacher instruction, working with their peers cooperatively on an assignment, or working

independently (usually on an assignment that involved technology).

The control group consisted of 80 students who exclusively used the TI-83 Plus

calculator for lesson instruction. The grade range for these students was eighth and ninth grade.

All of the students were in Algebra I. The control group did not use the Desmos calculator.

Table 2 shows the control groups' demographic information.

Table 2

Control Group Demographics

Grade	Math Class	Gender
8th	Algebra 1	61% Male ($n = 14$) 39% Female ($n = 9$)
9th	Algebra 1	42% Male ($n = 24$) 58% Female ($n = 33$)

(n=80)

The treatment group contained 66 students, ranging from eighth to eleventh grade.

Teachers taught these students with the aid of the Desmos calculator and students did not use the

TI-83 Plus calculator. Table 3 shows the treatment groups' demographic information.

Table 3

Treatment Group Demographics (n = 66)

Grade	Math Class	Gender
8th	Algebra I	66.7% Male ($n = 8$)
		33.3% Female ($n = 4$)
9th	Algebra I	56% Male ($n = 30$)
		44% Female ($n = 24$)

The school's guidance counselors made the group formations, as they constructed student schedules during the summer prior to the commencement of the school year. Student formations fell under one of two options, an academic algebra class and a regular algebra class. Students in need of special education services are included in both the regular and academic algebra classes. Both the control and treatment classes used the same course material. Moreover, in this study, the school district set the curriculum and the teachers followed a similar scope and sequence in the classes; the main difference between instruction among the control and treatment groups was the type of calculator used in class and the pace of the curriculum. Teachers in this study regularly employed a variety of teaching strategies that enhanced their classroom instructional practices, such as utilizing the Collins writing program to improve content writing and online resources such as Kahoots to increase content fluency and student participation.

Instrumentation

This study used the Problem Solving Inventory to measure students' confidence and the Measures of Academic Progress to measure students' achievement levels.

Problem Solving Inventory

The PSI, according to Heppner and Peterson (1982), is a measure that assesses a person's problem-solving confidence and provides a macro evaluation of that person as a problem solver.

Heppner and Baker (1997) defined problem solving as self-assurance while engaged in a diverse range of problem-solving tasks. Heppner and Krauskopf (1987) further delineated problem solving as the intricate weaving of cognitive, affective, and behavior processes with the aim of adapting to internal and external challenges.

Students' perceptions of their problem-solving abilities are of great interest to educators; especially given the fact that social cognitive theory discusses how one's schemas and expectations can interact with one's environment to influence behavior (Myers, 2014). Heppner and Baker (1997) highlighted this connection when they stated that educators are interested in increasing both content knowledge and a student's problem-solving abilities; thus making problem solving a central part of the educational system.

Heppner and Peterson (1982) developed the PSI as a self-report measure intended to (a) assess awareness, (b) evaluate a person's confidence in their problem-solving ability, and (c) provide a global appraisal of that individual as a problem solver. It is a 35-item 6-point Likert scale (1 = absolutely agree, 2 = usually behave like that, 3 = often behave like that, 4 = sometimes behave like that, 5 = rarely behave like that, and 6 = absolutely not agree). The inventory has three divisions or subscales: Problem-Solving Confidence, Approach-Avoidance Style, and Personal Control. The Problem-Solving Confidence subscale is of special interest to this study, given that Heppner and Baker (1997) defined the subscale as a student's self-assurance while actively dealing with a range of problem-solving activities and as a confidence in one's ability to problem solve.

The Problem-Solving Confidence subscale contains 11 of the 35 questions listed on the inventory. Researchers score these questions on a reverse scale. The scores generated by the inventory are within the range of 32-192, with 32-80 being the highest level and 81-192 being

the lowest level. A lower score (between 81 and 192) means that the student has a negative

perception of his problem-solving ability and consequently, a higher score (between 32 and 80)

indicates a positive perception of problem-solving skill (Kaya, Izgiol, & Kesan, 2014). The

subscale takes less than 10 minutes to administer. Appendix A has permission and information

concerning the administration of this instrument.

Researchers replicated every subscale of the PSI across various samples and populations

in both the United States and around the world. In recent years, numerous studies have

incorporated the PSI as an instrument for data collection (Izgar, 2008; Kaya, Izgiol, & Kesan,

2014; Temel, 2014; Uysal, 2014). According to Nezu, Nezu, and Perri (1989), researchers have

utilized the PSI in excess of 100 studies and Nezu et al. Nezu referenced the PSI as one of the

most extensively used self-report inventories in the problem-solving literature. Serin's (2011)

study on the PSI and computer-based instruction is particularly relevant because of its similarity

to the present study. Using a new technology to aid instruction and problem-solving skills is

akin to studying the effects the Desmos calculator has on problem solving. Ozyurt's (2014)

noted the importance of increasing problem-solving skills of engineering students. In this field

of applied advanced mathematics, researchers used the PSI to investigate critical thinking

dispositions. Ozyurt's rationale was that increasing problem-solving skills and dispositions is an

important objective of computer engineering education. Since increased problem-solving skills

are desirable in mathematics fields such as computer engineering, when investigating problem-

solving skills in mathematics classes at the high school level it is also important to examine tools

that engage students effectively.

