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THE IMPACT OF SIMULATIONS ON ACHIEVEMENT AND ATTITUDES IN MATHEMATICS CLASSROOMS

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ABSTRACT

A change in the national focus of education has led to a curriculum more focused on the student developing his or her own knowledge. The Common Core State Standards (CCSS) have been developed to place a greater focus on the learner and less focus on rudimentary mathematics. Teachers are faced with a daunting task to not only implement the CCSS but also use alternative teaching practices and tools in the classroom that teachers are not familiar with. Computerized simulations provide teachers with a possible tool in which students can expand on mathematical principles and further their knowledge of mathematical theory. This study focuses on the use of computerized simulations in a Common Core mathematics classroom versus classes not using simulations. This study examines the use of computerized simulations and changes in mathematical attitudes (*i.e.*, enjoyment, value, and motivation) compared to students not using simulations. Finally, this study examines the use of computerized simulations and changes in the technological attitudes (*i.e.*, confidence with technology and attitude to learning mathematics with technology) compared to students not using simulations.

Keywords: technology, mathematic education, Common Core State Standards

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CHAPTER I. INTRODUCTION

Mathematics teaching methods have changed throughout the years. During the 1980's and 1990's, there was a move toward a more student-centered learning environment, but teachers defaulted to ways they were instructed in school (Silver, 2013). Teachers provided hundreds of rudimentary problems through the use of worksheets and lectures that caused high school students to lose interest in mathematics (Buckley, 2010; Sherman, 2010). From the mid 1990's to mid 2000's, new approaches were introduced into the classrooms such as exploration, modeling, and real-life experiments, which make class more engaging and exciting (Boaler, 2002). In today's classroom, Common Core State Standards (CCSS) have been developed that allow teachers time in early grades to focus on a more conceptual understanding of principles.

In today's high school mathematics class, many traditional forms of mathematics teaching are still evident (Van De Walle & Lovin, 2006). Veteran and new teachers alike still use direct instruction and assign homework problems to reinforce in-class lectures (Stein, Kinder, Silbert, & Carnine, 2005). These traditional forms of instruction are ineffective in the CCSS-based classroom, where students are to be taught to be better problem solvers based on the constructivist curriculum (Burns, 2013).

In addition to the change in curriculum and instructional goals, today's children are exposed to different forms of technology that provide unlimited digital information (Prensky, 2008). Dejarnette (2012) reported that today's students need to be comfortable using technology in science-related fields because technology provides an efficient way of completing tasks and analyzing data. Prensky (2013) argued that teachers do a disservice to students by not utilizing the types of technologies that can enhance students' abilities. Technologies such as simulations can provide opportunities to improve students' understanding of different concepts (Grandgenett, 2011). The use of simulations allows for improved student engagement and allows students to explore mathematical principles that enhance their mathematical knowledge (Sokolowski, Yalvac, & Loving, 2011).

In mathematics classrooms, teachers have difficulty with actively engaging students (Villegas, 2011). Scheiter, Gerjets, and Schuh (2010) suggested that the addition of simulations allows students to explore multiple perspectives, which helps them to obtain a deeper understanding of a mathematics idea. Further research (Abbasi & Iqbal, 2009; Delen & Bulut, 2011) has shown that the use of technology reduces the achievement gap between students and allows them to become more engaged in the learning process. Simulations are a part of game-based learning (GBL), in that simulations can assist individuals in different types of virtual environments with learning experiences. Simulations and games allow for students to make connections between a simulated event and a theoretical concept. Gibson, Aldrich, and Prensky (2007) stated games and simulations are often referred to as experimental exercises that allow students to learn by doing. Gee (2003) stated that children in a science classroom need to make connections between new and old identities through a problem-solving approach in an engaging environment. Shaffer (2007) stated that games allow children to choose roles and interact in these roles in environments that are difficult for children to interact in real life. Shaffer suggested that games produce simulated events that allow for understanding of consequences for events and choices made by the child.

This research will present a study designed to investigate whether using simulations in mathematics classes improves students' understanding of mathematical principles. In addition, this study will examine whether the use of simulations has an impact on students' attitudes towards mathematics and technology. This chapter consists of the following sections:

Background, Statement of the Problem, Purposes of Research, Significance, Research Questions, Limitations and Assumptions, Researcher's Personal Statement, Summary, and Definition of Terms.

Background

In the State of Maryland, and nationally, mathematics classes have had to adapt a set of standards (CCSS) and develop curricula (CCSC). High school mathematics students complete a course sequence of algebra I, geometry, and algebra II. After a completion of these courses, a student is able to take a college-level mathematics course. Some schools offer supplemental courses to help students with struggles in the Common Core classes. As part of a graduation requirement, students must pass the algebra 1 Partnership for Assessment of Readiness for College and Careers (PARCC). In addition, students must also have a passing score on the algebra 2 PARCC to be deemed college and career ready.

With an increasing number of students needing to pass the algebra 2 PARCC and the adoption of CCSC, teachers are challenged to modify lessons and use different teaching tools to help engage students and prepare students for types of questions asked on the algebra 2 PARCC. The CCSC in mathematics lends itself to more student-centered approaches. With these new approaches, teachers need different tools to use within student-centered environments. This calls for the investigation of what teaching tools are useful that can lead to student success in achievement in different areas of mathematics.

Further, some students in mathematics classes already struggle with content, and that struggle can lead to the negative attitude in class. Identifying the potential teaching tools, such as a simulation, have on the attitudes and success of students is critical. Research has been conducted on different types of simulations in mathematics classrooms (Ke, 2008; Ke &

Grabowski; 2007). It is found that simulations can allow the learner to explore open-ended scenarios providing situated learning experiences (Alessi & Trollip, 2001). As well, simulations can provide a deeper and cognitive engaged learning experience (Duffy & Cunningham, 1996).

Research has been conducted examining the students' attitudes towards mathematics (Aiken, 1970; Iben, 1991), while other studies have focused on students' achievement (Stevenson & Newman, 1986; Lipnevich, et al., 2016). A student's attitude is important in class not only for the student's understanding of concepts but also for how the student can excel beyond the class. Using a simulation could provide the teacher with a tool that could help increase students' attitudes in a positive direction along with aiding in achievement. In studies about students' attitudes, the common result was there was no simulation used as a tool of instruction (Prendergast & Hongning, 2016).

However, there are limitations of the present body of research, which include simulations used as a tool of instruction and the impact on students' attitudes. Most studies involving simulations are conducted in the field of science, more specifically physics (Gourgouliatos, 2016; McKagen, 2010; Paulson et al., 2009; Wieman et al., 2008). Some studies have explored computer-based games and mathematics, but the focus is not on advanced algebra (Papastergiou, 2009; Ke, 2008, Watts et al. 2016).

With a changing curriculum that requires teachers to use more effective and engaging teaching methods, simulations offer teachers an alternative tool to use in the classroom. While it is worthwhile to offer students alternative tools in the classroom, the question needs to be investigated if tools such as simulations can be a successful alternative tool for teachers to use in the classroom as compared to traditional approaches, especially in advanced mathematics classes.

Statement of the Problem

Education in the United States has changed to a set of standards (e.g. CCSS) for teachers in the field of mathematics. The CCSC was developed that incorporates student-centered learning tasks. With the change in mathematics teaching following the CCSS, teachers are expected to use new teaching techniques to deliver a demanding curriculum. However, teachers, school systems, and counties are not prepared for the different teaching approaches needed to deliver the new curriculum (Gewertz, 2013). Specifically, teachers need alternative approaches to use in the classroom. Simulations offer mathematics teachers an alternative way to help students explore mathematical ideas and construct new understanding (Hwang & Hu, 2013). Research on the effectiveness of simulations in the classroom in relation to achievement and attitudes remains limited (Washbush & Gosen, 2001). Evidence needs to be provided to ensure that the uses of simulations can be an effective teaching tool in the Common Core classroom.

Purpose of Research

The first purpose of this research is to determine if there is a difference in students' achievement between students being taught using simulations and students not being taught using simulations in a Common Core classroom. The second purpose of this research is to determine if there is a difference in mathematical attitudes between students being taught using simulations and students not being taught using simulations. The third purpose of this research is to determine if there is a difference in technological attitudes between students being taught using simulations and students not being taught using simulations.

Significance

With the shift to lessons taught through the Common Core curriculum, alternative effective tools are needed in helping students learn mathematics. This research is significant because it can help determine whether using an alternative approach (*i.e.*, using simulations) can assist teachers in effectively teaching mathematics within the Common Core classroom. Further, this research may lead to determine if the alternative has any impact on students' attitudes towards mathematics and technology within a Common Core classroom. The results of this research can assist teachers' decisions on alternative approaches that can be used in the Common Core classroom. The results may advise teachers in the development of worthwhile mathematics lessons involving technology. While the results may lead to the conclusion that simulations are not an effective tool in mathematics instruction, specific mathematical and technological attributes might improve, making the use of simulations a feasible alternative.

Research Questions

In order to determine student achievement between control and treatment groups, as well as any change in mathematical and technological attitudes, the research was guided by the following questions:

1. Does the use of computerized simulations impact students' mathematics learning as reflected in their achievement?
2. Does the use of computerized simulations change the mathematical attitudes (*i.e.*, enjoyment, value, and motivation) of students compared to students not using simulations?

3. Does the use of computerized simulations change the technological attitudes (*i.e.*, confidence with technology, attitude to learning mathematics with technology) of students compared to students not using simulations?

Mathematical attributes are defined as the attitudes that influence success and persistence in mathematics (Lim & Chapman, 2013). Technological attributes of learning technology in mathematics are defined by how students perceive that the use of computers in mathematics is relevant for mathematics (Pierce, Stacey, & Barkatsas, 2007; Vale & Leder, 2004).

Limitations and Assumptions

This research was conducted in an attempt to control as many factors as possible. The attempt was to use the same approaches in the simulation-instructed classes (resources, teaching procedures, lesson plans, and assessments) as compared to the non-simulation classes, with the only difference being the use of simulations. This study acknowledges the following limitations.

- To make sure an adequate sample size was used, algebra 2 classes were used, and students in different classes were recruited. While every effort was made to ensure all materials and presentation methods remained the same, there will still be some differences in instruction with multiple instructors teaching the courses.
- Due to the need for a specific population of students (algebra 2), the researcher used a sample of convenience, so results may be biased and may not be able to be reproduced.
- There are concerns over reliability of the instruments used in the research study which cause a question about the validity of results.
- There are concerns of bias that could occur in the classroom such as consistent instruction, unforeseen instances, and technology issues. To help control these biases, the researcher will constantly be observing classes to make sure teachers follow the scripted

lessons. Another concern is the amount of technology that will be available for the students. Most classes range from 28 to 33 students. Labs only contain a maximum of 28 computers. Some laptops will be brought into those labs to accommodate the size of the classes. Lastly, students will not be familiar with having mathematics instruction in a computer lab. To make sure students are comfortable, teachers of the classes will take their students into the labs for mini lessons one week before the study. This will allow students and teachers to become more familiar with the setting.

Researcher's Personal Statement

As the researcher, I am independent from the instruction of the courses but could serve as an instructor for future courses. The implementation of the instructional methods and implementation of the results of this study could be subject to my perceptions, biases, beliefs, and experiences.

My experiences have shown that many students struggle with mathematics. Many students have developed a dislike for mathematics through previous bad experiences or due to the struggles they have had in the past. The simulations provided to the students are designed for students to have an increased enjoyment and help with the development of conceptual ideas. I believe students should have a nurturing environment of learning and should have the opportunity to challenge ideas to further their understanding of concepts.

For this study, I served as a mathematics teacher in the Howard County School System for 12 years. Of the 12 years, 8 of the years have been in high school mathematics. In the beginning of my teaching career, I was concerned with students' mastery of mathematical principles. I was concerned with how to effectively reach students and to provide effective instruction to them. With the changing curricula in mathematics and with a greater focus on conceptual understanding of topics, it seems teachers need more alternative approaches to engage students and allow them to explore and discover theories independently.

As a mathematics educator, I believe students have a better experience when discovering mathematical ideas. Students can have a better understanding on concepts from their success in class. I believe students have a better understanding of principles when related to the real world. I believe students have a better conceptual understanding when they apply the real-world problems to the mathematical experiences they have in class. I believe in order for students to have success, they need to feel comfortable in the learning environment. I often spend a great deal of time learning about what my students are involved with outside of the mathematics classroom. I feel it is important for students to understand that the teacher not only cares about the learning that takes place in the classroom but also what happens when students leave the classroom.

Summary

The Common Core Curriculum has triggered mathematics teachers to take a new approach to teaching. The days of following the textbook from section to section have disappeared. Currently, in education, the “how” is not the only thing that is important in a mathematics class; the “why” is equally, if not more, important. Teachers must look at alternative approaches to actively engage students. Teachers need to be able to prove to students that what they are learning in a mathematic classroom is important. Through this study, I can collect baseline data on students and apply an alternative tool — simulation — for students to use. Simulation has the capability of actively engaging students, allowing them to make real-world connections, and giving them multiple approaches and visibility to solving problems.

This research will help determine whether using an alternative approach in teaching mathematics (simulations) will be an effective tool for teachers. The results may help us identify specific mathematical and technological attitudes that could increase students' achievements in mathematics.

Definition of Terms

In the field of education, terms are required to provide a clear understanding of how they are used throughout the research.

Common Core State Standards (CCSS) – Focus on core conceptual understandings and procedures starting in the early grades.

Common Core State Curriculum (CCSC) – Derived from the state standards, each discipline has developed and has begun implementing the curriculum in the classroom.

Game Based Learning (GBL) – A type of game play that has defined outcomes.

High School Assessment (HSA) – Measures the individual student's progress towards the Maryland High School Core Learning Goals.

Partnership for Assessment of Readiness for College and Careers (PARCC) – A common set of assessments in K-12 education anchored in English and math for what it takes to be ready for college and careers.

Simulation – Reproduction of a behavior of a system using a model.

CHAPTER II. LITERATURE REVIEW

Mathematics teaching is changing in today's classroom through the implementation of the CCSC (Porter, McMaken, Hwang, & Yang, 2011). Through the CCSC, mathematical skills taught in the classroom are not changing, but the way teachers present material, the number of mathematical concepts taught, and the way students must present mathematical explanations are different (Hunt & Little, 2014). The new curriculum provides teachers with alternatives to strengthen students' skills in problem solving, which can enable students to have a more advanced understanding of mathematical concepts (Erbas & Okur, 2012). Technological tools, such as simulations, can allow teachers alternative approaches assisting students in their problem-solving abilities (Stevens, Beal, & Sprang, 2013). With the use of technology, students could become better problem solvers so they can be successful in upper-level mathematics courses (Cheung & Slavin, 2013). Allowing students to have a solid foundation in mathematics could lead to better appreciation of the subject. Also, having a solid foundation in mathematics could lead to greater success in future careers, as well as high school and college mathematics courses. Liebtag (2013) suggested that the CCSS was created to allow students to be college and career ready when they leave high school.

This literature review will show how mathematical practices and learning taught in the classroom have changed throughout the generations, how technology can be applied in the mathematics classroom, and how different learning theories can be incorporated with simulations.

Historical Perspective

Mathematics teaching methods have evolved throughout generations. Teachers have used different approaches during different time periods. Materials used in the classroom have advanced throughout time from basic (pencils, paper, textbooks) to more modernized (cell phones, tablets, computers); these materials are beginning to be used by teachers to assist in instruction and assessment in the classroom. One constant variable always present is that teachers tend to revert back to the teaching practices they were taught with during their schooling (Kensington-Miller, Sneddon, Yoon, & Stewart, 2013).

In the 1800’s, mathematics education mainly involved basic geometry and arithmetic for everyday use (Kidwell, Ackerberg-Hastings, & Roberts, 2008). Specialized mathematics content might have been learned for specialized areas. From the 1900’s to the 1950’s, mathematics became more standardized. The focus of mathematics teaching prior to that time was basic skills, repetition, and testing. According to Battista (1999), the behaviorist approach to instruction was predominant. A behaviorist approach to teaching could be referred to as “teacher-centered” and “traditional” (Barkatsas & Malone, 2005; Solso, 2009). Students were exposed to the same teaching methods that focused on repetition and practice (Schifter, & Fosnot, 1993). Most students did not pursue mathematics beyond the high school classroom. The biggest technology advancement during this timeframe was the slide rule. In the late 1950’s, with the launch of Sputnik by the Russians, a concern arose about American students’ mathematics skills (Bybee, 1997). American students were behind in mathematics and science, which prompted a new reform focusing on number theory and mathematical principles from first grade through high school (Dow, 1997). Lappan (1997) stated these approaches in mathematical principles and number theory were not well received. During this timeframe, students were being encouraged to attend college, and the technology used in the classroom was changing with the development of the calculator (Herrera & Owens, 2001). Throughout the 1960’s to 1980’s, there were many attempts to reform mathematics education, but teachers still tended to teach the way they were taught (Hatfield, Edwards, Bitter, & Morrow, 2000). Hiebert et al. (2005) argued that there was more of an emphasis on teaching procedures in mathematics and less on how conceptual ideas were developed.

In the 1990's, the Third International Science and Mathematics Study (TIMSS) and the National Assessment of Educational Progress (NAEP) still showed a lag behind other nations in mathematical progress (Aud, Fox, & KewalRamani, 2010). According to these reports, students in the United States continued to score low and struggled to solve challenging problems that required conceptual understandings (Hatfield et al., 2000). This finding prompted mathematics teachers to move to a more standards-based curriculum that focused on the big picture of mathematics, including how to solve problems, how to develop reasoning for answers, and how to communicate mathematically (Van de Walle & Lovin, 2006). The standards-based curriculum led to the evolution of three sets of standards: Curriculum and Evaluation Standards (1989), Professional Standards for Teaching Mathematics (1991), and Assessment Standards (1995) (Hatfield et al., 2000). Through the evolution of these standards, teachers were charged with the task of including problem solving as the primary focus in the classroom, along with involving technology as a tool of instruction (Borko, 2004). Suydam and Brosnan (1993) argued that the change in standards would promote the use of calculators and computers as informational tools and calculation devices. Witzel and Riccomini (2007) argued that even with the use of technology, teachers still need to develop strategies that allow for problem solving and that align towards the new curricula. There was a profound shift in the way mathematics was learned, starting with Thorndike's Stimulus-Response Bond Theory, which had an impact on how mathematics was taught and learned (English, 1997). Thorndike found through research that mathematics was best learned through drill and practice. Thorndike believed that there needed to be a careful sequence of concepts, a repetition of concepts, and practice. Through the progressive movement, there was a shift in education from rote memorization towards education focusing more on the child's ability to develop his or her own knowledge, the child having more of an interest in his or her own work, and the teacher moving away from the role as instructor and towards coach (Ellis & Berry, 2005).

In 1991, statewide systematic systems were launched to encourage states to align their mathematics standards with the NCTM standards (Klein, 2003). Through this alignment, standards-based education asserted that students learn by manipulating scientific and mathematical ideas that are related to real-life applications. Thompson (1984) suggested mathematics and science are learned best through doing rather than memorization. The use of manipulatives enhances problem-solving skills from a variety of perspectives (Neiss, 2005). Some authors suggested that there is a need for some memorization of basic skills in mathematics, but a more meaningful hands-on approach allows students to retain mathematics skills over the long term (Trujillo & Hadfield, 1999).

With the changing in mathematics teaching over the years, students have been exposed to different learning styles, environments, and teaching practices. These practices and styles can have positive or negative impacts on students. Research shows negative practices, such as direct instruction, can hold back students from a deeper understanding of knowledge (Stipek et al., 2001). As mathematics education advanced to the 2000's, a new push for national standards arose. In today's educational environment, the CCSS were developed so the standards are clear and understandable. The CCSS are consistent, include rigorous content and application of knowledge, and build upon strengths and current state standards. The CCSS are evidence-based and are aligned with college and work expectations (http://www.corestandards.org/about-the-standards). Throughout the evolution of mathematical learning, it has been noted that the focus on what students learn and how they learn has changed during different generations. Students' needs have changed throughout the years because of society's demands.

In the 1950's, the United States measured success based on Russia, but now the United States measures students' success in relation to China (Ma, 1999). According to the 2012 Program of International Student Assessment (PISA), Chinese teenagers outperformed American students by 27 percent in the areas of mathematics, reading, and science. The PISA is a unique test in that it is not directly linked to a state curriculum (Wu, 2009). Tests are designed to assess how students can apply their knowledge to real-world situations and be successful in society. U.S. students' scores have steadily declined over the past 12 years, with students from other countries such as Germany and Poland increasing. To address this problem, CCSC has been designed and adopted.

One significant change in the CCSC is fewer standards per grade level but with a more in-depth look at mathematics topics (Kendall, 2011). This in-depth look into topics requires mathematics teachers to focus on the why and how of mathematics and move beyond the step-by-step process that does not lead to full conceptual understanding of topics (Jackson, Garrison, Wilson, Gibbons, & Shahan, 2013). The intention of CCSS is to have more specific standards that allow teachers to develop ways to build on students' knowledge, produce engaging tasks, and make mathematics more meaningful (Wu, 2011). The CCSS in mathematics allows for the proper progress of topics that are mathematically coherent and leads to college and career readiness. However, Cobb and Jackson (2011) reported that teachers and states were not ready to implement the CCSC because of teachers being underprepared. Teachers are, therefore, challenged with new methodologies to teach in the context of CCSC (Cobb & Jackson, 2011;

Porter et al., 2011). Technology such as simulations may provide useful tools to help teachers meet these challenges. The effect of simulations in secondary mathematics classrooms, however, is limited.

Attitudes in Mathematics

Student attitudes play an important role in mathematics education. The definition of attitude assumes the role of a working definition (Daskalogianni & Simpson, 2000). Mathematical attitudes have been defined in many different ways. Vale and Leder (2004) define students' attitudes as being students' perceptions of achievement. Others (Haladyna, Shaughnessy & Shaughnessy, 1983; McLeod, 1992) define attitude as the positive or negative reaction towards a particular object. Hart (1989) argued that attitude is an emotional response and related behavior based on the individual. Researchers suggested that attitudes towards mathematics are a pattern of beliefs and feelings (Daskalogianni & Simpson, 2000; Tezer & Ozcan, 2015). Neale (1969) defined attitude towards mathematics as a "liking or disliking of mathematics, a tendency to engage in or avoid mathematical activities, a belief that one is good or bad at mathematics, and a belief that mathematics is useful or useless" (Ma & Kishor, 1997, p. 27). McLeod (1992) defined attitudes as a positive or negative disposition towards mathematics. For this study, the definition of attitude is related to intrinsic motivation, self-confidence, enjoyment, and values (Tapia & Marsh, 2004).

Hannula (2002) stated that attitude can be viewed as an emotional disposition towards mathematics. Hannula's definition has four components: the emotions students experience during mathematic activities, the emotions students automatically associate with the concept "mathematics," evaluations of situations students expect to follow as a consequence for doing mathematics, and the value of students' math-related goals in their global goal structure

(Hannula, 2002). Research has shown that attitudes in mathematics are very important to the participation and achievement of students in mathematics (Tapia, 1996). Through learning, students' attitudes change in different directions. A student's change in attitude could be from the exposure of different variables in class. Instruments have been created to measure students' attitudes towards mathematics and technology. These instruments provide researchers with a way to measure students' attitudes and make generalizations.

Students' attitudes towards mathematics have been referenced as a contributing variable to their success (Mata, Monteiro, & Peixoto, 2012). Attitudes in class help set the stage for a positive learning environment. Optimal conditions for learning are created by students' attitudes towards active exploration rather than having children adopt a passive role. Setting an active environment that is student centered and task oriented is important for the learning of mathematics (Fisher, Hirsh-Pasek, & Golinkoff, 2012), as children vary widely in their attitudes towards the subject. Research has shown positive relationships between learning styles and mathematics achievement, and a positive relationship between attitudes towards mathematics and achievement (Bramlett & Herron, 2009; Middleton & Spanias, 1999). The investigation of these characteristics within the CCSC is critical to understanding the function of the relationship between learning with different mathematical tools, attitudes towards mathematics, and mathematics achievement.

Yaratan and Kasapoğlu (2012) state that students' attitudes towards mathematics play an important role in mathematical achievement. Akin and Akin (2014) found developing positive attitudes towards mathematics courses increases students' achievement. The researchers stated a math student with negative attitudes and low motivation shows lower performance rates. Low performance rates within Common Core classes can be detrimental to the students' success beyond the class. Improving attitudes could possibly lead to higher performance rates. Yilmaz, Altun and Olkun (2010) found that attitudes are associated with the school, teachers, and teaching. Some of these factors that influence attitudes are teaching materials used by the teachers, teachers' classroom management, teachers' content knowledge and personality, teaching topics with real-life enriched examples, and other students' opinions about mathematics courses (Yilmaz, Altun & Olkun, 2010; Papanastasiou, 2000; Cater & Norwood, 1997).

In summary, attitudes can influence students' mathematics achievement and their performance, and they may ultimately have a lasting impact through their entire academic career. In the context of CCSC, therefore, it is important to examine how the use of new tools, such as simulation, can affect student attitudes.