Sahin, Sahin, and Heppner (1993) collected data from 224 university students in Izmir,

Turkey and replicated the factor structure of the PSI, with 28 out of the 32 items loading on the

same factors. The reliability Cronbach's alpha coefficient is .88 for the total inventory and .76

for the Problem-Solving Confidence, .78 for Approach-Avoidance, and .69 for Personal Control.

In addition, the Cronbach's alpha coefficient, which measures internal consistency among items,

was also high, with a total inventory scoring at .90 and the subscales scoring .85, .84, and .72.

The PSI is a stable instrument, particularly if re-administered within two weeks, with decreasing

changes noted over time (Heppner, 1998; Heppner, Witty, & Dixon, 1998). Since 1982, several

factors have demonstrated acceptable reliability scores and one of interest to this study is the

problem-solving confidence ($\alpha= .76$). Those were problems numbered 5, 11, 23, 24, 27, 28, 34

in the Turkish adaptation carried out in 1993 (Kaya, Izgiol, & Kesan, 2014).

Measures of Academic Progress

The Northwest Evaluation Association produces the Measures of Academic Progress

(MAP) and measures student achievement in a variety of subject areas including math, language

usage, and English (NWEA, 2016). The covariate in the current study consisted of solely the

math scores. The Oregon and Washington state school districts formed an alliance to build a

testing system that could measure an individual's academic level and growth. This alliance led

to the creation of the MAP test (NWEA, 2016). To do this, they use the valid, reliable, and

predictive Rasch Unit (RIT) scale to provide both teachers and school administrators data they

can use to make informed classroom instruction decisions. Researchers have also used this

academic instrument in a variety of studies (DeJoseph, 2012; Medford, 2014; Stone, 2009).

The MAP's reliability, or the set of indices of a test's consistency, spans across a

timeframe of 7 to 12 months (Northwest Evaluation Association, 2004). Reliability for the

mathematics portion of the test at the middle school and high school levels is between .89 and

.94, which indicates a high level of test reliability.

Validity for the MAP came from comparing the test to the Wyoming Comprehensive Assessment System. In the year 2000, MAP was able to attain validity of .81 for their math eighth grade. MAP also used the 9th Edition Stanford Achievement Test, which yielded validity scores of .87 in both seventh and eighth grade. In grade nine, validity scores were .81 in the Washington Assessment of Student Learning test. For tenth graders, validity scores were .72 for the Colorado Student Assessment.

MAP uses Rausch Unit (RIT) norms for their mathematics assessments (NWEA, 2016). The level in which students can correctly answer questions 50% of the time measures the RIT, and a scale reflects the difficulty and complexity of these problems. The RIT Scale is an equal interval score and does not change in relationship to the top, bottom or middle of the scale. Its purpose is to reflect an accurate achievement scale that measures growth over time, regardless of grade or student age. Its range is between 95 and 300. The scoring procedure is rather simple. MAP scores for students and administrators are available immediately after a student completes the online test. The MAP program automatically computes scores and compares these scores to the 2015 Mathematics Student Status Norms to find the grade level in which students are achieving.

The school district in which the MAP testing takes place administered the test in the fall, winter, and spring seasons. Math teachers are provided a time frame (generally a week) in which to complete the testing with the students and are provided a computer cart from the library that has NWEA's lockdown program on it. Once logged onto NWEA's program, it prevents students from using any of the other computer's function such as a computer calculator or Internet browser. Once logged onto the system by using their username and password, students are given a test session code that they must type into the program to open their specific test. Testing can

generally be finished within 90 minutes and students are provided with their scores immediately

after the test, as the computer grades their responses as the student answers the questions.

Procedures

Prior to gathering data for this study, Liberty University's Institutional Review Board

(IRB) reviewed and approved the study (see Appendix C). The duration of the study lasted an

equivalence of 12 weeks commencing at the beginning of the school year. The total time for the

study with the students occurred within a marking period.

Teacher training occurred during an in-service training day in August 2016 (see

Appendix D). The training consisted of recruiting five teachers and providing them with

information on the study. In this training, an overview of the details of the study was given and a

question and answer time was provided. It covered the study's length of time commitment and

reiterated teacher responsibilities concerning the control and experimental groups. As each

teacher would have a pair of similar classes (one utilizing each type of calculator), they were

instructed not to use the designated calculator with the other group. Teachers were, however, to

use the same lesson with both classes. Concerning the calculators themselves, the training

covered how to use each calculator, features available to each, and how to integrate it into

lessons. Teachers reported being comfortable with both calculators and their respective

functions and features. Lastly, the researcher instructed the teachers about the responsibility of

administering the secure surveys.