Games and Simulations

Technological tools such as games and simulations can not only change students' attitudes towards math, but also provide teachers with tools that could be used to help enhance instruction. The use of simulations can impact students' behaviors in a positive way, such as achievement and personalized learning (Bonk, 2010; Flores, Inan, & Lin, 2013). This is important due to the need to increase students' attitudes in Common Core mathematics classes. Through the use of simulations, students can design situations through their learning processes and speeds, which leads to more success and accountability for students. This accountability and success provides teachers resources to help motivate students; from this motivation comes a sense of value. Researchers (Cheung and Slavin, 2013; Liao, 2007) have suggested that the use of internet programs, such as a simulation program, can lead to a more successful learning environment that surpasses traditional approaches.

Students use cell phones, tablets, computers, calculators, and other sorts of devices in and outside of the classroom. Researchers have found that students have a positive attitude towards computer use (Ozgen & Bındak, 2012; Tekerek, Yeniterzi, & Ercan, 2011). These positive attitudes can be translated to the mathematics classroom, allowing teachers opportunities to use technology to help with student learning. Students are more comfortable learning with computers and other devices such as graphing calculators (Durmus & Karakirik, 2006). Roschelle, Pea, Hoadley, Gordin and Means (2000) suggest four fundamental characteristics in cognitive research that can be improved through the use of technology: active engagement, participation in groups, frequent interaction and feedback, and connection to real-world contexts. Simulations could be a possible alternative teaching device for teachers to use. This would allow for student exploration in which the students have the opportunity to develop a deeper understanding of knowledge. De Jong & Van Joolingen (1998) define a computer simulation as a program that contains a model of a system or process. Alessi and Trollip (2001) define a simulation as a "model of some phenomena or activity that users learn about through interaction with the simulation" (p. 18). Simulations can be divided into two types: those containing conceptual models and those containing operation models.

Conceptual models hold concepts, principles, or facts relating to what is being simulated. Operational models include cognitive and noncognitive procedures that can be applied to simulated systems. Examples of conceptual models are found in the field of economics (tutoring systems) and physics, whereas operational models can be found in science fields such as radar controls. Simulations rely on scaffolded practice, teacher coaching and feedback, and reflection through the learning process (Duffy & Cunningham, 1996; Quinn & Conner, 2005). Prensky (2001) presented a number of definitions for simulations such as "any synthetic or counterfeit creation, the creation of an artificial world which approximates the real one, something that creates the reality of the work place (or whatever place), a mathematical or algorithmic model, combined with a set of initial conditions, that allows prediction and visualization as time unfolds" (p. 6). Prensky stated simulations are a genre of games. Rieber (2005) stated that unless there are directions about what the goal of the simulation is, the simulation is rather useless and is only used to explore certain topics or principles. Having a clear goal in the class is crucial for the application of simulations in different learning environments such as Common Core classes in mathematics.

Using simulations can be considered as a form of game if the simulation is being used in a meaningful way (Panoutsopoulos & Sampson, 2012). Echeverri and Sadler (2011) define gaming as the “use of electronic video technology and systems designed to enhance learning and meaningful play that incorporates teachable moments in simulated environments" (p. 46). Evidence has shown that using educational games in classrooms provides for student growth in mathematical concepts (Ke, 2014). Researchers have found that gaming promotes a positive impact on classes (Gee, 2007; Prensky, 2006, 2010). In the field of mathematics, researchers have found that gaming can increase students’ spatial reasoning (Corradini, 2011) and abstract thinking (Avraamidou, Monaghan, & Walker, 2012). According to Hwang and Chang (2011), there is a close relationship between games and simulations, which is sometimes called “simulated games.” Leemkuil and De Jong (2012) stated that simulation games are competitive and challenging in which an underlying goal must be met. These goals are met through challenging problems that require the students to think and manipulate until the ultimate goal is met. Razak and Connolly (2013) argued that the students transmit all actions of game play through simulated events on a computer. Different events change through different scenarios presented, which requires students to problem-solve and manipulate different situations. The manipulation of these situations is the opportunity where students develop conceptions of ideas and make theoretical connections between real-world and simulated events.

According to Dunham and Dick (1994), simulation technologies have the potential to affect the learning of mathematics, particularly in the area of functions. Some authors recommend the use of technology at all levels of mathematics instruction (Yushau, Mji & Wessels 2003; Goos & Bennison, 2007). Researchers have been striving to establish better methods of teaching and learning of mathematics by integrating new technological methods such as simulations (Berger, 2010; Liu, 2010). Mathematics simulations are used in gaming platforms, and most agree that simulations are considered a subset of games.

Games in mathematics can improve students' cognitive awareness, attitudes towards learning mathematics, and mathematical achievement (Ke, 2008). There are many researchers who propose that computer-based gaming can be effective in the learning environment because of the engagement of students and the active learning that occurs (Leemkuil & De Jong, 2012; Malone, 1980). Barab, Thomas, Dodge, Carteaux, and Tuzun (2005) found using games can promote a positive and engaging classroom environment and motivate students. Games can portray real-world events or parts of people's lives. This portrayal allows for the gamer to be more actively involved. Students' active role in the environment is critical for them to have a purpose in what they are learning. Fengfeng and Abras (2013) examined the use of gaming on students' attitudes. The researchers concluded that using gaming programs improved student engagement. Students found games fun and were more interested in working with the gaming programs. Lopez-Morteo, and López, (2007) discovered students using simulations were more willing to participate in mathematics classes and were more motivated and invested in their academic success. Students' engagement and emotional investment are a regular part of their participation in the use of simulations (Gleek, 2014; Stover, 2005). Students who participate in games and simulations as a part of their studies experience a personal attachment to the goals of the class (Gee, 2005). Katmada, Mavridis, and Tsiatsos (2014) found that students had positive experiences using simulations. Students were more comfortable, engaged, and interested in more difficult types of mathematics problems. Engagement in the classroom is important because it provides students with meaningful experience.

Research demonstrated that using simulated manipulatives improved student achievement (Ngan Hoe, & Ferrucci, 2012). Kebritchi, Hirumi, and Bai (2010), in a sample of 193 high school students, found that there were gains in student achievement in pre- and post-test scores in algebra classes. When students were interviewed, they indicated that games were more challenging, which made learning mathematics more interesting and enjoyable. Fengfeng, and Grabowski (2007) examined 125 sixth-grade students and the effects of graphing simulations in algebra classes, and they discovered game playing did promote test-based cognitive learning achievement. The researchers also stated that math gains in achievement lead to significant gains in attitudes. Moreno (2002) discovered that students who learn actively with symbolic, visual, and verbal representations show a deeper understanding of mathematical concepts. Students in the visual representations group had a larger mean pre/post-test gain than students not using visual representations.

Rey (2010) believes that there are different theories that can be applied using computer simulations such as the dual-coding theory, the cognitive load theory, or the cognitive theory of multimedia learning. Rey also believes that learning with simulations follows the Scientific Discovery as Dual Search (SDDS) model. This model uses two problem spaces: the hypothesis space and the experimental space. The hypothesis space contains all the rules that can be contained within the domain and the rules the learner can generate about the domain. The experiments performed with the domain are called the experimental space. Sometimes, computer simulations are used as learning environments for scientific discovery learning (de Jong & van Joolingen, 1998). For example, Kistner, Vollmeyer, Burns, and Kortenkamp (2016) examined 47 secondary science students using computer simulations and torque development. The researchers found significant evidence that students were able to create the correct amount of torque when they applied the computer simulations to help determine the correct design of the levers. Another study examined 78 middle school students and the up thrust of objects floating in water (Reid, Zhang, & Chen, 2003). The students made hypotheses about different up-thrust scenarios and tested their hypotheses using a computerized simulation. Reid, Zhang, and Chen (2003) found no significant differences between the pre- and post-tests and students applying their hypothesis-testing skills.

Simulations can be found in mathematics education, but the role of simulation use is different. In some research models, simulations were used as a manipulation of objects; in others, simulations were used to test theories (Gravemeijer & Doorman, 1999). It has been shown that simulations can impact achievement and can change students' attitudes towards mathematics. Moila (2006) argues that the use of mathematical simulations promotes learners' higher order thinking skills, helps learners to apply mathematical ideas to problem situations, develops learners' computation and communication skills, introduces learners to the collection and analysis of data, facilitates learners' algebraic and geometric thinking, and presents the role of mathematics in an interdisciplinary setting. These skills are critical within the CCSC because students need to explore foundational mathematics skills and apply mathematical theories to different situations. Although the Moilia (2016) study examined simulation in algebra classes, his study only focused on basic algebra without considering advanced algebra courses like algebra 2. Finally, research has shown that simulations helped enhance students' motivation to learning and participation in the classroom.

While there are research studies that examine the impact in simulations in classrooms, a majority of those studies focus on other subjects such as physics. There are some research studies that have explored simulations in mathematics classrooms, but these studies were either conducted in primary grades, or in other areas of mathematics such as geometry or basic algebraic thinking skills, rather than advanced algebra lessons. None of those studies has explored simulations in the context of CCSC. This study therefore attempts to bridge this gap by investigating the potential impact of simulations on students' mathematics focusing on achievement and attitudes in advanced algebra courses in Common Core classrooms.

Theoretical Framework

Different learning theories have guided the integration of technology, in particular, simulations into mathematics classrooms. These learning theories are instrumental in the development of different learning environments. With the CCSC in place, mathematics teachers will need to apply different teaching methods in the classroom for students to be able to be successful in the Common Core environment (Coburn, Hill, & Spillane, 2016). These teaching methods will require teachers to use alternative instructional tools that could impact a student's achievement and attitude. This section starts with the discussion of the behaviorist perspective and shifts to a discussion on constructivism.

Without having the necessary basic skills, students will struggle with trying to progress through more advanced mathematical theory. Shapiro and Koren (2012) state that, to the behaviorist instructor, it is inconsequential how individuals think and make meaning. Behaviorist approaches rely on scripted lessons, which require students to follow the same approach for every single problem (Ewing, 2011; Stone, 2002). Too often, teachers fall into the trap of solving problems for students without allowing students to be the primary problem solvers, which can lend itself to behaviorist approaches (Von Glasersfeld, 1989). This approach is ineffective in the Common Core environment because lessons are supposed to be task oriented, in which students should be developing mathematical theories based off of situations rather than teachers using algorithms to instruct students.

A consistent theme involving computer simulations is the use of constructivist environments. Constructivism is defined "as how one constructs knowledge based on one's experiences, mental structures, and beliefs, which are used to interpret events" (Jonassen, 1991, p. 59). Cobb, Yackel, and Wood (1992) suggested that in the constructivist classroom, the teacher designs lessons based on students' past and present experiences. The students' past and present experiences bridge the understanding of what mathematical principles they are developing and allow for the development of problem-solving and mathematical reasoning abilities (Pugalee, 2001). Constructivist instruction focuses on students' current knowledge and contributes to cognitive and metacognitive strategies they already possess (Gales & Yan, 2001). There are two types of constructivism prevalent in the research involving simulations: cognitive constructivism and social constructivism. Cognitive constructivists emphasize learning activities that are discovery-oriented. Children can process and develop mathematics facts more quickly using what they already know as compared to what a teacher presents to them. The second type of constructivism is social constructivism. Social constructivists argue that students learn through their social interactions with other students (Eggen & Kauchak, 1993). Knowledge is constructed through the social interactions with others. Without these social interactions, the learner would have difficulty creating the knowledge needed, which in this case would be mathematical reasoning. Research suggests that collaboration is vital in understanding difficult concepts. Students working together create ideas on theories through the discussions they have with each other (Ampadu, 2013; Zain, Rasidi, & Abidin, 2012). Powell and Kalina (2009) stated that collaboration and social interaction are the keys to social constructivism. Since students will have to be socially active as they become older and graduate from school, it makes sense to prepare them for these interactions at an early age. Research suggests that there are positive benefits that exist in the incorporation of technology in a constructivist environment (Eyyam & Yaratan, 2014). Constructivism incorporates collaboration between individuals. Students become the central figure in the classroom, with the teachers taking on a more supportive or facilitator-based role. Mathematics teachers have to make use of a variety of instructional approaches that can allow students to build more robust understandings of mathematics.

Social constructivism centers on Lev Vygotsky's work. Vygotsky, who was a firm supporter of social interaction, believed there should be a sense of diversity in the classroom and that students should embrace the differences of others (Wormald, 2013). For example, Powell and Kalina (2009) suggested that some teachers believe talking in class is detrimental to learning. Vygotsky suggested that the chatter that occurs in class is important for critical thinking skills and the development of knowledge. It also allows students to build relationships and trust with others. Vygotsky (1981) stated "social relations or relations among people genetically underlie all higher functions and their relationships" (p. 163). Technology can bridge a gap of educational needs in the classroom. According to Gilakjani, Leong, and Ismail (2013), a positive effect bringing technology into the classroom is the collaboration between student and teacher.

Through the collaboration, students design and develop ideas that allow them to develop a true understanding of the principles being taught.

Bruner (1966, 1983) believed that people use information through an active process to create new possibilities on their own. According to Bruner, there are three modes of representing reality that occur: enactive, iconic, and symbolic. In mathematics education, the modes are often referred to as concrete, pictorial, and symbolic (Hatfield et al., 2000, p. 56). Researchers have found that using manipulatives, diagrams, and symbolic representations allow students to create a deeper understanding of math concepts and to be more actively engaged in the learning process (Carbonneau, Marley, & Selig, 2013; Manches, O'Malley, & Benford, 2010). The importance of student engagement with the use of manipulatives is relevant because students are now forced to construct their own knowledge and cannot rely on simple process-oriented mathematics. Students will have to apply the knowledge they have learned to real-world situations. Understanding the constructivist pedagogy is critical to examining a link between simulations and engagement. Student engagement is inherently prevalent in the social interactions between students. The use of simulations in classrooms is consistent with constructivist practices because simulations are used in environments in which students are actively engaged in problem solving and social relationships.

In a constructivist environment, using modeling is a technique often used by students and teachers. Ciltas (2013) defined mathematical modeling as the process of overcoming daily life problems. Using simulations as a tool for teachers allows students to model particular principles in the classroom. Mathematical modeling is an important tool used by teachers in today's classrooms. Dundar, Gokkurt, and Soylu (2012) stated that most mathematical modeling involves real-world situations that allow students to explore theories and principles and to apply these principles to other situations. Students can develop theories and strategies to solve problems through the use of exploration with mathematical models. A number of researchers (Redmond, Sheehy, & Brown, 2010; Takači, Takači, & Budinski, 2010) stated modeling allows students to make a prediction, test that prediction, and refine the prediction. Modeling is a scientific approach that is taught in every science classroom. It is an approach that some students struggle with because students are so used to the drill-and-practice approach from textbooks. Sekerák (2010) suggested that the ability students have with solving problems is connected to the modeling process demonstrated by their teachers. Modeling can be an effective strategy for teachers to use in the classroom because it allows students the opportunity to explore unique situations that cannot be represented through everyday situations (Doerr, Ärlebäck, & Costello Staniec, 2014; Hoskinson et al., 2014). Furthermore, research has found modeling can be effective in the development of concepts when used with technology (Hidiroglu & Guzel, 2013; Toptaş, Çelik, & Karaca, 2012). Neves, Silva, and Teodoro (2010) discussed that the modeling process can be made easier for students with programs such as Modellus, a java simulation program. By using the modeling process, teachers allow students to become better problem solvers and to become better thinkers when they leave the classroom. Having students model with simulations will allow students to develop a conceptual understanding of different mathematical theories and expand student knowledge. For this dissertation, lessons were developed to allow students that opportunity to model mathematical theories. Typically, children first learn to solve problems through modeling techniques (Carpenter & Fennena, 1992). The use of simulations applies modeling aspects to further help students with their understanding of mathematical concepts.

Research shows that the Cognitive Load Theory (CLT) is useful in the design and implication of simulations. Kalyuga (2011) stated that the CLT is “a learning and instruction theory that describes instructional design implications of a model of human cognitive architecture based on a permanent knowledge base in long-term memory” (p. 3). Kalyuga stated that based on Sweller’s work, the brain could only process a certain number of bits of information at a given time. Understanding how one organizes information can determine how one processes information. Kalyuga stated there are three types of cognitive load: intrinsic, extraneous, and germane. Hollender, Hofmann, Deneke, and Schmitz (2010) stressed that software programs should be designed to be easy to use in order to enhance the cognitive learning process. Software such as simulations should be user-friendly so there is not an overload on just learning how to use the software. If a user spends most of his or her time learning how to use the software, then it decreases the time of learning from the software.

Fong, Por, and Tang (2012) examined multiple simulations and the effects on student learning. The researchers’ background for the development of their study was around the Gagnes’ Information Processing Model and The Cognitive Theory of Multimedia Learning. The researchers used a single simulation presentation (SSP) model and a multiple simulation presentation (MSP) model. The researchers found the SSP to be more effective when used in the classroom. They found that there were positive results, and students were more interactive in the learning environment. Research has suggested that a deeper understanding of knowledge is greater from word and pictures than pictures alone (Dyer, Reed, & Berry, 2006). Words and pictures represent a visual representation of an object for students to use to develop a deeper understanding of knowledge because they are able to manipulate and change the position of the object. Kiili (2004) stated that one problem in multimedia learning materials is that the working memory capacity of learners is often overloaded. Sweller, van Merrienboer, and Paas (1998) stated the most important aspects of the cognitive load theory for educational game designers are extraneous cognitive load and germane cognitive load. Extraneous cognitive load is generated when information is presented and is under control of instructional designers (Chandler & Sweller, 1991). Germane Cognitive load is devoted to the processing, construction, and automation of schemas. In the development of games, it would be important to reduce the extraneous load and shift more towards the germane load. For example, in a study conducted by Chan and Black (2006), 198 students in seventh-grade science classes were studied to verify that learners may require different kinds of support to understand systems of varying degrees of complexity. In a series of written tests, verbal recalls, mental modeling tests (What-If scenarios), and transfer tasks, the study demonstrated that when a system was complicated, there seemed to be a relationship between a student's understanding of instructional content and the presentation format.

Demirbilek and Tamer (2010) stated that teachers often fear using computer games in class because of the fear of "losing control of the class." Some teachers complain about the technical aspects of the games or that gaming deviates from the lesson. Demirbilek and Tamer (2010) found that even teachers who might complain about management problems in the class felt there was some merit in using gaming in the classroom because of the interactivity students have with each other. In the CCSS-based classroom, teachers need to be aware that classes will be run in a different manner. The classes are instructed using a constructivist approach, which does not lend itself to the standardized class. Students will be involved and will interact with their peers, which will lead to the development of knowledge. Teachers teaching within the CCSS will need to have student involvement and will need to have students interacting with each other because classes will be instructed under an exploration approach (Kazakçı, 2013). Teachers will not lecture to students and will instead coach students through ideas and provide guidance that will lead to student understanding in the classroom.

When implementing technology into lessons, there needs to be organized objectives for the technology to be useful in instruction. Sabzian, Gilakjani, and Sodouri, (2013) found that just adding technology to a traditional approach of teaching does not enhance learning. Sabzian et al. (2013) suggested that in order for technology to be used in an effective manner, teachers need to look at what concepts they are teaching and how technology can benefit students. Sheehan and Nillas (2010) found that with teachers having a meaningful involvement of students using technology, students could make connections to the real world. Sheehan and Nillas (2010) suggested that in order for these connections to occur, the technology must be used in an effective manner. Research suggests that the positive effects of technology use in the classroom hinge on how well teachers implement the technology and the effectiveness of the technology used (Ozel, Yetkiner, & Capraro, 2008).

Learning theories play an important role in the development of curricula, lessons, and the determination of what technologies are appropriate to use at particular situations. Different learning theories are used in different situations depending on what the situation warrants. For rudimentary skills, the behaviorist approach seems to be the most prevalent theory found in the literature. For a deeper understanding of mathematical theory and more meaningful student interactions, the research shows the constructivist approach to be successful.

As discussed above, constructivism provides a valuable theoretical framework to guide the design of a meaningful learning environment to enhance students' learning of advanced mathematics with the support of technology that aligns with CCSC. This study therefore is grounded in constructivism in its design implementation and interpretation of the results.

Summary

Research has shown that mathematics instruction is evolving, but teachers need to take the time and embrace new approaches in the classroom. These approaches allow for student engagement and classroom discussion, and they motivate students to learn and explore new ideas. The old teaching methods used in the classroom are ineffective in the CCSC and do not allow for the exploration that students will need to develop mathematical theories.

Present research on simulations shows some positive signs of student engagement and allows for teachers to use an alternative approach in the classroom, but there is very little research that involves the Common Core and simulation use. This research would allow for simulations to be explored within a Common Core classroom. Research suggests that an alternative approach is necessary, but teachers have to be willing to use it in the classroom.

CHAPTER III. METHODOLOGY

The number of Common Core classes continues to increase, thereby causing changes in curricula and the delivery of instruction. With these changes in curricula, more courses need reformed tools to administer instruction aligned with the Common Core. Additionally, this study examined students' attitude changes in mathematics environments when using simulations.

This quantitative research study is a quasi-experimental design with non-equivalent groups that examines the impact of simulations on student achievement and attitudes. A quasi-experimental design examines the causal impact of an intervention on a target population (Shadish, Cook, & Campbell, 2002). This study uses a non-equivalent pre- and post-test control group design (Creswell, 2014, p.172). It is not feasible to randomly assign individual students to simulation/graphing calculator conditions; however, whole classes were randomly assigned. Pre- and post-tests were additional design features added on to the basic non-equivalent control group's design. Eight classes were randomly assigned into one of the two delivery methods: control (non-simulation taught) or treatment (simulation taught).

This chapter describes the research methods for this study and includes the following sections: research questions, sample, instruments, limitations and assumptions, research setting and procedures, pilot study and results, data collection and analysis, and summary.

Research Questions

In order to determine student achievement between control and treatment groups as well as any change in mathematical and technological attitudes, the research was guided by the following questions:

1. Does the use of computerized simulations impact students' mathematics learning as reflected in their achievement?

2. Does the use of computerized simulations change the mathematical attitudes (i.e., enjoyment, value, and motivation) of students compared to students not using simulations?
3. Does the use of computerized simulations change the technological attitudes (*i.e.*, confidence with technology, attitude to learning mathematics with technology) of students compared to students not using simulations?

Sample

This research study used a sample of convenience. The participants were a total of 225 students in algebra 2 classes. The ages of the participants ranged from 14 to 16 years old. Classes were selected and randomly assigned to either control or treatment groups. One-hundred and eleven participants participated in the control group, and 114 participants participated in the treatment group. Algebra 2 is the third required course for all students to take and pass. Success in algebra 2 means two things: the student has passed the course and can enroll in the next college-level mathematics class, and the student has received a passing score on the PARCC algebra 2 test, deeming them college and career ready. In order for a student to be declared college and career ready, a student must receive a minimum passing score on the PARCC assessment.

There are varying demographic and academic characteristics in this sample. Based on past enrollment, algebra 2 classes consist of 52% males and 48% female. Students' ethnicities in algebra 2 classes consist of: Caucasian (55%), African American (19%), Hispanic (6%), Asian (10%), and other (10%). Six percent of algebra 2 students receive Free and Reduced Meal Service (FARMS), and 10% of students enrolled in algebra 2 have either a 504 or Individual Educational Plan (IEP). IEPs and 504 plans are accommodation plans designed for students with disabilities that provide for modifications in the classroom towards a student's educational environment.

This research was conducted within the same subject (algebra 2) using the same lessons, same tests, and same scoring rubrics for the pre-/post-assessments. Meetings between the three instructors took place prior to the beginning of the study in order to train each on the different types of lessons. Teachers met with the researcher at the conclusion of each lesson to maintain consistency in all classes. The major difference among the classes was the use of simulations in the treatment group.

Effect Size

Effect size can be defined as either the standardized difference between two means or the correlation between the independent variable and the dependent variable. For this research study, Cohen's *d*, a type of standardized mean difference, was used to calculate the effect size. Cohen's *d* is calculated by dividing the mean difference by the pooled standard deviation, which is the weighted average of the treatment and control group standard deviations (Fritz, Morris, & Richler, 2012).

A review of literature was conducted to determine the appropriate effect size for this study. A total of three studies was identified that compared use of simulations versus not using simulations. These studies were selected because they utilized similar designs and methods to incorporate the use of computerized simulations in mathematics instruction. The effect sizes for studies comparing simulations versus not using simulations for instruction ranged from $d = 0.20$ to 0.52 (Akinsola & Animasahun, 2007; Hwang & Hu, 2013; Roseman & Jones, 2013). Based on these three research studies, a weighted average effect size was 0.41. This weighted average effect size was used to estimate the sample size necessary for the study to detect comparable effect size. Using the statistical tool G*power with a power of 80%, a significance level of 0.05, and a weighted effect size of 0.41, the sample size needed to detect a similar size effect is estimated to be 190 participants, with 95 students in the treatment group and 95 students in the control group (Faul, Erdfelder, Buchner, & Lang, 2009). For this study, a sample of 214 participants was used which exceeds the 190 participants calculated by the weighted effect size. The formula and calculations can be found in Appendix C.

Instruments

Four instruments were used to collect data for this study. Two instruments focus on students' attitudes towards mathematics, including mathematical and technological confidence and affective and behavioral engagement. The third instrument was the algebra 2 post-assessment of functional analysis. The fourth instrument was a demographic survey used to collect characteristics about the data groups (gender, ethnicity, and grade level). The two instruments used to collect data about students' attitudes were the Mathematics and Technology Attitudes Scale (MTAS) and Attitudes Towards Mathematics Inventory (ATMI) (Pierce et al., 2007; Tapia and Marsh, 2002). Eyyam and Yaratan (2014) stated when technology is used appropriately in the classroom, it can have a positive impact on students' attitudes towards mathematics. For this study, the MTAS was modified to include questions involving the use of simulations and mathematics.

Demographic Survey

For this research, a ten-question demographic survey (Appendix J) was created to gather information about the participants in the study. Questions 1–4 provided characteristics about the sample such as gender, age, class standing, and ethnicity. Questions 5 and 6 asked about previous mathematics classes taken and past assistance in mathematics (*i.e.*, through tutors, teachers, other students). Questions 7–10 provide information on computer use at home and in the mathematics classroom.

Mathematics and Technology Attitudes Scale

The MTAS examines the role of the students' attitudes towards learning mathematics, which is important in the process of learning mathematics (Pyzdrowski, et al., 2013). The survey includes 20 items, comprising five subscales: mathematics confidence (MC), confidence with technology (TC), attitude to learning mathematics with technology (MT), affective engagement (AE), and behavioral engagement (BE). Each item contains a statement about an attitude about mathematics and five response options that identify the frequency with which the participant engages in particular mathematics-related cognitions (Appendix L). An example of an item on the MTAS is as follows:

1. I concentrate hard in mathematics (BE)

a) Hardly ever
b) Occasionally
c) About half the time
d) Usually
e) Nearly always

Subscale scores were used as outcome measures. Pierce, Stacey, and Barkatsas (2007) report the maximum possible subscale score is 20 points, and the minimum subscale score is 4. The researchers report scores 17 or above to be high, indicating a positive attitude, 13–16 to be moderately high, and 12 or below to be a low score reflecting a negative attitude. Cronbach's alpha coefficients for each subscale were acceptably high, except for AE: MC, .87; MT, .89; TC, .79; BE, .72; and AE, .65 (Pierce & Stacey, 2004). Pierce, Stacey, and Barkatsas (2007) reported that "content validity and face validity of the scale are assumed by the development process" of the scale (p. 293). The statistical analysis from testing data indicates, "data satisfies the underlying assumptions of Principal Components Analysis and that together five factors (each with Eigen value greater than 1) explain 65% of the variance, with almost 26% attributed to the first factor, MC" (Pierce, Stacey, & Barkatsas, 2007, p. 294). Other researchers have evaluated the reliability of the MTAS as well. Shamoail and Barkatsas (2011) reliability analyses yielded satisfactory Cronbach's alpha values for each subscale of MTAS, indicating a strong or acceptable degree of internal consistency in each subscale. The lowest value was that of the MConf subscale (0.69); however, according to Hair, Black, Babin, Anderson, and Tatham (2006), they generally agreed upon the lower limit for Cronbach's alpha is 0.70. Hair et al. (2006) suggest that Cronbach's alpha coefficients for scales used in exploratory research are acceptable at 0.60 and larger. In a similar survey to the MTAS, Eyyam and Yaratan (2014) determined factorability to be sufficient and produced a Kaiser Meyer-Olkin Measure of Sampling Accuracy of .88, which was better than the cutoff value. Two tests run on over 57 items confirm that the Kasier Meyer-Olkin measure (.849 > .050) suggests that the correlation matrix is not an identity matrix, and The Bartlett's Test of Sphericity (p = .000 < .050) shows a high correlation between items (Kahveci, 2010). For this study, the MTAS was modified to include questions involving simulations and mathematics. Questions 17–20 were revised on the original MTAS to focus on simulations.

Reliability was tested on the pre- and post-MTAS scale for this study. For the pre-MTAS, Cronbach's alpha coefficients were acceptable on two of the four subscales: technology confidence, .73, and attitude to learning mathematics with technology, .82. Caution should be used with the subscale behavioral engagement, .61, and affective engagement, .45. For the post-MTAS, Cronbach's alpha coefficients were acceptable on three of the four subscales: technology confidence, .74; attitude to learning mathematics with technology, .75; and affective engagement, .74. Caution should be used with the subscale behavioral engagement, .61. These results are consistent with previous studies' reliability results on the MTAS except with the pre-MTAS score on affective engagement, which was .41.

Attitude Towards Mathematics Inventory

The ATMI was developed to investigate the underlying dimensions of attitudes in mathematics. The survey includes 40 items. The items follow a Likert-scale format: 1, strongly disagree; 2, disagree; 3, neutral; 4, agree; and 5, strongly agree (Appendix K). An example of an item on the ATMI is as follows:

After reading the choices, the participant selects his or her degree of agreement.

1. Mathematics is a very worthwhile and necessary subject.

    a) Strongly disagree
    b) Disagree
    c) Neutral
    d) Agree
    e) Strongly agree

Tapia and Marsh (2002) found that the ATMI was produced to measure six dimensions, but after an extensive item analysis, four factors were identified: self-confidence, value, enjoyment, and motivation. Each subscale was evaluated individually, and there was no total overall scale. Cronbach’s alpha coefficients were above 0.85 for all four subscales (self-confidence, .95; value, .89; enjoyment, .89; and motivation, .88) (Tapia & Marsh, 2004). For validity, a factor analysis was constructed for three, four, five, six, and seven factors with both three- and four-factor structures, resulting in good factor-loading matrices (Tapia & Marsh, 2002). The researcher found the four-factor structure provided the best structure fit, which accounts for 59.22% variance. Tapia and Marsh (2000) calculated a split half reliability of .85 and a Spearman-Brown reliability of .91. Content validity was constructed relating the variables (self-confidence, value, enjoyment, and motivation) using a three-factor model. Factor I, characterized as self-confidence, had a Cronbach alpha of .94; Factor II, characterized as enjoyment, had a Cronbach alpha of .89; Factor III, characterized as value of mathematics, had a Cronbach alpha of .84. In another test of reliability, Tabuk and Haciomerogu (2015) revealed that an adapted version of the ATMI was valid and reliable, measuring elementary preschool teachers' attitudes towards mathematics, and calculated a Cronbach's alpha of .79. Validity for the survey items was established through the use of principal axis factoring with oblique rotation (Forgaty, et al., 2001). The researchers found that the items defining the mathematical confidence factor had high loadings on this factor and showed no tendency to share variance with the other two factors. Correlations among subscale mathematical confidence were weakly related to computer confidence ($r = .19$, $p < 0.01$) and attitudes towards the use of technology in learning mathematics ($r = .17$, $p < 0.01$). Computer confidence and attitudes towards the use of technology in learning mathematics were moderately related ($r = .37$, $p < 0.01$).

Reliability was tested on the pre- and post-ATMI survey for this study. For the pre-ATMI, Cronbach's alpha coefficients were acceptable on three of the four subscales: self-confidence, .88; value, .82; enjoyment, .75. However, caution should be used with the subscale motivation, alpha=.63. For the post-ATMI, Cronbach's alpha coefficients were acceptable on three of the four subscales: self-confidence, .87; value, .81; enjoyment, .72. Again, caution should be used with the subscale motivation, alpha= .66. These scores are consistent with previous studies' reliability results on the ATMI except for the motivation scores, which were lower on this study's pre-/post-ATMI scores.

Algebra 2 Pre-/Post-Assessment

The algebra 2 post-assessment was designed to assess students' mastery of functions: quadratic, piecewise, and exponential. Using the County's curriculum and the McDougal textbook assessment manual, questions were selected to meet the content standards that must be covered in accordance to the County's curriculum. A team of two teachers, along with the researcher, developed and modified questions. Table 1 below states how each question fits in accordance to the County's curriculum. The pre-/post-assessment focuses on graphing functions, identifying specific graphical principles, and application of graphical functions.

In an effort to validate these assessment items, pre-/post-assessments were sent to three math experts for feedback. A questionnaire asked the experts about their teaching background as well as specific questions on the pre-/post-assessments in terms of difficulty, length, fairness, and coverage of objectives. The experts are teachers with an average of 18.5 years of high school experience. The experts made comments on the questionnaire concerning the assessments' length, content, and repetition of certain questions. There were also comments about questions being similar to questions that are administered on the PARCC assessment. Based on this feedback, the assessments were modified and administered during the pilot study.

When these exams were administered, the students were allowed to use pencil, scrap paper, and calculator, but no notes or textbooks were allowed. A scoring key was designed for teachers. The number of correct points was divided into the total points and converted to a percentage for the assessment grade. Pre-/post-assessments were double scored with two other scorers to check for agreement and consistency in scoring.

Table 1

County's Standards for Assessments

Content Standard	**Pre-/Post-Assessment**
F.IF.B.4 For a function that models a relationship between two quantities, interpret key features of graphs and tables in terms of the quantities, and sketch graphs showing key features given a verbal description of the relationship. *Key features include: intercepts; intervals where the function is increasing, decreasing, positive, or negative; relative maximums and minimums; symmetries; end behavior; and periodicity*.	Question #1, Question #2
F.IF.C.9 Compare properties of two functions each represented in a different way (algebraically, graphically, numerically in tables, or by verbal descriptions).	Question #3, Question #5
F.IF.B.5 Relate the domain of a function to its graph and, where applicable, to the quantitative relationship it describes.	Question #2, Question #5

Note: This table represents how each question aligned on the Algebra 2 Assessment is aligned to the Content Standards.

Limitations and Assumptions

This research was conducted in an attempt to control for as many factors as possible. The attempt was to use the same approaches in the simulation-instructed classes (resources, teaching procedures, lesson plans, and assessments) as compared to the non-simulation classes, with the only difference being the use of simulations. This study acknowledges the following limitations.

To increase sample size, algebra 2 classes were used, and students in different classes were recruited. While every effort was made to ensure all materials and presentation methods remained the same, there could still be some differences in instruction with multiple instructors teaching the courses.

Due to the need for a specific population of students (algebra 2) to prevent undercoverage, the researcher used a sample of convenience, so results may be biased and may not be able to be reproduced.

There were concerns over measures of the instruments used for this research. There have been very few articles that discuss the validity of the MTAS. Pierce et.al. (2007) stated that there are other instruments that can measure mathematical abilities, but each has its own faults from being too time consuming, outdated, or too long. The MTAS (Pierce et al., 2007) shortens administration time and allows for a simple way to monitor students' confidence and attitude with technology, along with students' engagement in learning mathematics.

Chamberlin (2010) stated the ATMI has been innovative because it incorporates confidence, anxiety, value, enjoyment, and motivation into one document. The original 49-item instrument reported a reliability of .96, but the altered 40-item instrument reported a reliability of .97. Chamberlin (2010) stated that although the mathematics community has not accepted this instrument, its long-lasting effects may not be realized. Through a comprehensive search through the literature, it was determined that the MTAS and ATMI were the best instruments to be used to measure the mathematical and technological attitudes of students.

There were concerns of bias that could occur in the classroom such as instruction, unforeseen instances, technology issues, and time frames of the classes. To help control these biases, the researcher constantly observed classes to make sure teachers followed the scripted lessons. Another concern is the amount of technology that was available for the students. Most classes range from 28 to 33 students. Labs only contained a maximum of 28 computers. Some laptops were brought into those labs to accommodate the size of the classes. Lastly, students are not used to having mathematics instruction in a computer lab. To make sure students were comfortable, the week before the study teachers of the classes took their students into the labs for mini-lessons. This allowed students and teachers to become more familiar with the setting.

Research Setting and Procedures

This study was conducted at a high school located in a suburban county in northeast US with an enrollment of 1,729 students. The ethnicities of students at the school include: 56.9% Caucasian, 19.6% African American, 9.5% Asian, 5.3% Hispanic, 0.3% American Indian, 0.2% Hawaiian, and 8.3% two or more races. A total of 90.2% of the faculty hold standard or advanced certificates in teacher certification. The school schedule is structured on a six-period day. Every day, the students have one period that rotates on an A-B day schedule, which consists of a time frame of 90 minutes, while all other classes are 50 minutes.

The mathematics department consists of 16 mathematics teachers ranging from 1 to 30 years of experience. The department also consists of three special education teachers who co-teach with the mathematics teachers in the three Common Core state-assessed classes: algebra 1, geometry, and algebra 2. The mathematics department offers 16 different classes ranging from algebra 1 to advanced mathematics. There are a variety of levels of mathematics classes offered from general and inclusion classes to gifted and talented and Advanced Placement classes.

The research occurred during the end of the second quarter in the winter of 2016 in the algebra 2 classes. Algebra 2 is a yearlong course required for students. For this study, the unit selected was function analysis. The study focused on quadratic, exponential, and piecewise functions. Algebra 2 extends the study of algebra 1, emphasizing linear, quadratic, exponential, logarithmic, polynomial, and rational functions. Algebra 2 classes vary in demographics (gender and ethnicity) and academic characteristics (on, above, and below grade level; repeaters; 504's; FARMS; and IEPs). Students enrolled in algebra 2 range from freshmen (2%), sophomores, (40%), juniors (55%), and seniors (3%). These distributions varied from class to class. In some cases, algebra 2 classes are co-taught with a special education teacher. Some algebra 2 classes include students with IEP and 504 plans. Having success in algebra 2 means that students have the prerequisite knowledge to move on to college-level mathematics courses (*i.e.*, pre-calculus, trigonometry, calculus, and statistics).

The students' parents completed the consent form (Appendix E) in order to provide permission for their child to participate in the study. If parental permission was not obtained, the student still participated in the lesson but did not complete any assessments or surveys. All students were informed of the research, invited to participate, and asked to complete a letter of assent. Students and parents were assured that participation or non-participation would not affect their course grade.

Teacher Training

Teachers went through lesson training prior to the study. In order to provide for a large sample, three teachers participated in this study. Teachers filled out the consent for participation in the study (Appendix D). Training was provided, so instruction was standardized. A training session was held after school for three days. During the training, teachers were given materials, reviewed the process and order in which lessons were taught, and were guided through the procedures of administering the assessments and survey instruments. The teachers used time to work through the graphing calculator and simulation websites. This ensured that teachers could maintain consistency across the delivery methods. To also ensure the consistency of instruction, the researcher observed teachers during class time to ensure all lessons followed the same plan as stated. Teachers also received and signed a validation form showing they attended the training and would follow the proper protocol for the study.

Teaching Procedures

On day one, of week one, control and treatment groups completed the demographic survey instrument (5 minutes), pre-MTAS (10 minutes), pre-ATMI (10 minutes), and pre-Algebra 2 Assessment (25 minutes). On the second and third days of class, control and treatment lessons completed the piecewise functions lesson. The piecewise lesson starts with a 5-minute warm-up followed by work individually with the guided notes involving piecewise function. The control group students used transparent paper, graphing calculators, and the guided notes packet. In the treatment class, students used the website http://www.simulation-math.com/GraphingCalculator1/AGraphingCalculator.cshtml and the guided notes packet. This portion of the lesson took 50 minutes on day two and 30 minutes during day three. At the conclusion of this lesson, both groups completed a three-question quiz that was scored and returned the next day.

On week two, day one consisted of both control and treatment groups beginning with the quadratic lesson. As in the first lesson, teachers were provided with a detailed lesson plan including problems and time frames for each portion of the lesson. Both groups completed a drill (5 minutes), the lesson activity of quadratic functions, and a quiz. The students were given two days to complete all of these tasks. The control group used a graphing calculator and graph paper along with the guided notes to complete this lesson. The treatment group used the computerized simulator http://www.simulation-math.com/GraphingCalculator1/AGraphingCalculator.cshtml and graph paper along with the guided notes. Both groups took 50 minutes on day one and 50 minutes on day two, followed by a quiz that was scored and returned the next day.

On week three, day one consisted of both control and treatment groups beginning the exponential lesson. Teachers were provided with a detailed lesson plan including practice problems and time frames for each portion of the lesson. In both groups, teachers started with a drill (5 minutes), the lesson activity on exponential functions, and a quiz. The control group used graphing calculators and the guided notes, and the treatment groups used the simulator http://www.simulation-math.com/GraphingCalculator1/AGraphingCalculator.cshtml and the guided notes. Both groups took 50 minutes on day one and 50 minutes on day two, followed by a quiz that was scored and returned.

At the end of week three, control and treatment groups completed the post-MTAS (10 minutes), post-ATMI (10 minutes), and post-Algebra 2 Assessment (35 minutes). Both groups were then debriefed about the study. Table 2 shows the common elements for control and treatment groups.

The control and treatment groups met either every day for 50 minutes or every other day for 90 minutes. The meeting times were predetermined by the county schedule at the beginning of the year. The teachers in both control and treatment groups used common materials, instructions, and examples in their lessons. Each lesson used the following format: drill, curriculum-based lesson instruction through an in-class activity, practice problems, and a quiz. If needed, teachers from both groups were available after school to provide students with extra time or more practice with concepts taught in the lesson. Teachers were provided with sign-in sheets to monitor students who received after-school help.

Table 2

Elements of Control/Treatment Groups

Common Elements (Control/Treatment Groups)	
Demographic Survey	
Pre-/Post-survey: Mathematics and Technology Attitudes Scale	
Pre-/Post-: Attitudes Towards Mathematics Inventory	
Lessons: Guided Notes, Transparency Paper, and Graph Paper	
Different Elements (Control/Treatment Groups)	
Control Group	**Treatment Group (Computer Simulation Only)**
Lesson #1: Piecewise Functions (Graphing Calculator)	Lesson #1: Piecewise Functions (Computerized Simulation)
Lesson #2: Quadratic Functions (Graphing Calculator)	Lesson #2: Quadratic Functions (Computerized Simulation)
Lesson #3: Exponential Functions (Graphing Calculator)	Lesson #3: Exponential Functions (Computerized Simulations)
Pre-/Post-Test: (Piecewise, Quadratic, & Exponential Functions: Using Graphing Calculator)	Pre-/Post-Test: (Piecewise, Quadratic, & Exponential Functions: Using Computerized Simulations)

Note: This table represents the layout of instruction between control and treatment groups.

Students instructed in the treatment group had computer access in class along with graphing materials (graph paper and transparency paper) to assist with the learning of each objective. Each objective had several activities to assist the students: teacher instruction, handouts, class notes, practice problems, and in-class examples. At the end of each lesson, students were given a quiz.

Students in both control and treatment groups had access to the same graphing materials, followed the same instructions, and used the same examples for drill problems, practice examples, and quizzes. The only difference between control and treatment groups was the use of simulations and graphing calculators. The control group used graphing calculators to assist in all three lessons and quizzes.

Through pre-teacher training and classroom observation from the researcher, every effort was made to ensure that the classes were the same except for the teaching tool used to instruct students. The researcher observed at the beginning of each lesson and remained in the class for 15 minutes. The researcher ensured that the lessons began correctly, technology was working, and that teachers had all necessary materials. If there were two classes going on at the same time, the researcher attended the first class at the beginning and then observed the second class midway through. The researcher also was available if the teacher needed any assistance. The researcher took notes on an observation sheet. The researcher used the general observation sheet designed by the school system for informal observations.

All groups used the same course layout and had the same amount of time to complete the class lessons, practice problems, and quizzes. Lessons were curriculum-based designed by the school system. These lessons were task-oriented. A lesson consisted with the start of warm-up reviewing the previous day's material. Once the warm-up was complete, the students were given a student-centered task, which they worked on in groups. There was no direct instruction from the teacher. The teacher was there to answer questions and provide support for the students. At the conclusion of each lesson, an informal quiz was given to the students for the teachers and students to have an idea of the understanding of the concepts. All quizzes were drawn from the same set of topics and questions, and they were timed. Both the pre- and post-tests were also created from the same test bank of questions and topics covered in each lesson. The pre-/post-assessments were identical in both control and treatment groups. These tests were timed, and both classes were given the same amount of time. In order to accommodate IEP/504 plans, special accommodations were made based on each student's individual plan. Lesson plans of the three lessons are located in Appendices F-H.

All of the students took the same pre- and post-assessment. The post-assessment covered all of the material in the function unit. The questions were scored on a scoring rubric, which was determined based on question difficulty. Both classes took the timed exam following the completion of all lessons. The researcher used a scoring key to score the assessments. After the post-assessment was administered, on the next day two surveys were administered to measure mathematics attitudes and technological attitudes. These surveys are the ATMI (Appendix K) and MTAS (Appendix L). The purpose of administration of these surveys is to determine a change in attitudes after the simulations have been used during the instruction. These surveys were administered separately by pencil and paper. Students had a maximum of 20 minutes each to complete both surveys. An application to the Instructional Review Board was submitted to both Towson University and the County's school system. Towson University's Institutional Review Board (IRB) for Research Involving the Use of Human Participants was approved on October 12, 2014 (Appendix A). The County's school system approved the study on August 29, 2014 (Appendix B).

Pilot Study and Results

A pilot study of this research was conducted in Fall 2015. The purpose of the pilot study was to determine if any logistical problems occurred during the study and if any modifications to the research design were needed.

The function algebra 2 lessons were taught in both treatment and control groups during the first quarter. One class in each environment was used in the pilot study with a total participation of 51 students: 25 in the control group and 26 in the treatment group. A total of 39 students participated in the study, a response rate of 71%. Both Towson University and Howard County Public Schools granted IRB approval.

Parental consent forms were administered the week prior to the beginning of the pilot study explaining the purpose of the study and what would be required of the participants. Once the approval was received, a cover letter was distributed to the students explaining the students' choice to participate and that it would not affect their course grade.

The three surveys in both treatment and control groups were completed within the first day of class. The three surveys completed produced a 100% response rate. The surveys were completed online. All students had access to the survey instrument. During the second day of class, both control and treatment groups completed the pre-assessment. Both classes finished the assessments in the allotted 50 minutes of class. Students in both treatment and control groups completed their lessons. Students in the control group used graphing calculators, and students in the treatment group used the computerized simulation. The next day, the students in both groups completed the post-surveys and post-tests.

Demographic information was analyzed on the participants. The average age in the control group was 16.5; the average age in the treatment group was 16.3. Gender differences were as follows: 8 females and 17 males were in the control group as compared to 13 females and 13 males in the treatment group. Class differences in the control group were 3 sophomores, 9 juniors, and 13 seniors as compared to the treatment group with 5 sophomores, 7 juniors, and 14 seniors. With a small sample, it is unclear if these differences are across the entire population or only for the participants of this study. Demographic information is located in Table 3.

Table 3

Demographics: Pilot Study

	Control (*n*=25)	Treatment (*n*=26)	*p*-value
Gender			
Male	17	13	.882[a]
Females	8	13	
Ethnicity			
Caucasian	12	14	.321[a]
Asian	1	3	
African American	6	5	
Hispanic	6	4	
Native American	0	0	
Other	0	0	
Age			.091[b]
13	0	0	
14	15	18	
15	10	8	
16	0	0	
17	0	0	
Class Standing			.221[a]
Freshman	22	20	
Sophomore	3	6	
Junior	0	0	
Computer Usage			
Watching Movies	16	15	
Music	14	20	
Internet	20	24	
Homework	19	19	
Homework Help	0	2	
Games	24	24	
Other	15	16	
Receive Outside Help			.222[a]
Yes	5	10	
No	20	16	

Note: a. Pearson chi-squared. b. 2 sample t-test.
*Note: *p< .001.*

Table 4

Adjusted Means Table: Pilot Study Learning Method

	Simulation			Non-Simulation			
	M	SE	N	M	SE	N	d
Pre-Piece	10.72	.17	26	10.70	.18	25	0.02
Post-Piece	10.10	.40	26	10.07	.51	25	0.01
Pre-Quad	5.51	.22	26	5.04	.22	25	0.43
Post-Quad	16.06	.31	26	16.17	.29	25	-0.07

*Note: *p<.001.*

Table 5

Adjusted Means Table: Pilot Study MTAS

	Simulation			Non-Simulation			
	M	SE	n	M	SE	n	d
Pre-Aff. Engagement	12.01	.30	26	11.10	.38	25	0.53
Post-Aff. Engagement	12.12	.28	26	11.20	.26	25	0.69
Pre-Beh. Engagement	15.01	.22	26	15.00	.21	25	0.01
Post-Beh. Engagement	15.55	.31	26	15.17	.24	25	0.28
Pre-Tech Confidence	14.11	.24	26	13.12	.27	25	0.78
Post-Tech Confidence	14.81	.24	26	13.74	.21	25	0.96
Pre-Math Tech.	11.74	.25	26	11.11	.27	25	0.49
Post-Math Tech.	12.20	.26	26	11.00	.28	25	0.90

*Note: *p<.001.*

During the pilot, two of three lessons were run, and pre- and post-assessment data were collected. Students completed a pencil and paper assessment in both simulation and non-simulation groups. There were no significant differences found on the piecewise or quadratics assessment subtest sections of the algebra 2 assessment. Students in both groups also completed pre- and post-ATMI and MTAS surveys. These surveys were collected using a survey tool by computer for both groups. There were no significant differences found on any of the subsections of each survey instrument. Results of achievement assessments, ATMI, and MTAS surveys are located in Tables 4 through 6.