Teachers at this school district were well equipped with current educational technology,

although individual proficiency and expertise with educational technology varied. In addition to

every student having a school issued iPad, each classroom is equipped with a Smart Board, a set

of classroom computers, a classroom set of scientific and graphing calculators, and an integrated

sound system. To maximize use of available technology, it was the expectation that teachers use technology as frequently as possible and run a hybrid model of instruction, meaning that students were to rotate among three sections within the room. Students learned independently in one section, another section was for group activities, and the third section was for direct instruction with the teacher. At the independent station, students used their iPad to access online curriculum options or worked on teacher provided materials. During the group session, students worked together to solve problems that varied in difficulty and time duration. During direct instruction, the teacher delivered instruction to the students.

Teachers gave the student survey of the Problem Solving Inventory (PSI) via SurveyMonkey and students completed the survey on their iPads. The survey did not include identifying information other than the class and teacher under which the students received instruction. One benefit that aided in the analysis was that SurveyMonkey automatically converted the responses into an Excel spreadsheet for the researcher.

Data Analysis

The researcher analyzed the data for the hypothesis using an analysis of covariance (ANCOVA). The ANCOVA allows the researcher to determine if a difference found between two groups can be explained by another factor, which in the case of this study could be differing mathematical knowledge and ability (Gall et al., 2007). The size of the sample was $N = 146$, which was greater than other similarly designed studies in the literature (Safari & Meskini, 2016; Serin, 2011), and which, according to Gall et al. (2007) exceeds the number required by the medium effect size for the ANCOVA hypothesis test with an $\alpha = .05$ and statistical power of .7. The ANCOVA test controls for initial differences within the classroom groups before comparing within-groups variance and between-groups variance. A significant factor that could influence

the scores of the Problem Solving Inventory (PSI) was the students' demonstrated knowledge as measured by the Measures of Academic Progress (MAP). This was an appropriate statistical tool due to the nature of the data generated from the two calculator conditions. The ANCOVA design recognizes and accommodates for variables present that could influence the posttest scores. Since students in this study have demonstrated mathematical knowledge as measured by the MAP test, this score served as the covariate.

The ANCOVA for this study was tested at the 95% confidence level. Due to the nature of the ANCOVA, the following assumptions were examined. First, extreme outliers from each group were removed from the study by the use of a Box and Whisker plot. Next, the assumption of normality was checked using a Kolmogorov-Smirnov and Shapiro-Wilk test. According to Elliott (2007), the results of the Kolmogorov-Smirnov test could violate the assumption of normality without compromising the ANCOVA test in sample sizes greater than 40. Ghasemi and Zhediasl (2012) and D'Agostino (1986) supported the Shapiro-Wilk test of normality as the better choice for testing normality of data as compared to the Kolmogorov. Scatterplots were used for each group to test for the assumption of linearity between the difference of test scores of the PSI and MAP scores. The next assumption was to examine the homogeneity of the slopes of the lines of best fit between the MAP test scores and the PSI scores for each group (Reinard, 2006). Lastly, the assumption of equal variance was checked using Levene's test of equality of error variance.

CHAPTER FOUR: FINDINGS

The purpose of this study was to examine the impact the Desmos graphing calculator has on the problem-solving confidence of middle school and high school students as compared to students who use a TI-83 Plus graphing calculator while controlling for students' math achievement scores. The independent variable was the type of calculator used and the dependent variable was students' score on the Problem Solving Confidence subscale of the Problem Solving Inventory (PSI). To control for achievement, students' results on the Measures of Academic Progress (MAP) math test was the covariate. As such, the researcher examined the following research question and null hypothesis.

Research Question

RQ1: As measured by the Problem Solving Inventory (PSI) is there a significant difference in middle and high school students' problem-solving confidence when provided the use of the Desmos calculator as compared to students who used the TI-83 Plus calculator while controlling for student achievement math scores?

Null Hypothesis

H$_0$1: As measured by the Problem Solving Inventory (PSI) there is not a significant difference in middle and high school students' problem-solving confidence when provided the use of the Desmos calculator as compared to students who used the TI-83 Plus calculator while controlling for student achievement math scores.

Descriptive Statistics

This study involved middle and high school students, $N = 146$, at an urban school district in south central Pennsylvania. Of these students, 34 were eighth-grade Algebra I students enrolled at the middle school. The other 112 students were ninth-grade students enrolled in

Algebra 1 classes at the high school.

All of the students in the study had been administered the district mathematics achievement test called the Measures of Academic Progress (MAP). The control group ($n = 80$), students who used the TI-83 Plus calculator, had a larger range (157 to 257) when compared to the treatment group ($n = 66$), students who used Desmos (176 to 225). The mean scores were in near proximity to each other, with the control group mean score of 220.15 ($SD = 19.15$) and treatment group mean score of 213.64 ($SD = 14.65$). Table 4 presents a summary of MAP scores for both groups.

Table 4

Measures of Academic Progress Achievement Test

Group	n	Min.	Max.	M	SD
Control	80	157	257	220.15	19.15
Treatment	66	176	225	213.64	14.65

The students were also administered the PSI as a posttest to assess problem-solving confidence levels after using the type of calculator provided. In the PSI, lower scores indicate greater confidence. There were 14 more students in the control group ($n = 80$) than the treatment group ($n = 66$). Concerning the PSI problem-solving confidence subscale and mean scores, the control group's mean score ($M = 34.23$, $SD = 8.62$) was higher than the treatment group's mean score ($M = 27.47$, $SD = 7.95$). Table 5 shows the mean PSI scores for both groups.

Table 5

Problem Solving Inventory: Problem Solving Confidence Subscale

PSI	Group	n	Min.	Max.	M	SD
Posttest	Control	80	18	53	34.23	8.62
	Treatment	66	14	52	27.47	7.95

The adjusted PSI scores used for the ANCOVA were as follows. The control group increased its mean score slightly (M_{adj} = 34.43, SE = .93). The treatment group also increased slightly (M_{adj} = 27.49, SE = 1.03). Table 6 shows the adjusted means for both groups.

Table 6

Adjusted PSI Scores

Calculator Type	n	Adjusted Mean	SE
Control (TI- 83 Plus)	80	34.43	.93
Treatment (Desmos)	66	27.49	1.03

Results

The following procedures were utilized to accept or reject the null hypothesis, which stated: As measured by the Problem Solving Inventory (PSI) there is not a significant difference in middle and high school students' problem-solving confidence when provided the use of the Desmos calculator as compared to students who used the TI-83 Plus calculator while controlling for student achievement math scores.

The researcher analyzed the data with IBM SPSS version 23, which has the capability to run an Analysis of Covariance (ANCOVA). The first step in following the ANCOVA testing procedures was to remove outliers. Removing outliers takes precedence before running the rest of the statistical assumptions. After running a Box and Whiskers Plot, there were no outliers identified within the data. Therefore, the researcher did not remove any individual student data from the study and proceeded to check the other assumptions.

Assumptions

Next, the assumption of normality was checked visually using histograms (Figures 1 and 2), and assessed using the Kolmogorov-Smirnov and the more powerful Shapiro-Wilk test (Table 7) (D'Agostino, 1986). Figures 1 and 2 approximate a normal distribution for the data. The

assumption of normality was not met; however, it should be noted that the results of the Kolmogorov-Smirnov test ($p = .02$) can violate the assumption of normality without compromising the ANCOVA test in sample sizes greater than 40 (Elliott, 2007). The results of the Shapiro-Wilk test shows a similar result in the data ($p = .03$).

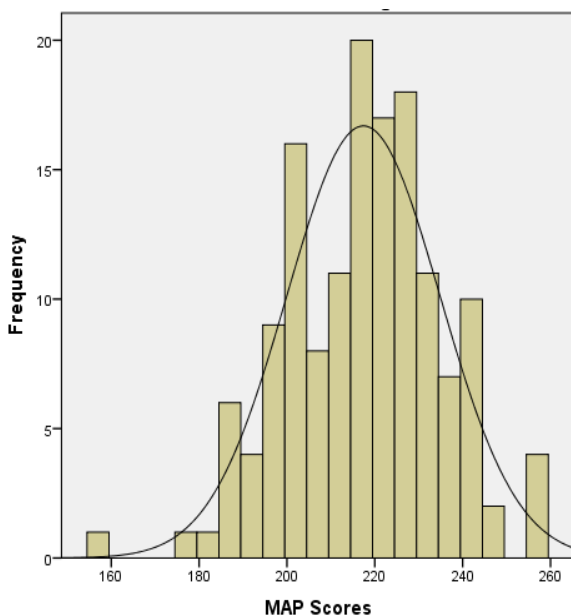*Frequency Chart of MAP Mathematics Achievement Scores*

Frequency Chart of PSI Posttest Scores

Figure 1: Distribution of MAP Mathematics Achievement Scores
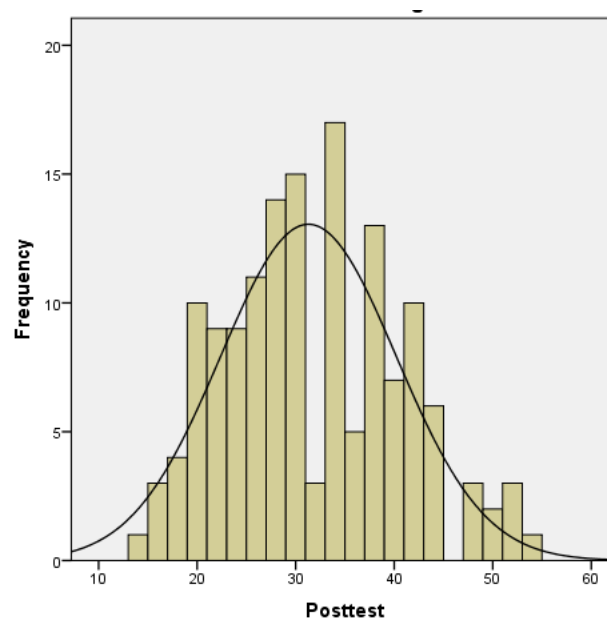
Figure 2: Distribution of PSI Posttest Scores