Table 6

Adjusted Means Table: Pilot Study ATMI

	Simulation			Non-Simulation			
	M	SE	n	M	SE	N	d
Pre-Motivation	14.62	.28	26	14.01	.31	25	0.42
Post-Motivation	15.42	.29	26	14.77	.27	25	0.47
Pre-Value	33.41	.50	26	33.14	.51	25	0.15
Post-Value	33.52	.47	26	34.02	.46	25	-0.26
Pre-Self-Confidence	48.52	.80	26	47.12	.81	25	0.35
Post-Self-Confidence	48.78	.81	26	47.10	.80	25	0.42
Pre-Enjoyment	30.12	.51	26	29.56	.51	25	0.22
Post-Enjoyment	30.89	.52	26	30.01	.50	25	0.35

*Note: *p<.001.*

Through the pilot study, the researcher observed several things. Suggestions were made to the researcher to add lines between questions on the pre-/post-test. Also, suggestions were made to add more space on the lesson and add guided notes for students to fill in more information about the results they received from their work. It was also suggested to provide students with the opportunity to experiment with the simulator to make sure they were familiar with the device before the start of the lesson. Based on the suggestions, revisions were made accordingly. Data collection tools for the ATMI and MTAS were changed to pencil and paper due to incomplete responses on some of the online survey questions. This provided an easier process for collecting data in the dissertation study.

Data Collection and Analysis

Participants in this study completed a demographic survey and received a cover letter explaining the study. The instructor kept attendance records of students in class for control and treatment groups. This included information on students arriving late; leaving class for appointments, health issues, or restroom issues; or having an early dismissal. These data were used for the researcher to make generalizations about the demographics in the study such as gender, ethnicity, class standing, and age. Assessment scores for each lesson through quizzes, including pre-/post-tests, were also collected. All information was coded with a participant ID to maintain confidentiality.

Data were collected using pencil and paper, entered into an Excel spreadsheet, and analyzed in a statistical software package (SPSS, Version 22). Descriptive statistics were computed for pre-/post-test scores. Post-test comparisons, adjusting for pre-test performances, were made using ANCOVA, with pre-test scores as covariates and the simulation/graphing calculator group status as the treatment variable. Differences in students' mathematical attributes (enjoyment, value, self-confidence, and motivation) and technological attributes (confidence with technology, attitude to learning mathematics with technology, affective engagement, and behavioral engagement) were similarly analyzed with ANCOVA matching the appropriate pre-test with its respective post-test. The level of significance for all analyses was 0.05. A layout of the data and analysis method is located in Table 7.

For research question 1, an ANCOVA was run to analyze if there was a difference between the control and treatment groups in mean achievement post-scores controlling for covariance between achievement pre-scores and achievement post-scores. For research question 2, an ANCOVA was run to analyze if there was a difference between the control and treatment groups – more specifically, if there was a change in each one of the three mathematical attitudes (*i.e.*, enjoyment, value, and motivation). For research question 3, an ANCOVA was run to analyze if there was a difference between the control and treatment groups – more specifically, if there was a change in each one of the two technological attributes (*i.e.*, confidence with technology and attitude to learning mathematics with technology).

Table 7

Data Collection and Analysis

Data	Analysis
Demographic Survey	Mean, Standard Deviation, Range, Minimum, Maximum
Pre-/Post-: Mathematics and Technology Attitudes Scale	ANCOVA
Pre-/Post-: Attitudes Towards Mathematics Inventory	ANCOVA
Pre-/Post-Test: (Piecewise, Quadratic, & Exponential Functions: Using Graphing Calculator)	ANCOVA

Note: This table represents how each data collection tool will be measured with each statistical test.

Summary

This study examined differences in student achievement along with examining changes in students' mathematical and technological attitudes. Every effort was made to standardize all materials, assessments, and instructional techniques. Survey instruments were used to examine if students' attitudes towards mathematics and technology changed using simulations. A post-assessment was used to measure the students' achievement in the functions unit. A pilot study was completed. Based on the results of the pilot study, modifications were made prior to the study. Participation in the study was voluntary. For this study, 225 students were involved: 111 in the control groups and 114 in the treatment groups.

CHAPTER IV: RESULTS AND FINDINGS

The purpose of this research was to determine if there is a difference in students' achievement between control and treatment groups. In this dissertation, the control group was defined as classes that do not use simulations, and the treatment group was defined as classes that use simulations. This research also investigated if there is a difference in mathematical attitudes between control and treatment groups. Lastly, this research studies whether there is a difference in technological attitudes between control and treatment groups. Data were collected from students enrolled in algebra 2 classes at a Mid-Atlantic high school.

Students were placed in algebra 2 through the completion of prerequisite mathematics courses. A total of eight algebra 2 classes was selected to participate. Four classes were randomly assigned to the treatment group, and four classes were randomly assigned to the control group. Students' technological and mathematical attitudes were studied as well as differences in achievement within each group. This chapter consists of the following sections: descriptive statistics, research questions, and a summary.

Descriptive Statistics

During the demographic survey, data were collected on gender, age, class standing, ethnicity, previous mathematics courses taken, outside mathematic help received, having a home computer, how often a home computer was used, what the use of the home computer was for, and how often a computer was used in class. Data were collected during the units on attendance and pre- and post-tests. Two surveys were used to collect data on the students' mathematical attitudes and technological attitudes. Information will be presented for the entire sample and then for the specific groups.

Description of Respondents

Out of the total of 224 students enrolled in algebra 2, 224 agreed to participate in the study. However, four students transferred out of the class, and five students were absent from the lessons and exams, resulting in a final total of 215 subjects. The gender of the sample was 54.9% female and 44.7% male. The average age was 14.6 years old. Most of the students were Caucasian (60.9%) or Asian or Pacific American (24.7%), with 17 African American students (7.9%), 7 Hispanic students (3.3%), and 1 Native American student (.5%); the final 6 students had selected Other (2.8%). Participants were asked their class standing with 115 (53.5%) classified as freshmen, 98 (45.6%) classified as sophomores, and 2 (.9%) classified as juniors.

Information was also gathered on the mathematics background. Participants were asked, “Do you receive any outside mathematics help?” Of the 215 sampled, 32 (14.9%) said they did receive help outside of class compared to 182 (84.7%) who did not receive any help outside of class. When asked about prior courses the participants have completed, 116 (54%) of the participants completed at least one GT mathematics course before algebra 2.

Information was also gathered on the participants’ technology use. When asked if the participants had a computer at their home, 99.5% responded yes between both groups. Between both groups, the majority of participants use their computers for homework (96.8%) and the use of the internet (92.1%). Some participants classified the category "Other" (32.1%) for activities on the computer. These activities classified as Other included: Twitter (42%), Facebook (22%), Instagram (39%), Soundcloud (2%), and YouTube (54%). When asked the question, “How often do you use computers in mathematics classes?” 107 (49.8%) of the participants stated “never” to “one to three times a week,” 49 (22.8%) stated “ten to twenty times a week,” 34 (15.8%) stated "more then twenty times a week," and 23 (10.7%) stated "one to ten times a week." A breakdown of demographics is located in Table 8.

Table 8
Demographics

	Control (n = 109)	Treatment (n = 106)	p-value
Gender			.785[a]
Male	49	47	
Female	57	61	
Ethnicity			.433[a]
Caucasian	68	63	
Asian	26	27	
African American	5	12	
Hispanic	4	3	
Native American	1	0	
Other	2	4	
Age			.080[b]
13	1	0	
14	49	40	
15	54	66	
16	2	2	
17	0	1	
Class Standing			*.020[a]
Freshman	66	49	
Sophomore	40	58	
Junior	0	2	
Computer Usage			
Watching Movies	64	69	
Music	64	69	
Internet	99	100	
Homework	104	105	
Homework Help	4	8	
Games	44	45	
Other	34	35	
Receive Outside Help			
Yes	13	20	.216[a]
No	93	89	

Note: a. Pearson chi-squared. b. 2 sample t-test.

*Note: *p < .001.*

Description of Learning Groups

The students' classes were either assigned to the control or treatment groups. There was no significant difference in age by learning method [$t(213) = 1.72$, $p = .080$], with the treatment group (M = 14.67, SD = 0.562), and the control group (M = 14.54, SD = 0.555). There was no significant difference in gender by learning method [$\chi^2(1, N = 215) = 0.10$, $p = .785$]. There was a significant difference in class standing by learning method [$\chi^2(2, N = 215) = 7.78$, $p = 0.020$], with the treatment group having a larger percentage of freshmen (57%) as compared to the control (42%), but the treatment group had a larger percentage of sophomores (59%) compared to the control group (41%). When examining ethnicity by learning method, no significant difference was found [$\chi^2(5, N = 215) = 4.86$, $p = .433$]. When examining learning method by receiving help outside of mathematics class, no significant difference was found [$\chi^2(1, N = 215) = 1.53$, $p = .216$]. Finally, when examining learning method by number of previous mathematics classes taken, a significant difference was found [$t(213) = 5.60$, $p < .001$].

Summary of Descriptive Statistics

The sample for this study was taken from algebra 2 classes offering the method of instruction with simulations or not using simulations at a Mid-Atlantic high school. Since students were required to attend school and were assigned to a class, attendance for the classes was controlled. Both simulation and non-simulation groups had the same amount of instruction and assessment time. Both simulation and non-simulation groups took the same demographic survey.

Research Questions

This study focused on the impact of using simulations as a teaching tool in mathematics classes. The research also investigated the change in students' mathematical and technological attitudes when using simulations. This section contains the results pertaining to the research questions for this study: (1) Does the use of computerized simulations impact students' mathematics learning as reflected in their achievement? (2) Does the use of computerized simulations change the mathematical attitudes (*i.e.*, enjoyment, value, self-confidence, motivation, behavioral and affective engagement) of students compared to students not using simulations? (3) Does the use of computerized simulations change the technological attitudes (*i.e.*, confidence with technology, attitude to learning mathematics with technology) of students compared to students not using simulations?

Research Question 1

This section presents the results for Research Question 1: Does the use of computerized simulations impact students' mathematics learning as reflected in their achievement? Data used to answer this question came from students' pre-/post-test scores. Student achievement was examined on content and basic skills on: (1) the overall post-test, (2) piecewise functions test, (3) exponential functions test, and (4) quadratic functions test. It is important to note that the combined three subtests make up the overall test results. Four ANCOVA tests were conducted to examine possible effects. The overall success on a test is defined as scoring 60% or higher, showing a student achieved mastery of the topic. Achievement is measured by a change between pre-/post-test scores.

The first ANCOVA test was conducted on the overall test. When examining the learning methods, an analysis revealed a statistically significant effect of instruction group simulations and non-simulation groups [$F(1, 212) = 14.87$, $p < .001$, $d = 0.53$]. The simulations group had a higher overall score (M = 52.81, SE = 0.83) as compared to the non-simulation group score (M = 48.27, SE = 0.84). Through these results, it can be concluded that the simulation group had a greater achievement gain than the non-simulation group on their overall test. In an attempt to further analyze specific results, three subtests of the post-test were examined. When examining the subtest on piecewise functions, no significant differences were found between simulation and non-simulation groups [$F(1, 212) = 0.26$, $p = .610$, $d = 0.07$]. This result shows that the simulation groups had a similar achievement gain compared to the non-simulation group. When examining the subsection of exponential functions, there was a statistically significant effect of simulations [$F(1, 212) = 20.58$, $p < .001$, $d = 0.64$] involving the learning method. The simulation group did better on exponential test content (M = 19.15, SE = 0.47) than students who did not use simulations (M = 16.23, SE = 0.44). Finally, when examining the subsection on quadratic content, a significant effect was found for learning methods [$F(1, 212) = 4.32$, $p = .039$, $d = 0.28$]. The simulation group involving quadratic functions had a higher mean score (M = 20.66, SE = 0.38) than the non-simulation group (M = 19.55, SE = 0.38).

These results demonstrated that the use of simulation provided an increase in overall achievement for the simulation group compared to the non-simulation group. Statistically significant effects were found on the overall post-test. When breaking into three subsections, the quadratic and exponential functions also showed significant impact of simulation on students' achievement. Piecewise functions in the simulation group did not show a gain difference in achievement compared to the non-simulation group. Results of achievement scores are located in Table 9.

Table 9
Adjusted Means Table: Algebra 2 Assessment

	Learning Method						
	Simulations			Non-Simulations			
	M	SE	n	M	SE	n	*d*
Pre-Test Quad	6.80	0.28	109	6.92	0.22	106	-0.05
Post-Test Quad*	20.66	0.38	109	19.55	0.38	106	0.28
Pre-Test Piece	0.61	0.16	109	0.67	0.16	106	-0.04
Post Test Piece	12.92	0.49	109	12.56	0.50	106	0.07
Pre-Test Exp	4.45	0.27	109	5.13	0.27	106	-0.25
Post-Test Exp*	19.15	0.44	109	16.23	0.44	106	0.65
Pre-Test Final	11.80	0.43	109	12.79	0.43	106	-0.22
Post Test Final*	52.81	0.83	109	48.27	0.84	106	0.53

*Note: *p<.001*

Research Question 2

This section presents the results for Research Question 2: Does the use of computerized simulations change the mathematical attitudes (*i.e.*, enjoyment, value, self-awareness, and motivation) of students compared to students not using simulations? The categories of mathematical attitudes were defined by the survey instrument. Students' mathematical attitudes are examined from six different perspectives: (1) motivation, (2) value, (3) self-confidence, (4) enjoyment, (5) behavioral engagement, and (6) affective engagement. Six ANCOVA tests were conducted to examine possible effects. Data to answer this research question were analyzed examining students pre- and post-MTAS scores along with pre- and post-ATMI scores.

Motivation. When examining the mathematical attitude of motivation, there was a significant effect involving the learning method on the post ATMI [$F(1, 212) = 12.58$, $p = .001$, $d = 0.48$]; therefore, the simulation group's motivation towards mathematics had a greater adjusted post-ATMI score than the non-simulation group. There should be caution when examining the significant value due to a low Cronbach's alpha coefficients on the pre- and post-ATMI survey. The simulation group had a higher mean score of motivation (M = 17.43, SE = 0.29) than the non-simulation group (M = 15.97, SE = 0.29). Students in the simulation groups were more motivated in mathematics class as compared to the non-simulation group.

Value. When examining the mathematical attitude of value, there was a significant effect involving the learning method on the value section of the post-ATMI [$F(1, 212) = 22.68$, $p < .001$, $d = 0.68$]; therefore, the simulation group's value towards mathematics had a greater adjusted post-ATMI score than the non-simulation group. The simulation group had a higher average value score (M = 38.25, SE = 0.46) than the non-simulation group (M = 35.00, SE =

0.46). Students in the simulation group had a greater average value of mathematics compared to the non-simulation group.

Self-Confidence. Examining the mathematical attitude of self-confidence, an analysis revealed a significant effect involving the learning method on the post-ATMI [$F(1, 212) = 28.79$, $p < .001$, $d = 0.73$]. Therefore, the simulation group's self-confidence had a greater post-ATMI score than the non-simulation group. The simulation group had a higher average self-confidence score (M = 55.72, SE = 0.76) than the non-simulation group (M = 49.93, SE = 0.77). Students in the simulation group had a greater self-confidence of mathematics compared to the non-simulation group.

Enjoyment. In the examination of the mathematical attitude of enjoyment, there were statistically significant effects involving the learning method on post-ATMI [$F(1, 212) = 10.78$, $p = .001$, $d = 0.45$]; therefore, the simulation group's enjoyment towards mathematics had a greater adjusted post-ATMI score than the non-simulation group. The simulation group had a higher average enjoyment score (M = 33.91, SE = 0.47) than the non-simulation group (M = 31.70, SE = 0.48). Students in the simulation group had a greater enjoyment of mathematics compared to the non-simulation group.

Behavioral and Affective Engagement. When examining the MTAS in relationship to mathematical attributes, an ANCOVA test revealed no significant difference in behavioral engagement [$F(1, 209) = 3.38$, $p = .070$, $d = 0.17$] between simulation (M = 15.55, SE = 0.23) and non-simulation groups (M = 14.95, SE = 0.23). Therefore, simulations had no impact on a student's behavioral engagement compared to the non-simulation group. However, an examination of affective engagement revealed a significant effect involving the learning method on the post-MTAS [$F(1, 210) = 19.07$, $p < .001$, $d = 0.60$] between simulation and non-simulation groups. The simulation group had a higher average affective engagement score (M = 13.98, SE = 0.25) than the non-simulation group average score (M = 12.46, SE = 0.25). Therefore, the simulation groups' affective engagement increased compared to the non-simulation groups. There should be caution in interpreting the affective and behavioral results due to low Cronbach's alpha coefficients on the pre- and post-MTAS.

Through these results, the use of simulations provided an increase in attitude for all categories on the ATMI and one of the two subsections of the MTAS. Statistically significant effects were found on the ATMI on categories of motivation, value, self-confidence, and enjoyment. Significant effects were found on the MTAS in the category of affective engagement. However, on the MTAS, there was no significant effect in the category of behavioral engagement. Table 10 below shows the means of each subsection of the ATMI. Table 7 shows the results for the MTAS.

Table 10
Adjusted Means Table: ATMI

	Learning Method						
	Simulations			Non-Simulations			
	M	SE	n	M	SE	n	*d*
Pre-Motivation	15.70	0.31	109	15.82	0.31	106	-0.04
Post-Motivation*	17.43	0.29	109	15.97	0.29	106	0.48
Pre-Value	35.78	0.52	109	36.94	0.53	106	-0.21
Post-Value*	38.25	0.46	109	35.00	0.46	106	0.68
Pre-Self Confidence	49.61	0.85	109	51.75	0.86	106	-0.24
Post-Self Confidence*	55.72	0.76	109	49.93	0.77	106	0.73
Pre-Enjoyment	32.15	0.52	109	32.34	0.53	106	-0.04
Post-Enjoyment*	33.91	0.47	109	31.70	0.48	106	0.45

*Note: *p<.001*

Research Question 3

This section presents the results for Research Question 3: Does the use of computerized simulations change the technological attitudes (*i.e.*, confidence with technology, attitude to learning mathematics with technology) of students compared to students not using simulations? The categories of technological attitudes were defined by the original survey instrument. Students' technological attitudes were examined from two different perspectives: (1) confidence with technology and (2) learning mathematics with technology. Two ANCOVA tests were conducted to examine possible effects. Data to answer this research question were analyzed examining students pre- and post-MTAS scores.

When examining technology confidence between learning methods, there was no significant difference on post-MTAS [$F(1, 208) = 3.49$, $p = .063$, $d = 0.26$] between simulations (M = 14.80, SE = 0.25) and non-simulations (M = 14.15, SE = 0.25). Therefore, simulations had no effect on a student's technological confidence. When examining attitudes towards learning mathematics with technology between learning methods, there was no significant effect on the post-MTAS [$F(1, 208) = 0.66$, $p = .418$, $d = –0.12$] between simulation (M = 12.65, SE = 0.27) and non-simulation (M = 12.96, SE = 0.28) groups. From these analyses, learning methods do not impact a students’ attitudes towards mathematics with technology.

Through these results, the use of simulations did not impact on student attitudes towards technology. Statistically significant effects were not found on the MTAS on subsections of technological confidence and attitudes toward learning mathematics with technology. Table 11 provides the details of means for the MTAS.

Table 11
Adjusted Means Table: MTAS

	Learning Method						
	Simulations			Non-Simulations			
	M	SE	n	M	SE	n	*d*
Pre-Aff. Engagement	13.00	0.37	109	13.42	0.38	106	0.11
Post-Aff. Engagement*	13.98	0.25	109	12.46	0.25	106	0.60
Pre-Beh. Engagement	14.88	0.25	109	15.17	0.25	106	-0.11
Post-Beh. Engagement	15.55	0.23	109	14.95	0.23	106	0.17
Pre-Tech. Confidence	14.10	0.25	109	14.00	0.25	106	0.04
Post-Tech. Confidence	14.80	0.25	109	14.15	0.25	106	0.26
Pre-Math Tech.	12.74	0.26	109	13.14	0.27	106	-0.15
Post-Math Tech.	12.65	0.27	109	12.96	0.28	106	-0.12

*Note: *p<.001*

Summary

Students participating in the research were predominantly sophomores with an average age of 14.6. The majority of sophomores (N = 209) had already completed 2 years of high school mathematics. Only 15.3% received outside help beyond school. Over half of the sample were Caucasian (60.9%). There was also a larger number of females (55.4%) compared to males.

Based on this research, the learning environment does have an impact on student achievement. Statistically significant effects in the overall assessment reveal simulations helped increase student achievement. In addition, statistically significant effects were found within two of the three subtests (quadratics and exponential functions), which is why there is an overall effect on the post-test. These results demonstrate that simulations help students learn mathematics as reflected by their achievement scores.

The learning environment also has a significant impact on students' attitudes toward learning mathematics. A statistically significant effect was found in survey results when examining five out of the six mathematical attitudes; specifically, increases were found in motivation, value, self-confidence, enjoyment, and affective engagement. There were no statistically significant effects found in the area of behavioral engagement. Finally, this study also examined the possible impact of learning method on student technological attitudes. There were no statistically significant effects found in technological confidence and attitudes towards learning mathematics with technology. This indicates that learning method does not have any impact on the technological attitudes of students in this study.

CHAPTER V. DISCUSSION

The CCSC has changed the way students are instructed. Classroom instruction is more collaborative, student-centered, and problem-based. One challenge for most teachers is finding ways to create these types of environments in the classroom. This study provides teachers with a possible tool to use in the classroom: the simulation. The results of this study show that not only can simulations help with student achievement, the simulation can also help improve students' attitudes towards mathematics in Common Core classrooms.

A strong algebra 2 background is vital for students to be successful in advanced mathematics courses (Gamoran & Hannigan, 2000). Successful students should not only be able to find a solution to problems, but also be able to explain why and how solutions work (Abbas & Al-Sayed, 2016; Chang, Wu, Weng, & Sung, 2012; Shin, Sutherland, Norris, & Soloway, 2012; Kim, & Chang, 2010). Yet, algebra 2 students tend to struggle with finding solutions to complex problems as well as applying problem-solving processes to other mathematical situations. With a struggle in the problem-solving approach and more advanced mathematics, there often is a negative impact on a student's attitude towards mathematics. In this study, algebra 2 students were provided two different approaches. The simulation group not only achieved higher scores, but they also had a more positive attitude towards mathematics than the non-simulation group. The more positive attitude may help students to be more successful in the long run. These positive attitudes often continue into future classes.

This chapter summarizes and discusses the research results for this study and includes the following sections: research summary, discussion of results, recommendations for future research, and conclusion.

Research Summary

This study examined if there is a difference in students' achievement between simulation and non-simulation groups. Achievement was measured on a final post-test on algebra 2 functions, which consisted of three subtests: piecewise, quadratic, and exponential functions. Also, this study examined if the use of computerized simulations changes the mathematical attitudes (*i.e.*, enjoyment, value, self-confidence, motivation, and behavioral and affective engagement) of students as compared to students not using simulations. This was examined through the ATMI and MTAS surveys. It also examined whether the use of computerized simulations changed the technological attitudes (*i.e.*, confidence with technology, attitude to learning mathematics with technology) of students as compared to students not using simulations. This was examined through the MTAS survey. These results were used to determine if a difference exists in student achievement and mathematical and technological attitudes.

The study participants were enrolled in algebra 2 classes. The course was offered in a 50-minute period or a 90-minute block. The course was taught in a traditional environment for the control group and computer lab for the treatment group. A total of 215 algebra 2 students agreed to participate in the study with 109 control subjects and 106 treatment subjects. A total of three instructors participated in the study with a total of eight classes.

Four instruments were used to collect data for this study. The instruments were demographic survey, pre-/post-functions test, MTAS, and ATMI. The demographics data were collected on day one of class along with the pre-test functions test. The pre-ATMI and pre-MTAS surveys were collected on day 2. The piecewise lesson, quadratic lesson, and exponential lessons were each taught in 4 days. The students then took the post-test. On the last day, the students took the post-ATMI/MTAS surveys. All 215 participants completed all surveys and tests.

Demographic data were collected for all participants showing similarities in the learning environments. The overall average age for both the treatment and control groups was 14.6 years old, and no significant age difference between groups was found. As well, no significant difference was found regarding gender. No significant difference for race was found across learning environments; however, the majority of students were Caucasian or Asian or Pacific American, with a small amount of African American, Hispanic, and Native American students. The final students selected the category called “other.” Participants were asked their class standing, with the majority classifying as 115 freshmen or sophomores, and only 2 as juniors. There was a significant difference in class standing by learning method, with the treatment group having a larger percentage of freshmen as compared to the control; the treatment group had a larger percentage of sophomores compared to the control group. No differences were found for ethnicity, computer usage, receiving extra help, or number of mathematics classes taken. The pre-test score on the functions algebra 2 test was statistically significant, with the treatment group having the higher average score between both groups. Group demographic differences occurred because these groups were randomly selected. The groups have a mixture of different students determined by the school system.

Discussion of Results

This study was conducted specifically with a high school population. This section will discuss the impact simulations had towards mathematics achievement. Also discussed in this section will be the results of the effects of simulations on students’ attitudes towards mathematics and technology. This section will discuss the results in relation to the questions that guided this research.