Table 7

Tests of Normality

Variable	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
MAP	.06	146	.20	.99	146	.37
PSI	.08	146	.02	.97	80	.03

The next step was to check the assumption of linearity. A visual inspection of the scatterplot (Figure 3) confirms the assumption of linearity between the covariate (MAP) and PSI test scores for each group.

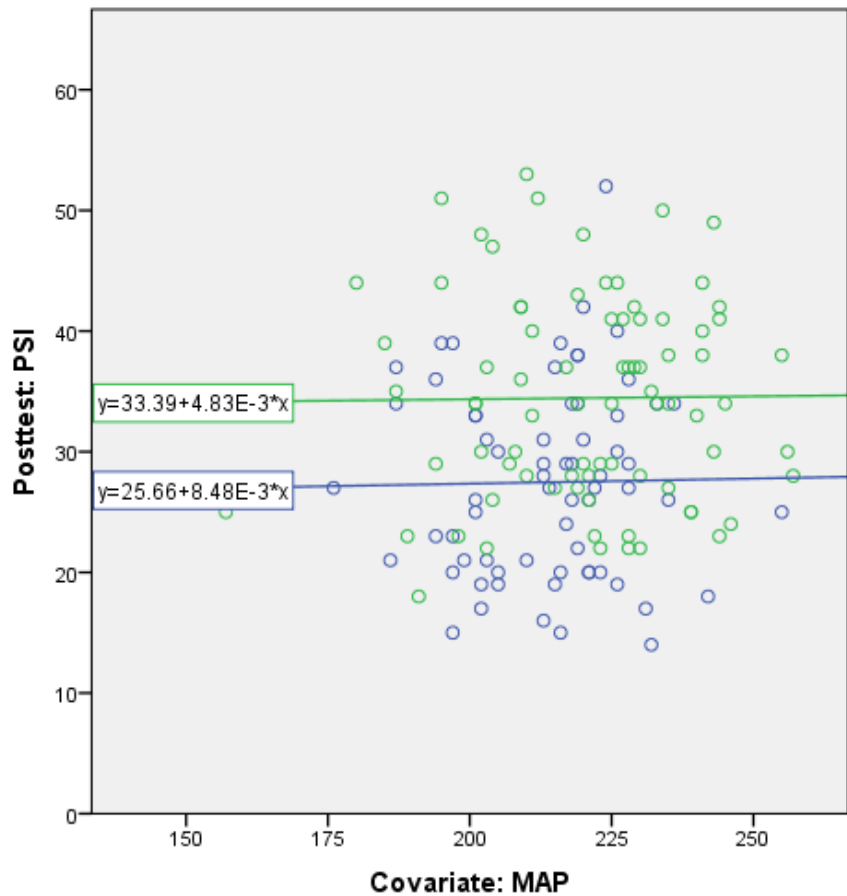*Scatterplot of MAP Scores and PSI Scores*

Figure 3: Scatterplot of MAP Scores and PSI Scores with lines of best fit

The assumption of homogeneity of regression slopes was tested and not violated. The interaction was not statistically significant, $F(1, 142) = .5$, $p = .97$ with an effect size ($\eta^2 = .00$). See Table 8 for the homogeneity of regression slopes test.

Table 8

Homogeneity of Regression Slopes Test

Dependent Variable: Posttest

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1763.76[a]	3	587.92	8.53	.00	.15
Intercept	695.99	1	695.99	10.10	.00	.07
Calculator Type	11.923	1	11.92	.17	.68	.00
MAP	1.659	1	1.66	.02	.88	.00
Calc*Map	.125	1	.13	.00	.97	.00
Error	9784.57	142	68.90			
Total	154533.00	146				
Corrected Total	11548.34	145				

a. R Squared = .142 (Adjusted R Squared = .124)

The last assumption tested was the homogeneity of variance. The researcher tested this utilizing Levene's Test of Equality of Error Variances. See Table 9 for Levene's test. This assumption was met since the error variance of the dependent variable was equal across groups, $F(1, 144) = 1$, $p = .43$, as indicated by a *p*-value greater than .05.

Table 9

Levene's Test of Equality of Error Variances

	F	df1	df2	Sig.
PSI: Posttest	1	1	144	.43

ANCOVA

Since the assumptions were satisfied, the researcher performed the ANCOVA test, which adjusted the means (Table 6).