Achievement Using Simulations

To respond to Research Question One, which focused on determining if there is a difference in students' achievement between control and treatment groups (simulation and non-simulation), four ANCOVA tests were run on three subtests of the post-test along with the overall post-test of the algebra 2 functions test. There was a significant effect in the overall post-test between simulation and non-simulation groups. The simulation group had a higher post-test average than the non-simulation group. A further analysis examined the subtests of the overall post-test. There was a significant effect in learning methods involving exponential and quadratic functions. The results of this study are consistent with the prior research on the effects of math games, including those reported by De Jong et al. (2012), Jimoyiannis and Komis (2001), Ke and Grabowski (2007), Kebritchi, Hirumi, and Bai (2010), Rosas et al. (2003), and Sedighian and Sedighian (1996). Their research suggested that computer math games may improve mathematics achievement. More generally, the results of this study also support findings from two meta-analysis studies. In the first meta-analysis, 32 empirical studies concluded that interactive simulations and games were more effective than traditional classroom instruction on learners' cognitive gains (Vogel et al., 2006). In a second meta-analysis, Dempsey, Rasmussen, and Lucassen (1994), who reviewed 94 empirical studies, concluded that students who played math computer games and attended the traditional classroom achieved higher mathematics scores than students who only attended traditional classrooms.

Results of this research show that students in the simulation classes performed better than students in the non-simulation classes. That is, students had a greater achievement gain using simulations; therefore, simulations could be used as an alternative teaching tool in the classroom. This finding is significant and worthy of further discussion. First, the data revealed that there was a gain in achievement in the areas of quadratic and exponential functions. However, there was not a significant gain in the area of piecewise functions. One possible explanation of this phenomenon is the order of the lessons being taught. The first lesson taught in the sequence of the three lessons (*i.e.*, piecewise, quadratic, and exponential functions) was piecewise functions. This is when the simulation group first started using the simulator. It is possible that since the students were still getting comfortable with the simulator, less efforts were devoted to the learning of the mathematics concepts (*i.e.*, piecewise function), and this might lead to the insignificant difference identified in their achievement. The results of this study are similar to the study by Kebritchi, Hirumi, and Bai (2010), in which their research showed a significant gain in achievement scores in video-based games involving 193 algebra and pre-algebra students. Their results indicated that motivation may have promoted students to perform better on understanding of concepts, allowing them to perform better on assessments. Specifically, using simulations could predict outcomes beyond what the lesson is teaching, which allows students to be more interested in expanding on their experiments. Through these experiments, the students were able to develop a deeper understanding of the basic principles in each lesson.

Second, as stated in Chapter 4, this study also shows that simulations had a positive impact on student attitudes, which will be discussed further in the next section. The positive impact of simulation on students' achievement may be contributed to the positive change of students' attitudes toward mathematics. That is, the simulations changed the students' perceptions of mathematics, which may lead to their improved mathematics learning as reflected in their achievement. Compared to the non-simulation groups, the simulation students were more interested in mathematics, enjoyed mathematics learning more, were more confident in their mathematical abilities, and held a higher value of mathematics. These may have reduced phobias students have. Too often, these phobias leave students with the attitudes that they cannot be successful (Suárez-Pellicioni, Núñez-Peña, & Colomé, 2016). This lack of success in turn may lead to poor grades and a negative attitude. With the positive experience through the use of simulations in this study, students' phobias might be reduced and they might feel more confident, which might lead to their increase in achievement (Panagiotakopoulos, 2011).

The implementation of Common Core has called for alternative approaches for students to be successful in the classroom (Boaler, 2016). Simulations could provide teachers with an approach that is meaningful and useful. Teachers often express their concerns of not having the time to find resources to assist in the teaching of mathematics (Swars, & Chestnutt, 2016). Not finding the time often leads to boring and dual lessons. In this study, the significant results provide teachers a teaching mechanism that can lead to increased achievement and also foster a positive environment, allowing students to develop a positive attitude about mathematics. Mathematics teachers not only strive for mathematics achievement, they also want their students to have a positive attitude that goes beyond the mathematics class.

Third, another possibility that the simulation group had a significant higher achievement gain as compared to the non-simulation group may be attributed to the increased engagement level of the students, including the enhanced social interactions among them. The simulations provided a tool that makes mathematics learning more efficient. The efficacy is reflected in two aspects. First, learning with simulations can save students time to do complex computations and manipulations. Students in the simulation group were also able to produce different examples besides the ones given because of the multiple graphing options that allow the user to save key features of graphs. In the non-simulation group, this feature was not available on the graphing calculator, which could have deterred students from exploring with other examples. Second, simulations allow students to organize, save, and manipulate data much easier. This provided more opportunities for students to interact with each other. For example, when students work in groups they can talk with each other and discuss possible solutions and approaches. They can come up with different hypotheses, test those hypotheses, and see the results of these tests immediately. Therefore, the simulations can offer opportunities for learners to discuss and interact with each other and with the content further. Such improved interactions may lead to enhanced understanding of mathematics. As discussed in Chapter 2, a guiding theoretical perspective of this study is social constructivism. As Vygotsky suggested, discussions that occur in the classroom are important to critical thinking skills and knowledge building. It also allows students to establish relationships and trust with others. Therefore, the efficiency provided by simulations may have contributed to an increase in students' interactions, which in turn may help enhance students' understanding of mathematics concepts.

Student achievement is an important area for mathematics teachers, administrations, and schools. Ultimately, the success of students, teachers, administrations, and school systems is measured by the achievement of students. This is important because of the scores students must receive on standardized tests for graduation and college and career readiness. Also, students' achievement in mathematics is important for students' success in more upper-level mathematics courses in college (Goodman, 2016). Mathematics achievement in U.S. classes consistently drags behind other countries from all over the world (Woessmann, 2016). U.S. national data reveal children in America tend to enjoy mathematics in primary grades, but when they advance through school this enjoyment tends to drop (Dossey, Mullis, Lindquist, & Chambers, 1988). A drop of enjoyment normally leads to a drop in achievement (Kaur, 2016; Milligan, 2016). Students need a high degree of success in mathematics for engagement in mathematics to seem worthwhile (Garcia et al., 2016). From the results of this study, simulations help with the students' achievement and also with students' affective engagement. Along with a change in achievement, it is also important for mathematics teachers to help guide students to have a more positive attitude toward mathematics.

Attitudes in Mathematics

In an effort to respond to Research Question Two, which focused on the attitudes towards mathematics, students completed two surveys in this study. The surveys measured mathematics attitudes (ATMI and MTAS) to determine if there were increases in motivation, value, engagement, self-confidence, behavioral engagement, and affective engagement. ANCOVA results were used to determine if there was a significant relationship between the students' scores on each instrument. This section will discuss the results from the two surveys.

Motivation. This study showed higher gain in motivation for students using simulations as compared to students not using simulations. The motivation section measures interest in mathematics and desire to pursue studies in mathematics (Singh, Granville, & Dika, 2002). In this research, a significant increase in motivation towards mathematics was found through the use of simulations. Research has shown that higher levels of motivation in mathematics can help with the decrease of math anxiety (Chang & Beilock, 2016). Those students less motivated may have a tendency to avoid math-related situations. Those students with high levels of motivation may have a greater chance to overcome negative situations in mathematics (Chen & Stevenson, 1995). In this study, simulations had a positive impact on students' motivations, which gauges students' interest in mathematics and could encourage students to have a further desire to study more about mathematics.

Attitudes towards mathematics and other school-related behaviors are flexible and can be changed through policy and changes in instructional practices. Positive attitudes can be inculcated through early success in mathematics and by integrating curricular and pedagogical changes (Zakaria, Chin, & Daud; 2010). Too often, teachers are stuck in the same procedural methods. This becomes boring and uneventful for students. Approaches such as teachers giving out worksheets in place of instruction in the classroom could cause a student to not be motivated to perform. In this study, the use of simulations showed students are more motivated to learn, which provides some additional evidence to support findings by Lopez-Morteo and Lopez (2007), Rosas et al. (2003), and Klawe (1998), who found game play using simulators may have a positive effect on math students' motivation. An increase in motivation could lead to a more positive environment for students and teachers. This positive experience could lead to students wanting to continue to learn in different areas. This current study also confirmed the results by Barkatsas, Kasimatis, and Gialamas (2009), which showed achievement in mathematics was associated with high levels of motivation. A lack of student motivation and engagement in academics has been an issue of concern to educators. There is a need to provide more information to students about mathematics/science subjects and their future use, which would stimulate further interest in mathematics and science (Burton, Kijai, & Sargeant, 2005).

Value. The current study showed students' value increased based on a significant effect between simulation and non-simulation groups. The increase of value is important in mathematics. The value of mathematics measures students' beliefs on the usefulness, relevance, and worth of mathematics in their lives now and in the future (Tapia & Marsh, 2004). Students having a higher value for mathematics could lead to more positive experiences in the classroom and future mathematics classes. Results from this study suggest that in math, classroom-level factors, such as the use of simulations, may play more of a role in determining changes in how students value mathematics. This study also shows that students who value mathematics believe that there is more meaningful knowledge to be gained in high school mathematics classes they are taking, even if mathematics is not their primary focus. This finding also agrees with the previous research of Orhun (2007), who concluded that students' attitudes towards mathematics are governed by their perceptions regarding the usefulness of mathematics and their confidence in their ability to learn it. Ma and Kishor (1997) stated that teachers tend to believe that students learn more effectively when they are interested in what they learn. When students are interested in what they learn, they tend to value what they learn (Köller, Baumert, & Schnabel, 2001). Students valuing mathematics is important for students advancing to upper-level mathematics classes. Past research clearly indicates that students' values are significant predictors of academic performance as well as their intentions to take future courses and subsequent enrollment in those courses (Yoon, Eccles, & Wigfield, 1996).

Self-Confidence. In the examination of self-confidence, there was a significant difference in post-survey results, indicating the simulation group had a greater increase in self-confidence towards mathematics. This study confirms results that an engaging mathematics lesson can lead to an increase in self-confidence (Awofala, 2014; Kloosterman, 1988). A greater level of self-confidence would mean a greater positive attitude for students (Nicolaidou, & Philippou, 2003). Having a higher level of self-confidence will lead to students advancing to higher level mathematics (Tella, 2007). According to Arem (2009), students with high mathematics anxiety levels engage in negative thinking about their self-ability. When working with mathematics, these students will exhibit less confidence through a problem-solving process (Lubienski, 2000). The present study has shown increased confidence in mathematics, which may result in a low anxiety regarding mathematics and can lead to a positive attitude towards mathematics and greater achievement. Students with high levels of confidence do not worry about learning difficult topics, expect good results, and feel good about mathematics (Hogan, 2016). However, students with low confidence expect mathematics to be difficult, are nervous about learning new materials, and worry more about mathematics than other subjects (Hart, 2016).

Enjoyment. Results of the research indicated a significant effect in post-survey results between learning environments when examining students' enjoyment. The simulation group had a greater increase in enjoyment in the classroom. Middleton and Spanias (1999) found that many students will agree that mathematics is important, but the interest in taking mathematics courses decreases as they progress through school. By the time students have reached college, they have already formed conclusions regarding their success in mathematics. In this study, student confidence with mathematics and their enjoyment for mathematics was also enhanced by the use of the simulations. This study's findings were similar to a study (Ma et al., 2016) where students reported that using simulators in algebra learned the concepts more easily, and the students felt they could accomplish more. They found simulators visualized many algebra concepts, differently compared to when students had to graph by paper and pencil, which made the work appear easier, and the students had a more enjoyable time in the classroom.

An increase in enjoyment means students are agreeing with statements such as liking mathematics, enjoying studying mathematics in school, and getting excited about mathematics. The enjoyment of mathematics category was designed to measure the degree to which students enjoy working with mathematics and attending mathematics classes (Ma, 1999). Classrooms with a positive learning environment enable teachers to best fulfill their teaching responsibilities and enable students to have enjoyable circumstances in the classroom. Teachers' goals should not simply be to make students happy. However, classrooms that are characterized by **enjoyment** of learning likely provide optimal grounds for overcoming obstacles and promoting positive development and achievement (Kiwanuka, et al., 2016).

Behavioral Engagement. There were no significant effects in behavioral engagement. Behavioral engagement encompasses the idea of active participation and involvement in academic and social activities and is considered crucial for the achievement of positive academic outcomes. These results contradict Oncu's (2007) research in which the researcher reported an increase in behavioral engagement through the use of simulations in educational games. Wilson et al. (2009) also stated that educational games can lead to a greater cognitive and emotional outcome. This research also contradicts a research study that shows educational game groups were more actively involved in the classroom than the non-game groups (Annetta et al., 2009). In this current research study, results are consistent with the results of Brom, Preuss, and Klement (2011), in which the researchers found that students were not more engaged in the courses that involve games compared to courses that do involve games.

Affective Engagement. There was also a significant effect in affective engagement between pre- and post-survey results. That is, simulation has a positive impact on students' affective engagement. Affective engagement includes students' reactions to school, teachers, peers, and academics, influencing their willingness to become involved in school work. Results from this study show that students in the simulation groups are more interested to learn new things in math, find mathematics more enjoyable, and have a higher sense of satisfaction when they solve math problems. These could lead to students who are trying to solve more problems or attempting more complicated problems, and who are willing to spend more time on mathematics learning. Students in the future may be willing to take more math classes. All of these could contribute to students' math achievement. The results confirm prior research on the effects of educational games on affective engagement (Charles et al., 2009; Clark et al., 2011; Echeverri & Sadler, 2011; Huizenga et al., 2009). This significant effect supports the claim by past research (*e.g.*, Charles et al., 2009) that educational games can improve student engagement and provide an increase in student achievement. Students are willing to experiment, fail, try again, and succeed. Students are using others to help with the problem-solving approach in the classroom. This is much better than some traditional classrooms in which the student is not engaged. In most traditional classrooms, teachers will present a problem and solution (Haycock, 1998). There is no experimentation on the student's part. Simulations allow the students to experiment and save work. Students can use those saved experiments to recreate other problems. Students can collaborate in groups and use one another to make educated guesses to solutions to mathematical tasks. This is important in the cognitive development of students. This is important in the development of mathematical theories and applying those theories to more complex situations (Schoenfeld, 1997).

This research confirms that affective engagement with mathematics increases student interest (Boaler and Greeno, 2000; Engle & Conant, 2002; Martin, 2009). Having engaging classrooms also offers students opportunities to engage with authentic mathematical work, rather than simply rehearse procedures that they may never need or use again. The results also supports that simulations are more engaging than traditional activities (Rieber, 1996). When students struggle with mathematics, a common practice is to give easier work rather than to change the methodology of teaching the lesson (Kazemi & Franke, 2004). Sometimes, giving easier work can increase students' disengagement in the classroom (Matsumura, Slater, & Crosson, 2008). This study showed that the use of simulations leads to an increase in engagement in the simulation-taught classes.

Another factor that can lead to an increase in engagement is the challenge students face with multiple situations offered by the simulations. By challenging students with multiple situations, there can be an impact on the students' engagement (Bishop & Kalogeropoulos, 2015). In this study, students with improved mathematics achievement may lead to high levels of mathematics confidence; strongly positive levels of affective engagement appear to have a positive attitude to learning mathematics with simulations. This current research supports previous work (Ma & Kishor, 1997; Singh, Granville, & Dika, 2002), which suggests that using simulations can increase mathematics engagement.

Many research studies (Pareto, Haake, Lindström, Sjödén, & Gulz, 2012; Divjak, & Tomić, 2011; Kebritchi, 2008) in game-based learning literature have confirmed students enjoy learning more and are more interested in learning when they use games. Some studies examine students' interest using simulations in a primary setting (Bitter, Puglisi, Gorges, & Uppal, 2016; Ke, 2006). While some studies examine students' engagement in other areas, such as science (Rutten, van Joolingen, & van der Veen, 2012; Rodrigues, S. (2007), this research adds to the existing literature of games-based learning that simulations can be an effective tool to help with students' affective engagement in algebra 2 classes in the context of CCSC.

Technological Attitudes

In an attempt to respond to Research Question Three, MTAS results were examined. The focus of this examination was students' confidence with technology and attitude to learning mathematics with technology. Pre- and post-surveys were given to both simulation and non-simulation groups.

When examining confidence in technology, there was no significant effect involving learning methods. This contradicts research that suggests students' attitudes towards technology could change positively or negatively with the use of technology (Elliott, Oty, McArthur, & Clark, 2001; Pierce, Stacey, & Barkatsas, 2007). A further examination was done for learning mathematics with the use of technology. There was also no significant effect on students' attitudes towards learning mathematics with technology.

The findings of no significance towards the technology attitudes could be explained differently. A possible explanation for this finding may be lifelong exposure to technology (Cress, 2013; Prensky, 2008) unique to this generation. If technology has become as commonplace in their lives as Prensky (2008) described, then it appears as though they would have an overall favorable view of their technology abilities. Though technology might be common outside of the classroom, technology such as computer use might not be a common everyday practice in school, especially in mathematics classes. Mathematics classes, traditionally, are not in computer labs and are not using computer simulations to explore theories. In addition, students are not having these exposures on a regular basis; this could be an explanation of having an unfamiliarity that makes technology use not as conformable in the classroom. Perhaps another reason for no significant effect is the lack of technology use in the classroom throughout the year. This lack of use could be due to the setup and age of the computers in the learning environment; the use of technology becomes cumbersome. This could also be due to the lack of confidence teachers have towards the use or effectiveness of technology. Since students are not familiar with using technology in their classroom, the use of the simulations over this short time could not have any long-term effect. Students could simply view the use of simulations as simply something different, but they know they will be going back to the old ways in the classroom.

Limitations and Recommendations for Future Research

The results of this study showed that students performed better in the simulation-learning environment. During the analysis, several questions were developed. These questions show a need for further research within the areas of achievement, learning environment, and attitudes in math and technology.

Achievement. There were significant results of the overall test along with significant effects in the subsections of quadratic and exponential functions. Future research can focus on more specifics involving factors such as gender and ethnicity. Many school systems want to focus more on the achievement of student subgroups rather than generalizing students as a whole. Since teachers are often asked to improve subgroups of the students they teach, it is worthwhile providing information to teachers if simulations impact these subgroups.

Due to the nature of the environment, the researcher did not warn students to not talk with each other across the simulation and non-simulation groups. However, this could potentially create treatment diffusion (Trochim, & Donnelly, 2001). For example, students could discuss between simulation and non-simulation groups what has happened within classes. Students in non-simulation groups could then feel it is unfair that they are not allowed to use simulations. This could lead to a shutdown in class and affect the statistical results. If treatment diffusion occurs, then that could lead to significant results for all topics examined. However, the results of this study show there are some topics (*e.g.*, quadratic functions) with a significance in gains but other areas without significance in gains (*e.g.*, piecewise functions). Therefore, the treatment diffusion did not occur.

Also, this study only examined one area in mathematics. When examining achievement, other areas of mathematics are recommended to be studied due to the significant effects found in the study. It is also worthwhile to note this study only examined algebra 2 students. More information should be gathered on the impact of simulations in other subject areas such as language arts and social studies. Another potential area is to focus on if social interactions are affected with the use of simulations. These interactions could be examined in a qualitative study.

Attitudes Towards Mathematics and Technology. This research did not show a significant change in students' attitudes towards technology. Further research should be gathered to examine the impact of simulations and the attitudes of students in different subgroups. There was a positive effect for all attitudes towards mathematics. An examination of these attitudes within different types of mathematics could be useful. In addition, a longer term study might yield different results. This study was done over a 3-week period using only three areas of functions to gauge a change in students' attitudes. A more in-depth look at the students' change in attitudes over a longer time frame might get different results. Also, possibly interviewing students afterwards to have them discuss their feelings might give different results rather than them filling out a survey. Since this is a quantitative study, a qualitative study could be performed to gather more perceptions from teachers of their feelings on the effectiveness of simulations and students' attitudes. This would be helpful to understand students' feelings through interviews and would assist the researcher in making themes about the use of technology.

Conclusion

This research showed that using simulations can lead to an increase in student achievement in mathematics. Further, using simulations can lead to a positive change of students' attitudes towards mathematics. In this study, there was an increase in a student's motivation, engagement, value, and self-awareness. Results from this study suggest that involving simulations in classes can allow high schools other opportunities to increase student achievement in mathematics. It could lead to more engaged students who are motivated to learn in mathematics classes.

This study impacts the field of mathematics theoretically and practically. The results of this study provide teachers in the field of mathematics with an alternative tool to use in the classroom. Simulations provide for an improvement in achievement and also allow for an increase in students' attitudes in mathematics. Too often, teachers are challenged with classes of unmotivated students. These students are not only unmotivated by their dislike of mathematics but also by their possible low ability (Asikhia, 2010). Simulations as shown provide an opportunity for teachers to provide a tool for students to not only enjoy mathematics but also improve mathematical ability. Simulations allow teachers a tool to use in classes that can help change a teacher-centered classroom into a more student-centered classroom (Jacobs, Renandya, & Power, 2016). Through this study, simulations help high-level mathematics and may also provide teachers with the opportunity to have a more student-centered classroom through the use of task-oriented lessons, which is promoted through the Common Core. Having a student-centered classroom lends instruction to be more task-oriented and makes the student the center of instruction. These instructional principles are principles that should be implemented in every classroom today to provide students the best opportunity to construct their own knowledge.

Practically, this research suggests how simulations can be helpful to teachers. First, teachers have an alternative tool, simulations that can be used to teach students mathematics. This research proved that simulations can improve student achievement. Teachers now have a tool that can assist in the academic success of students in the classroom. Second, simulations allow for students to have a greater appreciation of mathematics through their attitudes in mathematics. A teacher can now have a tool that increases the confidence students will have in the classroom, increase the value students have towards mathematics, and allow for mathematics to be more enjoyable for students. Finally, simulations provide students a tool that can take a theoretical principle such as functions and apply the principle in different situations with ease. For example, the student now has the luxury to take a quadratic or exponential function, manipulate the function, and develop characteristics about this function. The student can, in turn, save the data and apply them to a different function set. These are characteristics that are not available or limited on other pieces of technology. Simulations provide teachers a tool that allows for enjoyable mathematics and can expand students' knowledge, which in turn can be applied to more upper-level mathematics classes.

REFERENCES

Abbas, S., & Al-Sayed, R. (2016). A Program Based on Developmental Mathematics Approach to Develop Higher Order Mathematical Thinking Levels and Mathematics Appreciation for Primary Stage Students. *Education, 136*(3), 378-390.

Abbasi, S. J., & Iqbal, K. (2009). How learning and teaching of mathematics can be made interesting: A study based on statistical analysis. *International Journal of Mathematical Education In Science And Technology*, *40*(4), 505-515.

Aiken, L. R. (1970). Attitudes toward mathematics. *Review of educational research*, *40*(4), 551-596.

Akin, A., & Akin, U. (2014). Investigating predictive role of 2x2 achievement goal orientations on math attitudes with structural equation modeling. *Egitim ve Bilim*, *39*(173).

Akinsola, M. K., & Animasahun, I. A. (2007). The effect of simulation-games environment on students achievement in and attitudes to mathematics in secondary schools. *Online Submission*, *6*(3).

Alessi, S. M., & Trollip, S. R. (2001). Multimedia for learning. *Methods and Development, 3*.

Alper, A., & Gülbahar, Y. (2009). Trends and issues in educational technologies: A review of recent research in TOJET. *TOJET: The Turkish Online Journal of Educational Technology*, *8*(2).

Ampadu, E. (2013). Aspiring mathematicians: Students' views regarding what it takes to be successful in mathematics. *International Journal for Mathematics Teaching And Learning.*

Annetta, L. A., Minogue, J., Holmes, S. Y., & Cheng, M. T. (2009). Investigating the impact of video games on high school students' engagement and learning about genetics. *Computers & Education*, *53*(1), 74-85.

Anderman, E. M., Eccles, J. S., Yoon, K. S., Roeser, R., Wigfield, A., & Blumenfeld, P. (2001). Learning to value mathematics and reading: Relations to mastery and performance-oriented instructional practices. *Contemporary Educational Psychology*, *26*(1), 76-95.

Arem, C. (2009). *Conquering math anxiety*. Nelson Education.

Asikhia, O. A. (2010). Students and teachers' perception of the causes of poor academic performance in Ogun State secondary schools [Nigeria]: Implications for counseling for national development. *European Journal of Social Sciences*, *13*(2), 229-242.

Aud, S., Fox, M. A., & KewalRamani, A. (2010). Status and trends in the education of racial and ethnic groups. NCES 2010-015. *National Center for Education Statistics*.

Avraamidou, A., Monaghan, J., & Walker, A. (2012). Abstraction through game play. *Technology, knowledge and learning: Learning mathematics, science and the arts in the context of digital technologies*, *17*(1-2), 1.

Awofala, A. A. (2014). Examining personalisation of instruction: Attitudes toward and achievement in mathematics word problems among Nigerian senior secondary school students. *International Journal Of Education In Mathematics, Science And Technology*, *2*(4), 273-288.

Barab, S., Thomas, M., Dodge, T., Carteaux, R., & Tuzun, H. (2005). Making learning fun: Quest Atlantis, a game without guns. *Educational Technology Research and Development*, *53*(1), 86-107.

Barkatsas, A. T., Kasimatis, K., & Gialamas, V. (2009). Learning secondary mathematics with technology: Exploring the complex interrelationship between students' attitudes, engagement, gender and achievement. *Computers & Education*, *52*(3), 562-570.

Barkatsas, A., & Malone, J. (2005). A typology of mathematics teachers' beliefs about teaching and learning mathematics and instructional practices. *Mathematics Education Research Journal*, *17*(2), 69-90.

Battista, M. T. (1999). The mathematical miseducation of America's youth: Ignoring research and scientific study in education. *The Phi Delta Kappan*, (6). 424.

Berger, M. (2010). Using CAS to solve a mathematics task: A deconstruction. *Computers & education*, *55*(1), 320-332.