The ANCOVA test statistics are found in Table 10. The results of the ANCOVA revealed a significant difference between the *control* ($M_{adj} = 34.43$, $SE = .93$) and *treatment group* ($M_{adj} = 27.49$, $SE = 1.03$) on problem solving confidence levels while adjusting for their mathematics achievement scores, $F(1, 143) = 24.46$, $p = .00$, $\eta^2 = .15$. The results were

significant at $p < .05$. The *F* value tests the effects of the type of calculator used by students in the control and treatment groups. Based on the results, the null hypothesis was rejected.

Table 10

One-Way ANCOVA on PSI by Groups (Desmos vs. TI-83 Plus)

	SS	Df	MS	F	Sig.	Partial Eta Squared
Groups	1673.76	1	1673.76	24.46	.00*	.15
Error	9784.70	143	68.42			

*Significant at $p < .05$

Conclusion

In conclusion, since assumptions were satisfied, the researcher used an ANCOVA to find the potential significant differences in problem-solving confidence between the control and treatment groups, while controlling for achievement. The ANCOVA revealed a significant difference between the problem-solving confidence levels of students who received instruction using either the Desmos or TI-83 Plus graphing calculators. Since there was a significant difference between the two groups, the null hypothesis was rejected. In this study, the use of the Desmos graphing calculator significantly increased problem-solving confidence among middle and high school Algebra I students.

CHAPTER FIVE: DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS

Overview

Technology in mathematics education continues to advance towards intuitive applications (Freeman, 2012). In light of the production and distribution of new technologies among schools, the Office of Educational Technology (2014) desires that researchers conduct more studies in order to assist educators in their decisions. This study sought to establish a link between graphing calculator type and problem-solving confidence.

This study provides a way to study the effects of graphing calculators within Bandura's social cognitive theory. Students, through many facets of the theory that include observational learning, symbolic representation, and enactive learning, learn to solve problems in the mathematics classroom. Their experiences, including their successes and failures, contribute to their confidence in being able to solve math problems (Bandura, 1989). As such, this study examined problem-solving confidence in an effort to discover if using different calculators made an impact on students' confidence to solve problems.

Within this chapter, the discussion section presents the study's findings along with the conclusion. After the discussion, there is a summarization of practical implications and limitations. The study concludes with recommendations for future research.

Discussion

The purpose of this quasi-experimental, nonequivalent control group study was to examine the impact of the Desmos graphing calculator on the problem-solving confidence of middle and high school students as compared to students who used a TI-83 Plus graphing calculator. In this study, the ANCOVA yielded a p-value of .004, which led to a rejection of the null hypotheses.

The null hypotheses stated: As measured by the Problem Solving Inventory there is not a significant difference in middle and high school students' problem-solving ability when provided the use of the Desmos calculator as compared to students who used the TI-83 Plus calculator while controlling for student achievement math scores.

The quantitative findings presented in Chapter Four indicate that there is a significant difference in students' problem-solving confidence when using either the Desmos or TI-83 Plus calculators, when accounting for mathematics achievement. Students who used the Desmos graphing calculator had lower scores, which indicated statistically significant greater increases in their problem-solving confidence.

This study advances the literature on problem-solving abilities of students. Kaya, Izgiol, and Kesan (2014) and Kenney (2014) advocated for the advancement of problem-solving abilities of students with regard to the use of graphing calculators. Problem solving is a fundamental attribute in math and is not as advanced as it could be (Hillman, 2012; Ozyurt, 2014). In addition, the Office of Educational Technology (2014) called for further research on educational technology so that teachers can adjust their teaching practices. This study establishes a connection for educators between types of graphing calculators and problem-solving confidence. The results of this study can be used by teachers of middle and high school Algebra I students to make informed decision concerning graphing calculators.

This research is in line with previous research that found that increases in technology literacy skills have positive effects on students (Sun & Pyzdrowski, 2009; Tatar, Zengin, & Kagizmanh, 2015). One of the challenges of technology is to be able to minimize the inherent complexities within the device that hinder students from using it successfully (Hillman, 2012). In this study, the intuitive nature of the Desmos calculator minimized the need for extensive

teacher training, as several of the teachers noted that they had not used the graphing calculator extensively in their classrooms due to state testing requirement that limit the type of calculator that may be used. This adds a new dimension to Laumakis and Herman's (2008) study, which concluded that student achievement increased with the implementation of graphing calculators by trained teachers, since the training period only took a few minutes. This level of intuitiveness is also a benefit to students, as the math concepts may be more easily navigated with programs such as Desmos found on mobile technology (Freeman, 2012).

Implications

Given this research, a possible implication is that reducing the number of steps a student needs to perform may have an impact on their problem-solving confidence. This implication would support Hillman's (2012) conclusion that the inherent complexity of a device may hinder students from using it successfully. This reduction in complexity may have a connection to the time it requires teachers to train students on how to use graphing calculators.