Bishop, A. J., & Kalogeropoulos, P. (2015). (Dis) engagement and Exclusion in Mathematics Classrooms—Values, Labelling and Stereotyping. In *Diversity in mathematics education* (pp. 193-217). Springer International Publishing.

Bitter, G. G., Puglisi, J., Gorges, A., & Uppal, H. K. (2016). The effects of an online collaborative elementary math program using team-based games to improve student math achievement, attitude and motivation. *International Journal for Innovation Education and Research*, *4*(7).

Boaler, J. (2016). Designing mathematics classes to promote equity and engagement. *Journal of Mathematical Behavior*, (41), 172-178.

Boaler, J. (2002). *Experiencing school mathematics: Traditional and reform approaches to teaching and their impact on student learning*. Routledge.

Boaler, J., & Greeno, J. G. (2000). Identity, agency, and knowing in mathematics worlds. *Multiple perspectives on mathematics teaching and learning*, 171-200.

Bonk, C. J. (2010). For openers how technology is changing school. *Educational Leadership*, *67*(7), 60-65.

Borko, H. (2004). Professional development and teacher learning: Mapping the terrain. *Educational researcher, 33*(8), 3-15.

Brom, C., Preuss, M., & Klement, D. (2011). Are educational computer micro-games engaging and effective for knowledge acquisition at high-schools? A quasi-experimental study. *Computers & Education*, *57*(3), 1971-1988.

Bruner, J. S. (1966). *The process of education*. Cambridge, Harvard University Press.

Bruner, J. S. (1983). Education as social invention. *Journal of Social Issues*, *39*(4), 129-141.

Buckley, L. A. (2010). Unfulfilled hopes in education for equity: Redesigning the mathematics curriculum in a US high school. *Journal of Curriculum Studies*, *42*(1).

Burns, M. (2013). Go figure: Math and the Common Core. *Educational Leadership*, *70*(4), 42-46.

Burton, L. D., Kijai, J., & Sargeant, M. A. (2005). The relationship between students' perceptions of the teaching and learning process and academic performance in science of seventh and eighth graders enrolled in seventh-day adventist schools. *Journal of Research on Christian Education*, *14*(2), 177-212.

Bybee, R. W. (1997, October). The Sputnik era: Why is this educational reform different from all other reforms. In *Prepared for the Symposium "Reflecting on Sputnik: Linking the Past, Present, and Future of Educational Reform"* (*Washington*, *DC*).

Carbonneau, K. J., Marley, S. C., & Selig, J. P. (2013). A meta-analysis of the efficacy of teaching mathematics with concrete manipulatives. *Journal of Educational Psychology*, *105*(2), 380-400.

Carpenter, T. P., & Fennema, E. (1992). Cognitively guided instruction: Building on the knowledge of students and teachers. *International Journal of Educational Research, 17*(5), 457-470.

Chamberlin, S. A. (2010). A review of instruments created to assess affect in mathematics. *Journal of Mathematics Education*, *3*(1), 167-182.

Chan, M. S., & Black, J. B. (2006). Learning Newtonian mechanics with an animation game: The role of presentation format on mental model acquisition. In *Annual Meeting of the American Educational Research Association (AERA), San Francisco* (pp. 2-35).

Chandler, P., & Sweller, J. (1991). Cognitive load theory and the format of instruction. *Cognition and instruction*, *8*(4), 293-332.

Chang, H., & Beilock, S. L. (2016). The math anxiety-math performance link and its relation to individual and environmental factors: A review of current behavioral and psychophysiological research. *Current Opinion in Behavioral Sciences*, *10*, 33-38.

Chang, K. E., Wu, L. J., Weng, S. E., & Sung, Y. T. (2012). Embedding game-based problem-solving phase into problem-posing system for mathematics learning. *Computers & Education*, *58*(2), 775-786.

Chang, K. E., Chen, Y. L., Lin, H. Y., & Sung, Y. T. (2008). Effects of learning support in simulation-based physics learning. *Computers & Education*, *51*(4), 1486-1498.

Chapman, E. (2003). Development and validation of a brief mathematics attitude scale for primary-aged students. *Journal of Educational Enquiry*, 463-473.

Charles, D., Charles, T., & McNeill, M. (2009, March). Using player and world representation techniques from computer games to improve student engagement. In *Games and Virtual Worlds for Serious Applications, 2009. VS-GAMES'09. Conference in* (pp. 36-42). IEEE.

Chen, C., & Stevenson, H. W. (1995). Motivation and mathematics achievement: a comparative study of Asian-American, Caucasian-American, and East Asian high school students. *Child development*, *66*(4), 1215-1234.

Cheung, A. C., & Slavin, R. E. (2013). The effectiveness of educational technology applications for enhancing mathematics achievement in K-12 classrooms: A meta-analysis. *Educational Research Review*, *9*, 88-113.

Ciltas, A. (2013). The effects of the mathematical modeling method on problem solving success. *International Journal of Academic Research*, *5*(4), 352-358.

Clark, D. B., Nelson, B. C., Chang, H. Y., Martinez-Garza, M., Slack, K., & D'Angelo, C. M. (2011). Exploring Newtonian mechanics in a conceptually-integrated digital game: Comparison of learning and affective outcomes for students in Taiwan and the United States. *Computers & Education*, *57*(3), 2178-2195.

Cobb, P., Yackel, E., & Wood, T. (1992). A Constructivist alternative to the representational view of mind in mathematics education. *Journal for Research In Mathematics Education*, (1), 2. doi:10.2307/749161

Cobb, P., & Jackson, K. (2011). Assessing the quality of the common core state standards for mathematics. *Educational Researcher*, *40*(4), 183-185.

Coburn, C. E., Hill, H. C., & Spillane, J. P. (2016). Alignment and Accountability in Policy Design and Implementation The Common Core State Standards and Implementation Research. *Educational Researcher*, 0013189X16651080.

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

Corradini, A. (2011). *A study on Whether Digital Games Can Effect Spatial Reasoning Skills*. IGI Global.

Cress, U. (2013). Mass collaboration and learning. *Handbook on design in educational technology*, 416-425.

Creswell, J. W. (2014). *A concise introduction to mixed methods research*. Sage Publications.

Cunningham, D., & Duffy, T. (1996). Constructivism: Implications for the design and delivery of instruction. *Handbook of Research for Educational Communications and Technology*, 170-198.

Daskalogianni, K., & Simpson, A. (2000). Towards a definition of attitude: The relationship between the affective and the cognitive in pre-university students. In *PME CONFERENCE* (Vol. 2, pp. 2-217).

De Jong, T., Weinberger, A., Girault, I., Kluge, A., Lazonder, A. W., Pedaste, M., ... & Geraedts, C. (2012). Using scenarios to design complex technology-enhanced learning environments. *Educational Technology Research and Development*, *60*(5), 883-901.

De Jong, T., & van Joolingen, W. R. (1998). Scientific discovery learning with computer simulations of conceptual domains. *Review of Educational Research*, (2). 179.

Dejarnette, N. K. (2012). America’s children: Providing early exposure to stem (science, technology, engineering, and math) initiatives. *Education*, 133(1), 77-84.

Delen, E., & Bulut, O. (2011). The relationship between students' exposure to technology and their achievement in science and math. *Turkish Online Journal of Educational Technology*, *10*(3), 311-317.

Demirbilek, M., & Tamer, S. L. (2010). Math teachers' perspectives on using educational computer games in math education. *Procedia-Social and Behavioral Sciences*, *9*, 709-716.

Dempsey, J. V., Rasmussen, K., & Lucassen, B. (1994). Instructional gaming: Implication for technology. *ERIC Document Reproduction Service No. EJ368345*.

Divjak, B., & Tomić, D. (2011). The impact of Game-based learning on the achievement of learning goals and motivation for learning mathematics-literature review. *Journal of Information and Organizational Sciences*, *35*(1), 15-30.

Doerr, H. M., Ärlebäck, J. B., & Costello Staniec, A. (2014). Design and effectiveness of modeling-based mathematics in a summer bridge program. *Journal of Engineering Education*, *103*(1), 92-114.

Dossey, J. A., Mullis, I. V., Lindquist, M. M., & Chambers, D. L. (1988). The mathematics report card: Trends and achievement based on the 1986 national assessment. *Princeton: Educational Testing Service*.

Dow, P. (1997, February). Sputnik revisited: Historical perspectives on science reform. In *A symposium Reflecting on Sputnik: Linking the Past, Present, and Future of Educational Reform. Washington, DC: National Academy of Sciences.*

Dundar, S., Gokkurt, B., & Soylu, Y. (2012). Mathematical modeling at a glance: A theoretical study. *Procedia - Social And Behavioral Sciences*, *46*(4th WORLD CONFERENCE ON EDUCATIONAL SCIENCES (WCES-2012) 02-05 February 2012 Barcelona, Spain), 3465-3470.

Dunham, P. H., & Dick, T. P. (1994). Research on graphing calculators. *Mathematics teacher*, *87*(6), 440-445.

Durmus, S., & Karakirik, E. (2006). Virtual manipulatives in mathematics education: A theoretical framework. *The Turkish Online Journal of Educational Technology*, *5*(1).

Dyer, R., Reed, P., & Berry, R. (2006). Investigating the relationship between high school technology education and test scores for algebra 1 and geometry. *Journal of Technology Education*, *17*(2), 7-17.

Echeverri, J., & Sadler, T. D. (2011). Gaming as a platform for the development of innovative problem-based learning opportunities. *Science Educator*, *20*(1), 44-48.

Eggen, P. D., & Kauchak, D. (1993). *Educational psychology: Classroom connections*. Simon & Schuster Books for Young Readers.

Elliott, B., Oty, K., McArthur, J., & Clark, B. (2001). The effect of an interdisciplinary algebra/science course on students' problem solving skills, critical thinking skills and attitudes towards mathematics. *International Journal of Mathematical Education in Science and Technology*, *32*(6), 811-816.

Ellis, M. W., & Berry III, R. Q. (2005). The paradigm shift in mathematics education: Explanations and implications of reforming conceptions of teaching and learning. *Mathematics Educator*, *15*(1), 7-17.

Engle, R. A., & Conant, F. R. (2002). Guiding principles for fostering productive disciplinary engagement: Explaining an emergent argument in a community of learners classroom. *Cognition and Instruction*, *20*(4), 399-483.

English, L. D. (1997). The development of fifth-grade children's problem-posing abilities. *Educational Studies in Mathematics*, *34*(3), 183-217.

Erbas, A., & Okur, S. (2012). Researching students' strategies, episodes, and metacognitions in mathematical problem solving. *Quality & Quantity*, *46*(1), 89-102.

Ewing, J. (2011). Mathematical intimidation: Driven by the data. *Notices of the AMS*, *58*(5), 667-673.

Eyyam, R. & Yaratan, H. S. (2014). Impact of use of technology in mathematics lessons on student achievement and attitudes. *Social Behavior & Personality: An International Journal*, *42*, 31-42.

Faul, F., Erdfelder, E., Buchner, A., & Lang, A. G. (2009). Statistical power analyses using G* Power 3.1: Tests for correlation and regression analyses. *Behavior Research Methods*, *41*(4), 1149-1160.

Fengfeng, K., & Grabowski, B. (2007). Gameplaying for maths learning: Cooperative or not?. *British Journal of Educational Technology*, *38*(2), 249-259.

Fengfeng, K., & Abras, T. (2013). Games for engaged learning of middle school children with special learning needs. *British Journal of Educational Technology*, *44*(2), 225-242. doi:10.1111/j.1467-8535.2012.01326.x

Fennema, E., & Sherman, J. A. (1976). Fennema-Sherman mathematics attitudes scales: Instruments designed to measure attitudes toward the learning of mathematics by females and males. *Journal for Research in Mathematics Education*, 324-326.

Flores, R., Inan, F., & Lin, Z. (2013). How do the different types of computer use affect math achievement? *Journal of Computers In Mathematics And Science Teaching*, *32*(1), 67-87.

Fogarty, G., Cretchley, P., Harman, C., Ellerton, N., & Konki, N. (2001). Validation of a questionnaire to measure mathematics confidence, computer confidence, and attitudes towards the use of technology for learning mathematics. *Mathematics Education Research Journal*, *13*(2), 154-160. doi:10.1007/BF03217104

Fong, S. F., Por, F. P., & Tang, A. L. (2012). Effects of multiple simulation presentation among students of different anxiety levels in the learning of probability. *Turkish Online Journal of Educational Technology*, *11*(3), 105-114.

Fritz, C. O., Morris, P. E., & Richler, J. J. (2012). Effect size estimates: Current use, calculations, and interpretation. *Journal of Experimental Psychology: General*, *141*(1), 2-18.

Gales, M., & Yan, W. (2001). Relationship between constructivist teacher beliefs and instructional practices to students' mathematical achievement: Evidence from TIMMS.

Gamoran, A., & Hannigan, E. C. (2000). Algebra for everyone? Benefits of college-preparatory mathematics for students with diverse abilities in early secondary school. *Educational Evaluation and Policy Analysis*, *22*(3), 241-254.

García, T., Rodríguez, C., Betts, L., Areces, D., & González-Castro, P. (2016). How affective-motivational variables and approaches to learning predict mathematics achievement in upper elementary levels. *Learning and Individual Differences, 49*, 25-31.

Gee, J P. (2003). *What video games have to teach us about learning and literacy*. New York: Palgrave Macmillan.

Gee, J. P. (2005). Learning by design: Good video games as learning machines. *E-Learning and Digital Media*, *2*(1), 5-16.

Gee, J. P. (2007). *Good video games+ good learning: Collected essays on video games, learning, and literacy*. New York: P. Lang.

Gewertz, C. (2013). Teachers say they are unprepared for Common Core. *Education Week*, *32*(22), 1-12.

Gibson, D., Aldrich, C., & Prensky, M. (2007). *Games and Simulations in Online Learning: Research and Development Frameworks*. Hershey, PA: Information Science Pub.

Gilakjani, A., Leong, L., & Ismail, H. (2013). Teachers' use of technology and constructivism. *International Journal of Modern Education & Computer Science*, *5*(4), 49.

Gleek, C. (2014). *Understanding Student Engagement During Simulations* (Doctoral dissertation, Lynn University).

Goodman, J. (2016, November). The Effects of Early Math Coursework on College Readiness: Evidence from Targeted Middle School Math Acceleration. In *2016 Fall Conference: The Role of Research in Making Government More Effective*. Appam.

Goos, M., & Bennison, A. (2007). Technology-enriched teaching of secondary mathematics: Factors influencing innovative practice. *Mathematics: Essential Research-Essential Practice*, *1*, 315-324.

Grandgenett, N. (2011). Phet interactive simulations. *Mathematics & Computer Education*, *45*(1), 83-85.

Gravemeijer, K., & Doorman, M. (1999). Context problems in realistic mathematics education: A calculus course as an example. *Educational studies in mathematics*, *39*(1-3), 111-129.

Hair, J. F., Black, W. C., Babin, B. J., Anderson, R. E., & Tatham, R. L. (2006). *Multivariate data analysis* (Vol. 6). Upper Saddle River, NJ: Pearson Prentice Hall.

Haladyna, T., Shaughnessy, J., & Shaughnessy, J. M. (1983). A causal analysis of attitude toward mathematics. *Journal for Research in Mathematics Education*, 19-29.

Hannula, M. S. (2002). Attitude towards mathematics: Emotions, expectations and values. *Educational Studies in Mathematics*, *49*(1), 25-46.

Hart, S. (2016). Eighth Grade Mathematics Intervention: Improving Student Self-Esteem and Content Knowledge of Targeted Mathematic Skills.

Hart, L. E. (1989). Describing the affective domain: Saying what we mean. In *Affect and mathematical problem solving* (pp. 37-45). Springer: New York.

Hatfield, M., Edwards, N. T., Bitter, G. G., & Morrow, J. (2000). Mathematics methods for elementary and middle school teachers. *Applied Mathematics and Computation, 10*, 12.

Haycock, K. (1998). Good teaching matters... a lot. *OAH Magazine of History, 13*(1), 61-63.

Heiman, G. (2001). *Understanding research methods and statistics: An integrated introduction for psychology* (2nd ed.). Boston, MA: Houghton Mifflin.

Herrera, T. A., & Owens, D. T. (2001). The" new new math"?: Two reform movements in mathematics education. *Theory into Practice, 40*(2), 84-92.

Hidiroglu,, Ç. N., & Guzel, E. B. (2013). Conceptualization of approaches and thought processes emerging in validating of model in mathematical modeling in technology aided environment. *Educational Sciences: Theory & Practice, 13*(4), 2499-2506.

Hiebert, J., Stigler, J. W., Jacobs, J. K., Givvin, K., Garnier, H., Smith, M., & ... Gallimore, R. (2005). Mathematics teaching in the United States today (and tomorrow): Results from the TIMSS 1999 video study. *Educational Evaluation and Policy Analysis*, (2). 111.

Hogan, K. A. (2016). Understanding the Relationships Among Students' Goal Orientations, Self-Efficacy, Anxiety, and Accelerated Academic Success in the Redesign of Developmental Mathematics.

Hollender, N., Hofmann, C., Deneke, M., & Schmitz, B. (2010). Review: Integrating cognitive load theory and concepts of human–computer interaction. *Computers in Human Behavior, 26*(Online Interactivity: Role of Technology in Behavior Change), 1278-1288. doi:10.1016/j.chb.2010.05.031

Hoskinson, A. M., Couch, B. A., Zwickl, B. M., Hinko, K. A., & Caballero, M. D. (2014). Bridging physics and biology teaching through modeling. *American Journal of Physics*, *82*(5), 434-441.

Huizenga, J., Admiraal, W., Akkerman, S., & Dam, G. T. (2009). Mobile game-based learning in secondary education: Engagement, motivation and learning in a mobile city game. *Journal of Computer Assisted Learning*, *25*(4), 332-344.

Hunt, J. H., & Little, M. E. (2014). Intensifying interventions for students by identifying and remediating conceptual understandings in mathematics. *TEACHING Exceptional Children*, *46*(6), 187-196.

Hwang, G., & Chang, H. (2011). A formative assessment-based mobile learning approach to improving the learning attitudes and achievements of students. *Computers & Education*, *56*(4), 1023-1031.

Hwang, W. & Hu, S. (2013). Analysis of peer learning behaviors using multiple representations in virtual reality and their impacts on geometry problem solving, *Computers and Education*, *62*, 308-319.

Iben, M. F. (1991). Attitudes and mathematics. *Comparative education*, *27*(2), 135-151.

Jacobs, G. M., Renandya, W. A., & Power, M. (2016). *Simple, powerful strategies for student centered learning*. Springer.

Jimoyiannis, A., & Komis, V. (2001). Computer simulations in physics teaching and learning: A case study on students' understanding of trajectory motion. *Computers & Education*, *36*(2), 183-204.

Jonassen, D. H. (1991). Objectivism versus constructivism: Do we need a new philosophical paradigm? *Educational Technology Research and Development*, *39*(3), 5-14.

Kahveci, M. (2010). Students' perceptions to use technology for learning: Measurement integrity of the modified Fennema-Sherman attitudes scales. *Turkish Online Journal of Educational Technology*, *9*(1), 185-201.

Kalyuga, S. (2011). Effects of information transiency in multimedia learning. *Procedia - Social and Behavioral Sciences*, 302nd World Conference on Psychology, Counseling and Guidance - 2011, 307-311. doi:10.1016/j.sbspro.2011.10.061

Katmada, A., Mavridis, A., & Tsiatsos, T. (2014). Implementing a game for supporting learning in mathematics. *Electronic Journal of E-Learning*, *12*(3), 230-242.

Kaur, P. S. (2016). *Mathematics for all: the effects of heterogeneous grouping and community circles on student achievement and attitude* (Doctoral dissertation, San Francisco State University).

Kazakçı, A. (2013). On the imaginative constructivist nature of design: A theoretical approach. *Research in Engineering Design*, *24*(2), 127-145.

Kazemi, E., & Franke, M. L. (2004). Teacher learning in mathematics: Using student work to promote collective inquiry. *Journal of mathematics teacher education*, *7*(3), 203-235.

Ke, F. (2008). Computer games application within alternative classroom goal structures: Cognitive, metacognitive, and affective evaluation. *Educational Technology Research and Development*, *56*(5-6), 539-556.

Ke, F. (2014). An implementation of design-based learning through creating educational computer games: A case study on mathematics learning during design and computing. *Computers & Education*, *73*, 26-39.

Ke, F., & Grabowski, B. (2007). Gameplaying for maths learning: Cooperative or not? *British Journal of Educational Technology*, *38*(2), 249-259.

Ke, F. (2006). Classroom goal structures for educational math game application. In *Proceedings of the 7th international conference on Learning sciences* (pp. 314-320). International Society of the Learning Sciences.

Kebritchi, M., Hirumi, A., & Bai, H. (2010). The effects of modern mathematics computer games on mathematics achievement and class motivation. *Computers & Education*, *55*427-443. doi:10.1016/j.compedu.2010.02.007

Kebritchi, M. (2008). *Effects of a computer game on mathematics achievement and class motivation: An experimental study*. ProQuest.

Kendall, J. S. (2011). *Understanding common core state standards*. ASCD.

Kensington-Miller, B., Sneddon, J., Yoon, C., & Stewart, S. (2013). Changing beliefs about teaching in large undergraduate mathematics classes. *Mathematics Teacher Education & Development*, *15*(2), 1-16.

Kidwell, P. A., Ackerberg-Hastings, A., & Roberts, D. L. (2008). Tools of American mathematics teaching, 1800-2000. *Applied Mathematics and Computation*, *10*, 12.

Kiili, K. (2004). Learning with technology: Cognitive tools in multimedia learning materials. In *Proceedings of ED-MEDIA world conference on educational multimedia, hypermedia & telecommunications* (pp. 134-140). Chesapeake, VA: AACE.

Kistner, S., Vollmeyer, R., Burns, B. D., & Kortenkamp, U. (2016). Model development in scientific discovery learning with a computer-based physics task. *Computers in Human Behavior*, *59*446-455. doi:10.1016/j.chb.2016.02.041

Kim, S., & Chang, M. (2010). Computer Games for the Math Achievement of Diverse Students. *Educational Technology & Society*, *13*(3), 224-232.

Kiwanuka, H. N., Van Damme, J., Van Den Noortgate, W., Anumendem, D. N., Vanlaar, G., Reynolds, C., & Namusisi, S. (2016). How do student and classroom characteristics affect attitude toward mathematics? A multivariate multilevel analysis. *School Effectiveness and School Improvement*, 1-21.

Klawe, M. (1998, June). When does the use of computer games and other interactive multimedia software help students learn mathematics. In *NCTM Standards 2000 Technology Conference*.

Klein, D. (2003). A brief history of American K-12 mathematics education in the 20th century. *Mathematical Cognition*, 175-259.

Köller, O., Baumert, J., & Schnabel, K. (2001). Does interest matter? The relationship between academic interest and achievement in mathematics. *Journal for Research in Mathematics Education*, 448-470.

Kloosterman, P. (1988). Self-confidence and motivation in mathematics. *Journal of Educational Psychology*, *80*(3), 345.

Lappan, G. (1997, October). Lessons from the Sputnik era in mathematics education. In *National Academy of Sciences symposium titled Reflecting on Sputnik: Linking the past, present, and future of educational reform. Retrieved March* (Vol. 7, p. 2003).

Leemkuil, H., & De Jong, T. (2012). Adaptive advice in learning with a computer-based knowledge management simulation game. *Academy of Management Learning & Education*, *11*(4), 653-665. doi:10.5465/amle.2010.0141

Leroy, N., & Bressoux, P. (2016). Does amotivation matter more than motivation in predicting mathematics learning gains? A longitudinal study of sixth-grade students in France. *Contemporary Educational Psychology*, *44*, 41-53.

Liao, Y. (2007). Effects of computer-assisted instruction on students' achievement in Taiwan: A meta-analysis. *Computers and Education*, *48*(2), 216-233.

Liebtag, E. (2013). Moving forward with common core state standards implementation: Possibilities and potential problems. *Journal of Curriculum & Instruction*, *7*(2), 56-70.

Lim, S., & Chapman, E. (2013). Development of a short form of the attitudes toward mathematics inventory. *Educational Studies in Mathematics, 82*(1), 145-164.

Lipnevich, A. A., Preckel, F., & Krumm, S. (2016). Mathematics attitudes and their unique contribution to achievement: Going over and above cognitive ability and personality. *Learning and Individual Differences*, *47*, 70-79.

Liu, T. C. (2010). Developing Simulation-based Computer Assisted Learning to Correct Students' Statistical Misconceptions based on Cognitive Conflict Theory, using" Correlation" as an Example. *Educational Technology & Society*, *13*(2), 180-192.

Lopez-Morteo, G., & López, G. (2007). Computer support for learning mathematics: A learning environment based on recreational learning objects. *Computers & Education*, *48,* 618-641. doi:10.1016/j.compedu.2005.04.014

Lubienski, S. T. (2000). Problem solving as a means toward mathematics for all: An exploratory look through a class lens. *Journal for Research in Mathematics Education*, 454-482.

Ma, L. (1999). *Knowing and teaching elementary mathematics: Teachers' understanding of fundamental mathematics in China and the United States*. Mahwah, NJ: Lawrence Erlbaum Associates.