Another implication, based on Ocak's (2006) finding that established a correlation on math knowledge and graphing calculator use proficiency, is that there may be differentiated levels of math knowledge based on proficiency of graphing calculator usage. The implication is that there could be significant benefits to student math knowledge based on the type of graphing calculator used. This research could have an impact on the established meta-analysis literature that has demonstrated a modest effect on achievement and problem solving (Nikolaou, 2001).

This research may also have practical implications for schools looking to find reasons to upgrade their technology. Not all schools have one-to-one (one mobile device for each student) and may be looking for worthwhile reasons to move in this direction. Since this study

demonstrated a benefit for using Desmos, it may have an impact on administrators' decisions to move in this direction.

Limitations

This study provides a beneficial analysis into the effects of two different graphing calculators on students' problem-solving confidence, yet there are limitations that researchers should consider. These limitations include non-randomization, student population, self-reported measure, device exposure, and technology diffusion.

In this study, randomization of students was not practical. Campbell and Stanley (1963) referred to this as selection bias, and it is an internal source of invalidity. Selection bias most likely happens when researchers use intact groups (Ary, Jacobs, Sorensen, & Razavieh, 2009). School counselors placed the students into these classes before the study began. As such, randomization was not possible.

Furthermore, the participants in this study were eighth- and ninth-grade students from an urban setting in south central Pennsylvania. They were not representative of all high school students in districts across the nation. As such, one cannot expect the study to represent all students in general. In addition, this study did not examine factors such as gender, race, or socio-economic levels of students. There was no distinction made between English Language Learners (ELLs) and non-ELL students, or students with learning accommodations (Individual Learning Plans).

Another limitation was the self-reported measure used in the study. While teachers encouraged their students to answer every question, it was not possible to monitor that they did so. As such, there were students who left blank answers. To mitigate this issue, the researcher

only used completed surveys and removed from the study the students who did not answer the entire survey.

An internal threat to validity was the fact that all students in this study had access to the Desmos calculator. This threat was minimal because of the timing (first part of the school year), the subjects (first year algebra students), and location of calculators (students had to be told which app to download on their devices). In other words, the first-year algebra students in this school district are not yet familiar with graphing calculators, and their awareness of this tool is still novel at the beginning of the school year. In addition, teachers completed graphing activities in class because students did not have access to the TI-83 Plus calculator at home. The teachers in the study controlled the diffusion of the TI-83 Plus calculator since each had a storage case to put them in after use.

The differences that exist within the technological infrastructure of schools may limit the generality of this study. Ary, Jacobs, Sorensen, and Razavieh (2009) referred to this as setting-treatment interaction, in which the setting may limit the generalizability of the results. This study may be difficult to reproduce since it may be cost prohibitive for some districts to provide one-to-one technology for all students. While access to the Desmos calculator is available on classroom computers with Internet access, the students in this study each had their own mobile device. Since not every student has access, this study is limited to schools that have the resources to provide the necessary technology for students.

Extending the results of this study to higher-level math classes may present an external threat. The study was limited to Algebra I students and it may not be possible to predict an increase of problem-solving confidence in all mathematics classes, such as Algebra II,

Precalculus, or Calculus. It may be likely that higher-level classes have already used graphing technology extensively and that student exposure to both calculators exists.

Recommendations for Future Research

In order to continue this line of research, future research could consider various student groups and different mathematics classes, both at the high school and collegiate levels. The participants in this study were eighth- and ninth-grade students who were all enrolled in Algebra I classes. Opportunities to use the graphing calculators were readily present in such concepts as equations, linear functions, tables, and graphs within the Algebra I curriculum. A future researcher may find it convenient to carry over these concepts to Algebra II, Precalculus, and Calculus curricula since these courses work extensively with linear systems, quadratic functions, polynomial functions, and numerous other types of advanced functions; including conic sections, trigonometric equations and graphs. An internal validity issue would be prior exposure to the Desmos calculator.

After extending this research to the various grades and curricula, the next logical step would be to investigate the effect the Desmos graphing calculator has on achievement. This study verified problem-solving confidence; the next step is student problem-solving ability or achievement. A sample research question could be, "Is there a relationship between changes in students' mathematical achievement while using the Desmos calculator as compared to using a different graphing calculator?"

Many researchers are interested in the difference gender plays in math. Since Perveen (2010) noted that better attention to the problem-solving approach improved the academic outcome of females, it could be beneficial to test whether the Desmos calculator has an impact on problem-solving confidence between males and females.

Research has shown that race plays a factor in aspirations and achievement (Riegle-Crumb, Moore, & Ramos-Wada, 2011). Researchers could investigate whether using the Desmos graphing calculator would lead to a decrease in the existing achievement differences between students of different races.

Another recommendation would be to investigate the change in ELL students' confidence levels when using the Desmos calculator versus a different calculator. English language learners require additional scaffolding within the classroom to aid their academic progress. The intuitiveness and reduction of steps and language needed to communicate mathematics problems within lessons while using the Desmos graphing calculator could simplify academic content and make mathematics more accessible to these students. Specifically, further research could investigate whether the reduction of steps and increased intuitiveness affects the academic language load and thus makes it easier for the acquisition of academic content.

Lastly, although it would be difficult to check, the reduction of steps inherent to teaching and learning with the Desmos calculator could also benefit students with individual learning plans (IEPs). Since, according to Bakken and Gaddy (2014), learning disabilities and attentional disorders include a large portion of the special education population, it would be worth investigating if the reduction of steps (i.e. smaller chunks of information) by the Desmos calculator plays a factor on lowering demands on students' processing speed and working memory. A researcher could posit that a reduction in the demand of complicated, yet menial calculator sequences could lead to more time on task and increased achievement levels.

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APPENDIX A:

Problem-Solving Inventory

Permission for Problem-Solving Inventory: According to Heppner and Petersen (1982), researchers may reproduce the test for non-commercial educational research without written permission. The authors ask that the test distribution be controlled and only given to those within the research. Further information can be found at Heppner, P.P., & Petersen, C.H. (1982). Problem-Solving Inventory. doi: 10.1037/t04336-000.

Documentation of the General Self-Efficacy Scale   8

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Permission granted

to use the General Self-Efficacy Scale for non-commercial reseach and development purposes. The scale may be shortened and/or modified to meet the particular requirements of the research context.

http://userpage.fu-berlin.de/~health/selfscal.htm

You may print an unlimited number of copies on paper for distribution to research participants. Or the scale may be used in online survey research if the user group is limited to certified users who enter the website with a password.

There is no permission to publish the scale in the Internet, or to print it in publications (except 1 sample item).

The source needs to be cited, the URL mentioned above as well as the book publication:

Schwarzer, R., & Jerusalem, M. (1995). Generalized Self-Efficacy scale. In J. Weinman, S. Wright, & M. Johnston, *Measures in health psychology: A user's portfolio. Causal and control beliefs* (pp.35-37). Windsor, UK: NFER-NELSON.

Professor Dr. Ralf Schwarzer
www.ralfschwarzer.de

APPENDIX B:
Student/Parent Information Form

Principal Investigator: Edwin Montijo
Liberty University
Department of Education

Dear Student & Parent:

My name is Mr. Montijo, a doctoral candidate in the School of Education at Liberty University. This fall, I will be conducting a study to determine whether there is a difference in problem solving perceptions when using different graphing calculators in your child's algebra class.

Your child will be using one of two different types of graphing calculators and will be completing a brief survey at the beginning and end of the marking period.

Participation: Participating in this study is voluntary and you may withdraw at any time.

The Research Data: All surveys will be confidential, and in the possession of the researcher. The electronic database will be kept secure and password protected. Once the data is no longer needed, it will be erased from the electronic source that contains it. Data will consist of survey results and math achievement scores students took last year.

The Limitations of Data: The data collected during this study is to be used solely for the study and is not intended to be used for teacher or program evaluation.

The Benefits: In addition to providing the researcher with important information, your child will receive tokens of appreciation for their time such as candy, chocolate bars, and/or personalized school pencils.

The Risks: There are no known risks involved in this study.

Thanks for your time!

Mr. Montijo
LHS Mathematics
Doctoral Candidate

APPENDIX C:
Liberty University IRB Approval

LIBERTY UNIVERSITY.
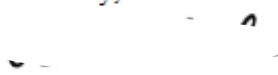## INSTITUTIONAL REVIEW BOARD

9/7/2016

Edwin Montijo
IRB Approval 2615.090716: The Effects of Desmos and Ti-83 Plus Graphing Calculators on the Problem-Solving Confidence of Middle and High School Mathematics Students

Dear Edwin Montijo,

We are pleased to inform you that your study has been approved by the Liberty IRB. This approval is extended to you for one year from the date provided above with your protocol number. If data collection proceeds past one year, or if you make changes in the methodology as it pertains to human subjects, you must submit an appropriate update form to the IRB. The forms for these cases were attached to your approval email.

Thank you for your cooperation with the IRB, and we wish you well with your research project.

Sincerely,

G. Michele Baker, MA, CIP
Administrative Chair of Institutional Research
The Graduate School

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APPENDIX D:

Agenda for Participating Teachers

1. Overview and Details of Dissertation
2. Timeline
3. Responsibilities
    a. Control Group
    b. Experimental Group
    c. Student Survey Responsibilities and Security
    d. Overview of both calculators
        i. When to use
        ii. When not to use
        iii. Functions and Features
4. Instructions before administering the test

Please have students use their iPads and go on Survey Monkey to take the
assessment. The site is: _____.

Once all the students are signed in, please read the following:

Posttest

Students, now that we have completed a marking period's worth of mathematics,
we would like to measure the impact the graphing calculator had on your
confidence in solving math problems. Please answer the following questions as
truthfully as you can as you think about solving the algebra problems learned in
this marking period with your graphing calculator. At this time, you may begin
the survey. Take your time and provide a thoughtful response to each question.