Ma, T., Brown, I. A., Kulm, G., Davis, T. J., Lewis, C. W., & Allen, G. D. (2016). Constructing and Role-Playing Student Avatars in a Simulation of Teaching Algebra for Diverse Learners. *Urban Education*, *51*(5), 534-555.

Ma, X., & Kishor, N. (1997). Assessing the relationship between attitude toward mathematics and achievement in mathematics: A meta-analysis. *Journal for Research in Mathematics Education*, 26-47.

McKagan, S. (2010). Laptops and Diesel Generators: Introducing PhET Simulations to Teachers in Uganda. *The Physics Teacher*, *48*(1), 63-66.

Malone, T. W. (1980). What makes things fun to learn? Heuristics for designing instructional computer games. *SIGSMALL/PC: Symposium On Small Systems*, 162 doi:10.1145/800088.802839

Manches, A., O'Malley, C., & Benford, S. (2010). The role of physical representations in solving number problems: A comparison of young children's use of physical and virtual materials. *Computers & Education*, *54*(Learning in Digital Worlds: Selected Contributions from the CAL 09 Conference), 622-640.

Martin, A. J. (2009). Age appropriateness and motivation, engagement, and performance in high school: Effects of age within cohort, grade retention, and delayed school entry. *Journal of Educational Psychology*, *101*(1), 101.

McLeod, D. B. (1992). Research on affect in mathematics education: A reconceptualization. *Handbook of Research on Mathematics Teaching and Learning*, 575-596.

Middleton, J. A., & Spanias, P. A. (1999). Motivation for achievement in mathematics: Findings, generalizations, and criticisms of the research. *Journal for Research in Mathematics Education*, 65-88.

Milligan, E. (2016). *"Math Class is Tough": The Role of Mindset in Middle School Girls' and Boys' Math Achievement* (Doctoral dissertation, Ohio Dominican University).

Moila, M. M. (2008). The use of educational technology in mathematics teaching and learning:

an investigation of a South African rural secondary school.

Moreno, R. (2002). Who Learns Best with Multiple Representations? Cognitive Theory Implications for Individual Differences in Multimedia Learning.

Neale, D. C. (1969). The role of attitudes in learning mathematics. *The Arithmetic Teacher*, 631-640.

Nicolaidou, M., & Philippou, G. (2003). Attitudes towards mathematics, self-efficacy and achievement in problem solving. *European Research in Mathematics Education III. Pisa: University of Pisa*.

Niess, M. L. (2005). Preparing teachers to teach science and mathematics with technology: Developing a technology pedagogical content knowledge. *Teaching and Teacher Education*, *21*(5), 509-523.

Neves, R., Silva, J., & Teodoro, V. (2010). Computational Modelling with Modellus: An Enhancement Vector for the General University Physics Course.

Ngan Hoe, L., & Ferrucci, B. J. (2012). Enhancing learning of fraction through the use of virtual manipulatives. *Electronic Journal of Mathematics & Technology*, *6*(2), 126-140.

Oncu, S. (2007). *The relationship between instructor practices and student engagement: What engages students in blended learning environments?* ProQuest.

Orhun, N. (2007). An investigation into the mathematics achievement and attitude towards mathematics with respect to learning style according to gender. *International Journal of Mathematical Education in Science and Technology*, *38*(3), 321-333.

Ozel, S., Yetkiner, Z., & Capraro, R. M. (2008). Technology in K-12 mathematics classrooms. *School Science and Mathematics*, *108*(2), 80.

Ozgen, K., & Bindak, R. (2012). Examining student opinions on computer use based on the learning styles in mathematics education. *Turkish Online Journal of Educational Technology*, *11*(1), 79-93.

Paulson, A., Adams, W., & Perkins, K. (2009). PhET simulations: Should we show the invisible?. In *American Association of Physics Teachers Conference 2009: Ann Arbor, MI*.

Panoutsopoulos, H., & Sampson, D. G. (2012). A study on exploiting commercial digital games into school context. *Journal of Educational Technology & Society*, *15*(1), 15-27.

Papastergiou, M. (2009). Digital game-based learning in high school computer science education: Impact on educational effectiveness and student motivation. *Computers & Education*, *52*(1), 1-12.

Pareto, L., Haake, M., Lindström, P., Sjödén, B., & Gulz, A. (2012). A teachable-agent-based game affording collaboration and competition: evaluating math comprehension and motivation. *Educational Technology Research and Development*, *60*(5), 723-751.

Phillips, V., & Wong, C. (2010). Tying together the common core of standards, instruction, and assessments. *Phi Delta Kappan*, *91*(5), 37.

Pierce, R., & Stacey, K. (2004). A framework for monitoring progress and planning teaching towards the effective use of computer algebra systems. *International Journal of Computers for Mathematical Learning*, *9*(1), 59-93.

Pierce, R., Stacey, K., & Barkatsas, A. (2007). A scale for monitoring students' attitudes to learning mathematics with technology. *Computers and Education*, *48*(2), 285-300.

Porter, A., McMaken, J., Hwang, J., & Yang, R. (2011). Common core standards the new US intended curriculum. *Educational Researcher*, *40*(3), 103-116.

Powell, K. C., & Kalina, C. J. (2009). Cognitive and social constructivism: Developing tools for an effective classroom. *Education*, *130*(2), 241.

Prendergast, M., & Hongning, Z. (2016). A Comparative Study of Students Attitudes towards Mathematics in Two Different School Systems. *International Journal for Mathematics Teaching and Learning*, *17*(2).

Prensky, M. (2001). Fun, play and games: What makes games engaging. *Digital game-based learning*, *5*, 1-05.

Prensky, M. (2006). Don't bother me Mom-I'm learning: How computer and video games are preparing your kids for 21 century success and how you can help. *St. Paul, EUA: Parangon House*.

Prensky, M. (2008). Turning on the lights. *Educational Leadership, 65*(6), 40.

Prensky, M. R. (2010). *Teaching digital natives: Partnering for real learning*. Corwin Press.

Prensky, M. (2013). Our brains extended. *Educational Leadership*, *70*(6), 22.

Pugalee, D. K. (2001). Algebra for all: The role of technology and constructivism in an algebra course for at-risk students. *Preventing School Failure*, *45*(4), 171.

Pyzdrowski, L., Sun, Y., Curtis, R., Miller, D., Winn, G., & Hensel, R. (2013). Readiness and attitudes as indicators for success in college calculus. *International Journal Of Science & Mathematics Education*, *11*(3), 529-554. doi:10.1007/s10763-012-9352-1

Quinn, C. N. (2005). *Engaging learning: Designing e-learning simulation games*. John Wiley & Sons.

Raines, J. M., & Clark, L. M. (2011). A brief overview on using technology to engage students in mathematics. *Current Issues in Education*, *14*(2).

Razak, A. A., & Connolly, T. M. (2013). Using games-based learning: How it influences the learning experience and outcomes of primary school children. *International Journal of Emerging Technologies In Learning*, *8*(SPL.ISSUE2), 47-54. doi:10.3991/ijet.v8iS2.2782

Redmond, T., Sheehy, J., & Brown, R. (2010). Exploring the relationship between mathematical modeling and classroom discourse. *Mathematics Education Research Group of Australasia.*

Rey, G. D. (2010). Instructional advice, time advice and learning questions in computer simulations. *Australasian Journal of Educational Technology*, *26*(5), 675-689.

Reid, D. J., Zhang, J., & Chen, Q. (2003). Supporting scientific discovery learning in a simulation environment. *Journal of Computer Assisted Learning*, *19*(1), 9-20.

Rieber, L. P. (2005). Multimedia learning in games, simulations, and microworlds. *The Cambridge Handbook of Multimedia Learning*, 549-567.

Rieber, L. P. (1996). Seriously considering play: Designing interactive learning environments based on the blending of microworlds, simulations, and games. *Educational Technology Research and Development*, *44*(2), 43-58.

Rodrigues, S. (2007). Factors that influence pupil engagement with science simulations: the role of distraction, vividness, logic, instruction and prior knowledge. *Chemistry Education Research and Practice*, *8*(1), 1-12.

Rosas, R., Nussbaum, M., Cumsille, P., Marianov, V., Correa, M., Flores, P., ... & Rodriguez, P. (2003). Beyond Nintendo: Design and assessment of educational video games for first and second grade students. *Computers & Education*, *40*(1), 71-94.

Roschelle, J. M., Pea, R. D., Hoadley, C. M., Gordin, D. N., & Means, B. M. (2000). Changing how and what children learn in school with computer-based technologies. *The Future of Children*, (2). 76.

Roseman, R. B., & Jones, D. L. (2013). Utilization of hands-on and simulation activities for teaching middle school lunar concepts. *AIP Conference Proceedings, 1513*(1), 346-349. doi:10.1063/1.4789723

Rutten, N., van Joolingen, W. R., & van der Veen, J. T. (2012). The learning effects of computer simulations in science education. *Computers & Education*, *58*(1), 136-153

Sabzian, F., Gilakjani, A., & Sodouri, S. (2013). Use of technology in classroom for professional development. *Journal of Language Teaching & Research*, *4*(4), 684-692. doi:10.4304/jltr.4.4.684-692

Saeed, S., & Zyngier, D. (2012). How motivation influences student engagement: A qualitative case study. *Journal of Education and Learning*, *1*(2), 252.

Santos-Trigo, M., & Espinosa-Perez, H. (2002). Searching and exploring properties of geometric configurations using dynamic software. *International Journal of Mathematical Education in Science and Technology*, *33*(1), 37-50.

Scheiter, K., Gerjets, P., & Schuh, J. (2010). The acquisition of problem-solving skills in mathematics: How animations can aid understanding of structural problem features and solution procedures. *Instructional Science*, *38*(5), 487-502.

Schifter, D., & Fosnot, C. T. (1993). *Reconstructing Mathematics Education: Stories of Teachers Meeting the Challenge of Reform*. Teachers College Press, New York.

Schoenfeld, A. H. (1987). *Cognitive science and mathematics education*. Psychology Press.

Sedighian, K., & Sedighian, A. S. (1996). Can educational computer games help educators learn about the psychology of learning mathematics in children. In *18th Annual Meeting of the International Group for the Psychology of Mathematics Education* (pp. 573-578).

Sekerák, J. (2010). Competences of mathematical modeling of high school students. *Mathematics Teaching*, (220), 8-12.

Shadish, W. R., Cook, T. D., & Campbell, D. T. (2002). *Experimental and quasi-experimental designs for generalized causal inference*. Houghton, Mifflin and Company.

Shaffer, D W. (2007). *How Computer Games Help Children Learn*. New York: Palgrave Macmillan.

Shamoail, E., & Barkatsas, A. (2011). Students' attitudes towards handheld computer algebra systems (CAS) in mathematics: Gender and school setting issues. *Mathematics: Traditions and [New] Practices*, 685-692.

Shapiro, A., & Koren, A. (2012). Are educators lemmings? Now, it's standards, another behaviorist hoax. *Journal Of Education Policy*, 1-5.

Sheehan, M., & Nillas, L. (2010). Technology integration in secondary mathematics classrooms: Effect on students' understanding. *Journal of Technology Integration In The Classroom*, *2*(3), 67-83.

Sherman, B. (2010). High school mathematics teaching in the USA. *Australian Senior Mathematics Journal*, *24*(1), 52-56.

Shin, N., Sutherland, L. M., Norris, C. A., & Soloway, E. (2012). Effects of game technology on elementary student learning in mathematics. *British journal of educational technology*, *43*(4), 540-560.

Silver, E. A. (Ed.). (2013). *Teaching and Learning Mathematical Problem Solving: Multiple*

Research Perspectives. Routledge.

Singh, K., Granville, M., & Dika, S. (2002). Mathematics and science achievement: Effects of motivation, interest, and academic engagement. *The Journal of Educational Research*, *95*(6), 323-332.

Sokolowski, A., Yalvac, B., & Loving, C. (2011). Science modeling in pre-calculus: How to make mathematics problems contextually meaningful. *International Journal of Mathematical Education In Science & Technology*, *42*(3), 283-297.

Solso, D. (2009). *The Effect Constructivist and Traditional Teaching Methods on Students' Mathematical Achievement* (Doctoral dissertation, The Evergreen State College).

Stein, M., Kinder, D., Silbert, J., & Carnine, D. W. (2005). *Designing Effective Mathematics Instruction: A Direct Instruction Approach*. Pearson.

Stevens, R., Beal, C. R., & Sprang, M. (2013). Assessing students' problem solving ability and cognitive regulation with learning trajectories. In *International Handbook of Metacognition and Learning Technologies* (pp. 409-423). Springer New York.

Stevenson, H. W., & Newman, R. S. (1986). Long-term prediction of achievement and attitudes in mathematics and reading. *Child development*, 646-659.

Stipek, D. J., Givvin, K. B., Salmon, J. M., & MacGyvers, V. L. (2001). Teachers' beliefs and practices related to mathematics instruction. *Teaching and teacher education*, *17*(2), 213-226.

Stone, R. (2002). *Best Practices for High School Classrooms: What Award-Winning Secondary Teachers Do*. Corwin Press.

Stover, C. (2005). Measuring and understanding student retention. *Distance Education Report*, *9*(16), 1-7.

Suárez-Pellicioni, M., Núñez-Peña, M. I., & Colomé, À. (2016). Math anxiety: a review of its cognitive consequences, psychophysiological correlates, and brain bases. *Cognitive, Affective, & Behavioral Neuroscience*, *16*(1), 3-22.

Suharwoto, G. (2006). *Secondary mathematics preservice teachers' development of technology pedagogical content knowledge in subject-specific, technology-integrated teacher preparation program* (Doctoral dissertation).

Suydam, M. N., & Brosnan, P. A. (1993). Research on mathematics education reported in 1992. *Journal for Research In Mathematics Education*, *24*(4), 329.

Swaak, J., Van Joolingen, W. R., & De Jong, T. (1998). Supporting simulation-based learning; the effects of model progression and assignments on definitional and intuitive knowledge. *Learning and instruction*, *8*(3), 235-252

Swars, S. L., & Chestnutt, C. (2016). Transitioning to the Common Core State Standards for Mathematics: A Mixed Methods Study of Elementary Teachers' Experiences and Perspectives. *School Science and Mathematics*, *116*(4), 212-224.

Sweller, J., Van Merrienboer, J. J., & Paas, F. G. (1998). Cognitive architecture and instructional design. *Educational Psychology Review*, *10*(3), 251-296.

Tabuk, M., & Haciomerogu, G. (2015). Turkish adaptation of attitude towards mathematics instrument (English). *Journal of Theory & Practice In Education*, *11*(1), 245-260.

Takači, D., Takači, A., & Budinski, N. (2010). On visualization problems by using the GeoGebra and Scientific Work Place Packages. *International Journal for Technology In Mathematics Education*, *17*(4), 191-196.

Tapia, M. (1996). The Attitudes toward Mathematics Instrument.

Tapia, M., & Marsh, G. I. (2000). Attitudes toward Mathematics Instrument: An Investigation with Middle School Students.

Tapia, M., & Marsh, G. I. (2002). Confirmatory factor analysis of the attitudes toward mathematics Inventory.

Tapia, M., & Marsh, G. E. (2004). An instrument to measure mathematics attitudes. *Academic Exchange Quarterly*, *8*(2), 16.

Tekerek, M., Yeniterzi, B., & Ercan, O. (2011). Math attitudes of computer education and instructional technology students. *Turkish Online Journal of Educational Technology*, *10*(3), 168-174.

Tella, A. (2007). The impact of motivation on student's academic achievement and learning outcomes in mathematics among secondary school students in Nigeria. *Eurasia Journal of Mathematics, Science & Technology Education*, *3*(2), 149-156.

Tezer, M., & Ozcan, D. (2015). A study of the validity and reliability of a mathematics lesson attitude scale and student attitudes. *Eurasia Journal of Mathematics, Science & Technology Education*, *11*(2), 371-379. doi:10.12973/eurasia.2015.1349a

Thompson, A. G. (1984). The relationship of teachers' conceptions of mathematics and mathematics teaching to instructional practice. *Educational Studies in Mathematics*, *15*(2), 105-127.

Toptaş, V., Çelik, S., & Karaca, E. (2012). Improving 8th grades spatial thinking abilities through a 3D modeling program. *The Turkish Online Journal Of Educational Technology*, *11*(2), 128-134.

Vale, C. M., & Leder, G. C. (2004). Student views of computer-based mathematics in the middle years: Does gender make a difference? *Educational Studies in Mathematics, 56*(2/3), 287-312.

Van de Walle, J. A. & Lovin, L. H. (2006) Foundations of student-centered instruction. *Teaching Student-Centered Mathematics.* (3), 1-37.

Villegas, R. R. (2011). Helping Continuation High School Student Become Successful in Mathematics. *Online Submission.*

Vogel, J. J., Vogel, D. S., Cannon-Bowers, J., Bowers, C. A., Muse, K., & Wright, M. (2006). Computer gaming and interactive simulations for learning: A meta-analysis. *Journal of Educational Computing Research*, *34*(3), 229-243.

Von Glasersfeld, E. (1989). Cognition, construction of knowledge, and teaching. *Synthese*, *80*(1), 121-140

Vygotsky, L. S. (1981). The Genesis of Higher Mental Functions. In J. Wertsch, M. Cole (Eds.), *The Concept of Activity in Soviet Psychology* (pp. 144-188). Armonk, NY: Sharpe.

Wieman, C. E., Adams, W. K., & Perkins, K. K. (2008). PhET: Simulations that enhance learning. *Science*, *322*(5902), 682-683.

Wilson, A. J., Dehaene, S., Dubois, O., & Fayol, M. (2009). Effects of an adaptive game intervention on accessing number sense in low-socioeconomic-status kindergarten children. *Mind, Brain, and Education*, *3*(4), 224-234.

Witzel, B. S., & Riccomini, P. J. (2007). Optimizing math curriculum to meet the learning needs of students. *Preventing School Failure*, *52*(1), 13-18.

Woessmann, L. (2016). The importance of school systems: Evidence from international differences in student achievement. *The Journal of Economic Perspectives*, *30*(3), 3-31.

Wormald, R. J. (2013). A participatory evaluation of the use of social networking tools in a high school math class. *Dissertation Abstracts International Section A*, *73,*

Wu, H. H. (2011). Phoenix rising: Bringing the common core state mathematics standards to life. *American Educator*, *35*(3), 3-13.

Wu, M. (2009). A comparison of PISA and TIMSS 2003 achievement results in mathematics. *Prospects*, *39*(1), 33-46.

Yaratan, H., & Kasapoğlu, L. (2012). Eighth grade students' attitude, anxiety, and achievement pertaining to mathematics lessons. *Procedia-Social and Behavioral Sciences*, *46*, 162-171.

Yoon, K. S., Eccles, J. S., & Wigfield, A. (1996, April). Self-concept of ability, value, and academic achievement: A test of causal relations. In *Annual Meeting of the American Educational Research Association, New York, NY. Retrieved from* *http://www.rcgd.isr.umich.edu/garp/articles/eccles96o.pdf*.

Yushau, B., Mji, A., & Wessels, D. C. J. (2003). Creativity and Computer in the Teaching and Learning of Mathematics. *Retrivied from www. kfupm. edu. sa/math/UPLOAD/Tech Reports/31*, *1*.

Zain, S., Rasidi, F., & Abidin, I. (2012). Student-centered learning in mathematics: Constructivism in the classroom. *Journal of International Education Research*, *8*(4), 319-328.

Zakaria, E., Chin, L. C., & Daud, M. Y. (2010). The effects of cooperative learning on students' mathematics achievement and attitude towards mathematics. *Journal of social sciences*, *6*(2), 272-275.

APPENDICES

Appendix A

Towson University IRB Approval

EXEMPTION NUMBER: 15-X018

To:	Charles Boling
From:	Institutional Review Board for the Protection of Human Subjects, Stacy Spaulding, Member VS
Date:	Monday, September 22, 2014
RE:	Application for Approval of Research Involving the Use of Human Participants

Office of Sponsored Programs
& Research

Towson University
8000 York Road
Towson, MD 21252-0001

t. 410 704-2236
f. 410 704-4494
www.towson.edu/ospr

Thank you for submitting an application for approval of the research
Effects of Simulations in a Common Core Classroom

to the Institutional Review Board for the Protection of Human Participants (IRB) at Towson University.

Your research is exempt from general Human Participants requirements according to 45 CFR 46.101(b)(1). No further review of this project is required from year to year provided it does not deviate from the submitted research design.

If you substantially change your research project or your survey instrument, please notify the Board immediately.

We wish you every success in your research project.

CC: Qing Li
File

Appendix B

Howard County Public Schools (HCPSS) IRB Approval

Dear Mr. Boling, August 29, 2014

Thank you for the opportunity to review your application to conduct research in the Howard County Public School System. In your dissertation research, you plan to evaluate the effectiveness of computer simulations versus classes not using simulations in high school mathematics classrooms. You are proposing to conduct your research at Howard High School, with 4 classes and 3 teachers who will be trained by you in the methodology. You approximate that this would include 100 students. Your proposed Pilot Study timeline is to conduct the data collection beginning in September 2014 and ending by November 2014 in two classes of Algebra 2. Your proposed Dissertation Study timeline is to conduct the data collection in January 2015 and ending in April 2015 in four classes of Algebra 1.
The committee who reviewed your proposed research found that your topic is of high relevance both within our district, as well as at a national level. Due to the highly relevant nature of your research, your proposal is conditionally accepted.

Once the following conditions are met and the requested information/forms are sent to the parties indicated, you will be given full approval.

- Send Bill Barnes the instructional technology applications being featured in the study. The final approval of your research is contingent upon the computer program you are using to be on the HCPSS approved list of software (Math XL or similar). Both Bill Barnes and Bob Cole have offered their support to work with you and ensure that the technology you are using with students is approved and appropriate.
- Once your university's IRB is granted, please send me a PDF copy for your file. You may not begin your research until the IRB is received by our office.

Other conditions of our approval include the following:

- The staff who you select must voluntarily agree to be part of your study. It must be clear to them that they can elect to not participate and/or to withdraw at any time, if they so choose.
- The names of the teachers, students, school and district will be de-identified in your research, identifying the school system as "a medium sized public school district in a Mid-Atlantic state in the United States."
- Connect directly with Dr. Masella, or her designee, to coordinate details related to your study.
- You agree to share your results and materials with the Secondary Mathematics Office, the Accountability Office, and the Instructional Technology Office, once they are available.

Congratulations on making it to this stage of completing your doctoral degree. We wish you well as you come to a successful completion of your research.

Sincerely,

Mary Klyap

Mary Klyap, Ph.D.
Coordinator, Shared Accountability

Appendix C

Effect Size Calculations

Roseman & Jones

Assume the *p*-value reported is from the post-test comparison. Using the inverse *t* and degrees of freedom of 111 (*df* = 47 + 66 = 113 – 2 = 111) to find the computed value for *t* that yielded the *p*-value reported (*p* = 0.30).

Using Excel: TINV(0.3,111) = 1.041298

Standardized Mean Difference

$$n_T = 66$$
$$n_c = 47$$
$$t = 1.04$$

Standardized Mean Difference Effect Size = .1987

Hwang & Hu

$$\overline{x_1} = 70.24 \qquad s_1 = 23.78$$
$$\overline{x_2} = 59.17 \qquad s_2 = 18.79$$

Cohen D= $\dfrac{|x_1 - x_2|}{\sqrt{(\sigma_1^2 + \sigma_2^2)/2}} = \dfrac{|70.24 - 59.17|}{\sqrt{\left(\dfrac{(23.78)^2 + (18.79)^2}{2}\right)}} = .517$

Akinsola, & Animasahun

$$\overline{x_1} = 1\;.79 \qquad \sigma_1 = 5.4$$
$$\overline{x_2} = 1\;54 \qquad \sigma_2 = 3.8$$

Cohen D = $\dfrac{|x_1 - x_2|}{\sqrt{(\sigma_1^2 + \sigma_2^2)/2}} = \dfrac{|17.90 - 15.41|}{\sqrt{\left(\dfrac{(5.46)^2 + (3.87)^2}{2}\right)}} = .526$

Weighted Average Effect Size:

Roseman & Jones	N=113	ES=.199
Hwang & Hu:	N=58	ES=.517
Akinsola & Animasahun	N=146	ES=.526

WES = $\dfrac{113(.199) + 58(.517) + 146(.526)}{113 + 58 + 146} = .408$

Appendix D

INFORMED CONSENT FORM: Teacher

I, ____________________________________, agree to participate in a study entitled "Effects of Simulations in the Common Core Classroom," which is being conducted by doctoral student, Charles C. Boling II of the Technology and Literacy Department, Towson University. This research project is a ten day study investigating the effectiveness of computer simulations in teaching mathematics. The purpose of this study is to evaluate the effectiveness of simulations in an Algebra II unit compared to classes not using simulations. The researcher hopes to use the information obtained from this study to provided teachers with an alternative tool in teaching mathematics in the Common Core classroom.

I understand that I will be expected to participate in a number of experimental tasks including administration of pre/post assessments of students, instruction of three lessons (quadratics, piecewise, and exponential functions), and the occasional observation of my activities.

I have been informed that any information obtained in this study will be recorded with a code number that will allow Charles C. Boling II to determine my identity. At the conclusion of this study, the key that relates my name with my assigned code number will be destroyed. Under this condition, I agree that any information obtained from this research may be used in any way thought best for publication or education, provided that I am in no way identified and my name is not used.

I understand that there is no personal risk or discomfort directly involved with this research, that my participation is voluntary, and that I am free to withdraw my consent and discontinue participation in this study at any time. A decision to withdraw from the study will not affect my employment with HCPSS.

If I have any questions or problems that arise in connection with my participation in this study, I should contact Charles C. Boling II, the principle researcher at 443-326-2006 or Dr. Debi Gartland, Chairperson of the Institutional Review Board for the Protection of Human Participants at Towson University at (410) 704-2236.

____

(Date) (Signature of Participant)

____

(Date) (Investigator)

____

(Date) (Witness)**

THIS PROJECT HAS BEEN REVIEWED BY THE INSTITUTIONAL REVIEW BOARD FOR THE PROTECTION OF HUMAN PARTICIPANTS AT TOWSON UNIVERSITY.

**If investigator is not the person who will witness participant's signature, then the person administering the informed consent should write his/her name and title on the "witness" line.

Appendix E

INFORMED CONSENT FORM: Parental Consent Letter

Dear Parents:

I will be conducting a research project designed to study how the use of computer simulations affect student learning and attitudes towards mathematics and technology. I request permission for your child to participate. The study consists of a 3 week period involving three lessons taught using computer simulations and three lessons taught without using computer simulations. The goals of this study are to explore students' achievement and attitudes are affected by their exposure to using math simulations.

Each child will participate in a class lesson that either involves computer simulations or does not involve computer simulations. Children usually enjoy working with computers, so I expect that they will be interested and enthusiastic about participating; however, any child who expresses a desire to not participate will be given supplemental materials to assist in the content and excused from using simulations. Students will be pre- and post-assessed to for the purposes of the study. These assessments in no way will affect your student's grade. Children's responses will be reported as group results only.

Your decision whether or not to allow your child to participate will in no way affect your child's standing in his or her class/school and you may withdraw your consent for your child to participate in the study at any time. At the conclusion of the study, a summary of group results will be made available to all interested parents. Should you have any questions or desire further information, please call me at 443-326-2006, or you may contact Dr. Debi Gartland, Chairperson of the Institutional Review Board for the Protection of Human Participants, at (410) 704-2236. Thank you in advance for your cooperation and support.

Sincerely,

Charles C. Boling II
Doctoral Student/Instructional Team Leader
Towson University/Howard High School

Please indicate whether or not you wish to have your child participate in this project, by checking a statement below and returning this letter to your child's teacher as quickly as possible.

_____ I grant permission for my child, ______________________________________ to participate in this project.

_____ I do not grant permission for my child,____ to participate in this project.

_____ Affirmative agreement of child**

____ ____________
Parent/Guardian's signature Date

THIS PROJECT HAS BEEN REVIEWED BY THE INSTITUTIONAL REVIEW BOARD FOR THE PROTECTION OF HUMAN PARTICIPANTS AT TOWSON UNIVERSITY (PHONE: 410-704-2236).

Appendix F

Lesson #1: Piecewise Functions (Control/Treatment)

Lesson Title: __Piecewise Functions___(Treatment)________________ Course: _Algebra 2________
Date: ______________ Teacher(s): _____________________ Start/end times: 50 mins_____

<table>
<tr><td colspan="2">Lesson Objective(s): What mathematical skill(s) and understanding(s) will be developed?

Students will be able to:
• Represent piecewise functions</td></tr>
<tr><td>Lesson Launch Notes: Exactly how will you use the first five minutes of the lesson?

Have the students graph the following linear function:
$f(x)=\frac{2}{3}x-3$ and determine the domain and range.</td><td>Lesson Closure Notes: Exactly what summary activity, questions, and discussion will close the lesson and provide a foreshadowing of tomorrow? List the questions.</td></tr>
</table>

Lesson Tasks, Problems, and Activities (attach resource sheets): *What specific activities, investigations, problems, questions, or tasks will students be working on during the lesson?*

Warm-up:

1. Have the students write a model for the following situation: You have a summer job at the pool that pays time and half for overtime. That is, if you work more than 40 hours per week, your hourly wage for the extra hours is 1.5 times your normal hourly wage of $7.

Procedures/Development:

***Students will be working in pairs to understand relationships of quadratic graphs. Students will use the Piecewise graphing simulator (http://www.simulation-math.com/GraphingCalculator1/AGraphingCalculator.cshtml). ***

1. Administer the pre-quiz and collect it once finished. This will test the students' prior knowledge on the subject matter.

2. Distribute the worksheet on piecewise functions. Students will experiment looking at the piecewise functions and creating these functions through the use of a simulator.

3. Students will work in pairs. They will follow along the guided worksheet. The teacher can assist with any questions.

*** The simulator is designed to have students explore the different piecewise functions, and then use the functions to write rules/properties for the students to use.***

4. Working with a partner, the students will work through the "Piecing Together Piecewise Functions" worksheet. This work sheet will allow students to explore the properties of piecewise functions. They will also develop knowledge on what will be the most important parts of graphing piecewise functions.

5. Using the warm-up, students will graph the functions they developed and interpret what the piecewise graph means.

6. Administer the post quiz and collect it once the students have completed. This will measure the knowledge gained by the students.

Evidence of Success: *What exactly do I expect students to be able to do by the end of the lesson, and how will I measure student mastery? That is, deliberate consideration of what performances will convince you (and any outside observer) that your students have developed a deepened (and conceptual) understanding.*

At the end of this lesson, students should be able to draw, interpret, and evaluate a piecewise function. Students should be able to graph given the certain constraints for each function.

Notes and Nuances: *Vocabulary, connections, common mistakes, typical misconceptions, etc.*
Piecewise function, function, domain, range

Resources: *What materials or resources are essential for students to successfully complete the lesson tasks or activities?*	**Homework:** *Exactly what follow-up homework tasks, problems, and/or exercises will be assigned upon the completion of the lesson?*
Will be using the http://www.simulation-math.com/GraphingCalculator1/AGraphingCalculator.cshtml	Pg 117 #21-26, all

Lesson Reflections: *What questions, connected to the lesson objectives and evidence of success, will you use to reflect on the effectiveness of this lesson?*

Lesson Title: __Piecewise Functions___(Control)___________ Course: _Algebra 2
Date:___Teacher(s): __________________ Start/end times: ___50 mins___

Lesson Objective(s): *What mathematical skill(s) and understanding(s) will be developed?*

Students will be able to:

- Represent piecewise functions

Lesson Launch Notes: *Exactly how will you use the first five minutes of the lesson?*

Have the students graph the following linear function: $f(x) = \frac{2}{3}x - 3$ and determine the domain and range.

Lesson Closure Notes: *Exactly what summary activity, questions, and discussion will close the lesson and provide a foreshadowing of tomorrow? List the questions.*

Lesson Tasks, Problems, and Activities (attach resource sheets): *What specific activities, investigations, problems, questions, or tasks will students be working on during the lesson?*

Warm-up:

Have the students write a model for the following situation: You have a summer job at the pool that pays time and half for overtime. That is, if you work more than 40 hours per week, your hourly wage for the extra hours is 1.5 times your normal hourly wage of $7.

Procedures/Development:

***Students will be working in pairs to understand relationships of piecewise graphs. Students will use the transparent paper and graphing techniques to assist in the development of piecewise graphs. ***
Administer the pre-quiz and collect it once finished. This will test the students' prior knowledge on the subject matter.

1. Distribute the worksheet on piecewise functions. Students will experiment looking at the piecewise functions with the use of transparent paper.

2. Students will work in pairs. They will follow along on the guided worksheet. The teacher can assist with any questions.

*** Students will use transparent paper to assist them in the development of piecewise functions.***

3. Working with a partner, the students will work through the "Piecing Together Piecewise Functions" worksheet. This worksheet will allow students to explore the properties of piecewise functions. They will also develop knowledge on what will be the most important parts of graphing piecewise functions.

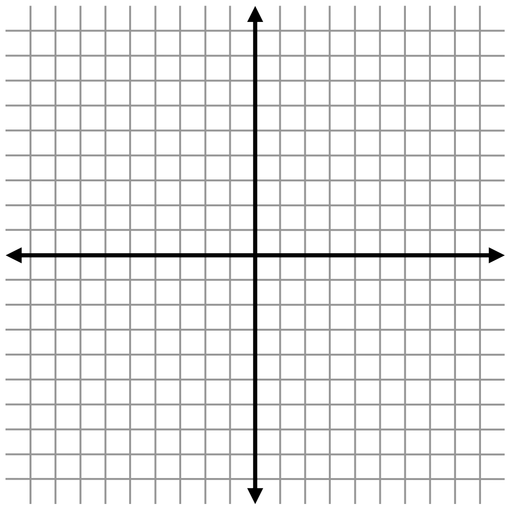
4. Using the warm-up, students will graph the functions they developed and interpret what the piecewise graph means.

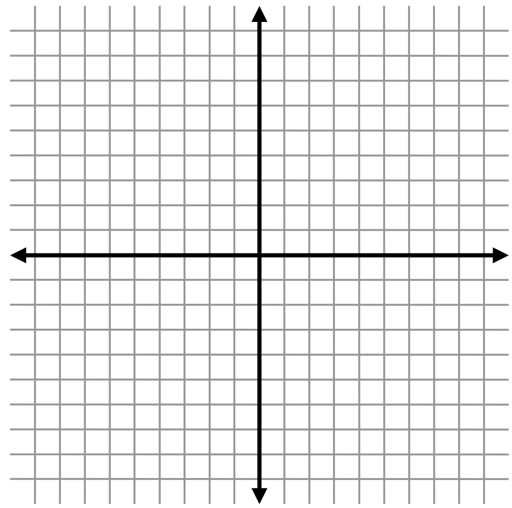
5. Administer the post quiz and collect it once the students have completed. This will measure the knowledge gained by the students.

Evidence of Success: *What exactly do I expect students to be able to do by the end of the lesson, and how will I measure student mastery? That is, deliberate consideration of what performances will convince you (and any outside observer) that your students have developed a deepened (and conceptual) understanding.* At the end of this lesson, students should be able to draw, interpret, and evaluate a piecewise function. Students should be able to graph given the certain constraints for each function.	
Notes and Nuances: *Vocabulary, connections, common mistakes, typical misconceptions, etc.* Piecewise function, function, domain, range	
Resources: *What materials or resources are essential for students to successfully complete the lesson tasks or activities?* Worksheet, transparent paper	**Homework:** *Exactly what follow-up homework tasks, problems, and/or exercises will be assigned upon the completion of the lesson?*
Lesson Reflections: *What questions, connected to the lesson objectives and evidence of success, will you use to reflect on the effectiveness of this lesson?*	

Piecing Together Piecewise Functions

1) Given the following linear equations, represent solutions graphically on two separate coordinate planes. y = 3x and y = -2x+20



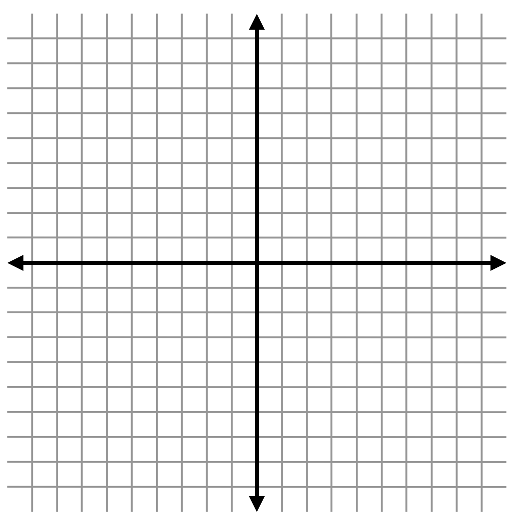


2) Using the coordinate plane below, place a piece of transparent paper on top and graph the solution of the first equation according to the given domain.

y = 3x where $-1 \leq x < 4$

Now place a second piece of transparent paper on top and using a different colored pencil, graph the solution of the second equation according to the given domain.

y = -2x+20 where $4 \leq x \leq 6$



3) What are some similarities between your first two graphs? What are some differences?

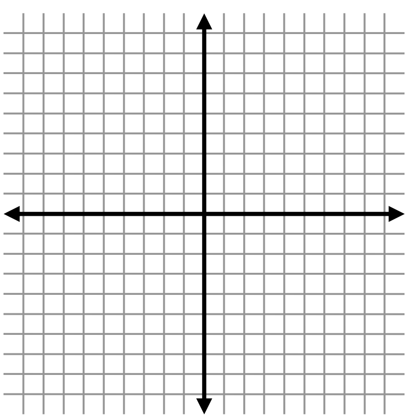
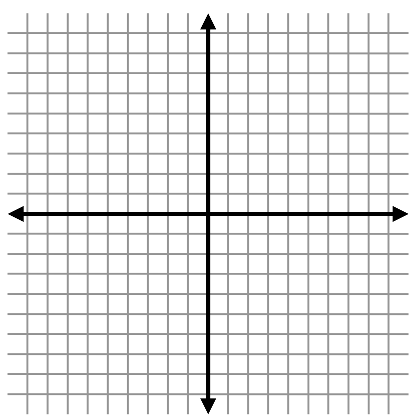
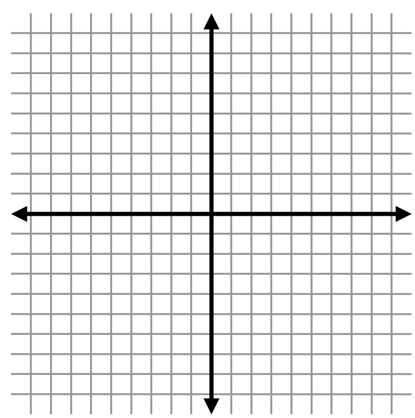
Written in functional notation, number two would look like the following:

4) This is known as a piecewise function. Using the third graph and the discussion we just had, write your own definition for a piecewise function.

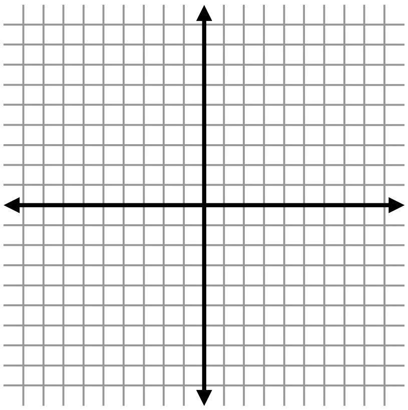
5) Using transparent paper, graph the following piecewise functions. What features do you notice when graphing each function.

a) $$f(x) = \begin{cases} x + 3, & \text{if } x \le 0 \\ 2x, & \text{if } x > 0 \end{cases}$$

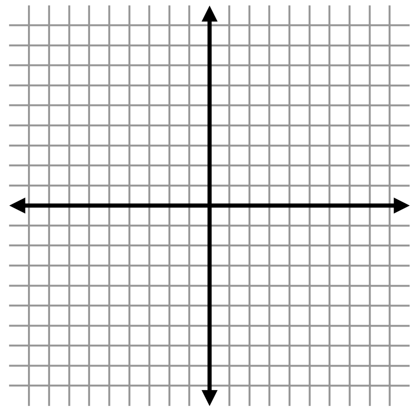
b) $$y = \begin{cases} -\frac{1}{4}x - 3 & x \le -3 \\ 3x & -3 < x \le 3 \\ -\frac{1}{4}x + 3 & x > 3 \end{cases}$$

c) $f(x)=\begin{cases} x-4, & if(-\infty,2) \\ 3-x, & if(2,\infty) \end{cases}$



d) $f(x)=\begin{cases} x+6,(-\infty,-3] \\ \frac{-2}{3}x-3,(-3,\infty) \end{cases}$



Appendix G

Lesson #2: Quadratics (Control/Treatment)

Lesson Title: __Parabolic Graphs___(Treatment)________________ Course: _Algebra 2________
Date: ______________ Teacher(s): ____________________ Start/end times: ___50mins____

Lesson Objective(s): *What mathematical skill(s) and understanding(s) will be developed?*

Students will be able to:

- Sketch how a parabola changes as a, b, and c vary ($y=ax^2 + bx + c$)
- Predict how a parabola will look given equations in a variety of forms

Lesson Launch Notes: *Exactly how will you use the first five minutes of the lesson?*

Students will use their graphing calculators graph the function: $f(x)=x^2+4x-3$. Students will write two sentences describing features of the graph.

Lesson Closure Notes: *Exactly what summary activity, questions, and discussion will close the lesson and provide a foreshadowing of tomorrow? List the questions.*

Lesson Tasks, Problems, and Activities (attach resource sheets): *What specific activities, investigations, problems, questions, or tasks will students be working on during the lesson?*

Warmup:

Students will graph the function $f(x)=x^2+4x-3$. Sketch the axis of symmetry. What does the axis of symmetry tell use?

Procedures/Development:

***Students will be working in pairs to understand relationships of quadratic graphs. Students will use the Equation Grapher simulation (http://www.simulation-math.com/GraphingCalculator1/AGraphingCalculator.cshtml).
***

1. Administer the pre-quiz and collect it once finished. This will test the students' prior knowledge on the subject matter.
2. Distribute the worksheet on quadratic functions. Students will experiment looking at the quadratic functions and make adjustments to their functions.
3. Students will work in pairs. They will follow along the guided worksheet. The teacher can assist with any questions.

Work with a partner on this activity to share ideas and paper. Remember that talking about your learning helps you understand and recall what you learn. Use one part of your graph paper for each number.

1. Sketch the line $y=x^2$ on your graph paper.
   a. Use another color to draw what you think $y=2x^2$ will look like.
   b. Use the *Equation Grapher* simulation to check your ideas. Make corrections if necessary.

c. Design and do experiments to test how changing the number in front of x^2 changes the look of lines.

2. Your friend, Eli, asked you to help him with his graphing homework. What would you tell Eli to help him use the number in front of x^2? Draw graphs that would help you explain the idea to Eli.

3. Sketch the line $y=x^2$ on your graph paper.
   a. Use another color to draw what you think $y=x^2 + 2$ will look like.
   b. Use the *Equation Grapher* simulation to check your ideas. Make corrections if necessary.
   c. Design and do experiments to test how changing the last number changes the parabola.

4. Your friend, Vanessa, heard that you helped Eli understand graphing so she asked to you to help her. What would you tell Vanessa to help her use the number at the end of the equation? Draw graphs that would help you explain the idea to Van.

5. Sketch the line $y=x^2$ on your graph paper.
   a. Use another color to draw what you think $y=x^2 + 2x$ will look like.
   b. Use the *Equation Grapher* simulation to check your ideas. Make corrections if necessary.
   c. Design and do experiments to test how changing the number in front of x changes the parabola.

6. Your friend, Ryan, asked to you to help him how to use the number in front of x? Draw graphs that would help you explain the idea to Ryan.

7. Now put all three ideas together to sketch $y=3x^2+2x+4$. Check your sketch and make corrections if necessary.

8. Sketch graphs for the following, checking your work.
   a. $y = 2x^2+3x-2$
   b. $y = -1x^2+2x+3$
   c. $y = 3x^2+1/3x -1$
   d. $y= 3x^2-2x + 4$
   e. $y=1/2x^2+1/4x-2$

9. Bob is trying to graph the line $y = 2 -.3x^2 + 1/2x$. He can't understand how this problem fits with the lesson because the x^2 isn't at the beginning of the equation.
   a. What could you tell Bob to help him?
   b. Sketch what you think the graph will look like.
   c. Use the sim to check your graph and then make any corrections.

*** The simulator is designed to have students explore the different quadratic functions, and then use the functions to write rules/properties for the students to use.***

10. Administer the post quiz and collect it once the students have completed. This will measure the knowledge gained by the students.

Evidence of Success: *What exactly do I expect students to be able to do by the end of the lesson, and how will I measure student mastery? That is, deliberate consideration of what performances will convince you (and any outside observer) that your students have developed a deepened (and conceptual) understanding.*

<table>
<tr><td colspan="2">At the end of this lesson, students should be able to discuss the impact of the value in from on “a”, “b”, and “c”. Students will be pre/post assessed. The teacher will be assessing that the students understand the impact of values in front of a, b, and c. Also, the teacher will be looking to see if students can sketch a graph without using the simulator and using the properties developed by the students.</td></tr>
<tr><td colspan="2">Notes and Nuances: Vocabulary, connections, common mistakes, typical misconceptions, etc.
Parabola, axis of symmetry, vertex, shifts</td></tr>
<tr><td>Resources: What materials or resources are essential for students to successfully complete the lesson tasks or activities?

Will be using the http://phet.colorado.edu/en/simulation/equation-grapher</td><td>Homework: Exactly what follow-up homework tasks, problems, and/or exercises will be assigned upon the completion of the lesson?

Pg 254 #20-24, 50 a and b</td></tr>
<tr><td colspan="2">Lesson Reflections: What questions, connected to the lesson objectives and evidence of success, will you use to reflect on the effectiveness of this lesson?</td></tr>
</table>

Lesson Title: __Parabolic Graphs___(Control)________________ Course: _Algebra 2________
Date: _____________ Teacher(s): ____________________ Start/end times: ___50mins_

Lesson Objective(s): *What mathematical skill(s) and understanding(s) will be developed?*

Students will be able to:

- Sketch how a parabola changes as a, b, and c vary ($y=ax^2 + bx + c$)
- Predict how a parabola will look given equations in a variety of forms

Lesson Launch Notes: *Exactly how will you use the first five minutes of the lesson?*

Students will use their graphing calculators to graph the function: $f(x)=x^2+4x-3$. Students will write two sentences describing features of the graph.

Lesson Closure Notes: *Exactly what summary activity, questions, and discussion will close the lesson and provide a foreshadowing of tomorrow? List the questions.*

On an index card, students will summarize the ideas they have developed by adjusting the a, b, and c values of a graph in comparison to the parent function.

Lesson Tasks, Problems, and Activities (attach resource sheets): *What specific activities, investigations, problems, questions, or tasks will students be working on during the lesson?*

Warm-up:

Students will graph the function $f(x)=x^2+4x-3$. Sketch the axis of symmetry. What does the axis of symmetry tell us?

Procedures/Development:

1. Administer the pre-quiz and collect it once finished. This will test the students' prior knowledge on the subject matter.
2. Distribute the worksheet on quadratic functions. Students will experiment looking at the quadratic functions and make adjustments to their functions.
3. Students will work in pairs. They will follow along the guided worksheet. The teacher can assist with any questions.

***Students will be working in pairs to understand relationships of quadratic graphs. Graphing calculator and graph paper. ***

Work with a partner on this activity to share ideas and paper. Remember that talking about your learning helps you understand and recall what you learn. Use one part of your graph paper for each number.

4. Sketch the line $y=x^2$ on your graph paper.
    a. Use another color to draw what you think $y=2x^2$ will look like.
    b. Use the graphing calculator to check your ideas. Make corrections if necessary.
    c. Design and do experiments to test how changing the number in front of x^2 changes the look of lines.

5. Your friend, Eli, asked you to help him with his graphing homework. What would you tell Eli to help him use the number in front of x^2? Draw graphs that would help you explain the idea to Eli.

6. Sketch the line $y=x^2$ on your graph paper.
    a. Use another color to draw what you think $y=x^2 + 2$ will look like.
    b. Use the graphing calculator to check your ideas. Make corrections if necessary.
    c. Design and do experiments to test how changing the last number changes the parabola.

7. Your friend, Vanessa, heard that you helped Eli understand graphing so she asked to you to help her. What would you tell Vanessa to help her use the number at the end of the equation? Draw graphs that would help you explain the idea to Van.

8. Sketch the line $y=x^2$ on your graph paper.
    a. Use another color to draw what you think $y=x^2 + 2x$ will look like.
    b. Use the graphing calculator to check your ideas. Make corrections if necessary.
    c. Design and do experiments to test how changing the number in front of x changes the parabola.

9. Your friend, Ryan, asked to you to help him learn how to use the number in front of x? Draw graphs that would help you explain the idea to Ryan.

10. Now put all three ideas together to sketch $y=3x^2+2x+4$. Check your sketch and make corrections if necessary.

11. Sketch graphs for the following, checking your work.
    a. $y = 2x^2+3x-2$
    b. $y = -1x^2+2x+3$
    c. $y = 3x^2+1/3x -1$
    d. $y= 3x^2-2x + 4$
    e. $y=1/2x^2+1/4x-2$

12. Bob is trying to graph the line $y = 2 -.3x^2 + 1/2x$. He can't understand how this problem fits with the lesson because the x^2 isn't at the beginning of the equation.
    a. What could you tell Bob to help him?
    b. Sketch what you think the graph will look like.
    c. Use the calculator to check your graph and then make any corrections.

*** The lesson is designed to have students explore the different quadratic functions, and then use the functions to write rules/properties for the students to use.***

Administer the post quiz and collect it once the students have completed. This will measure the knowledge gained by the students.

Evidence of Success: *What exactly do I expect students to be able to do by the end of the lesson, and how will I measure student mastery? That is, deliberate consideration of what performances will convince you (and any outside observer) that your students have developed a deepened (and conceptual) understanding.*

At the end of this lesson, students should be able to discuss the impact of the value in from on "a", "b", and "c". Students will be pre/post assessed. The teacher will be assessing that the students understand the impact of values in front of a, b, and c. Also, the teacher will be looking to see if students can sketch a graph without using the simulator and using the properties developed by the students.

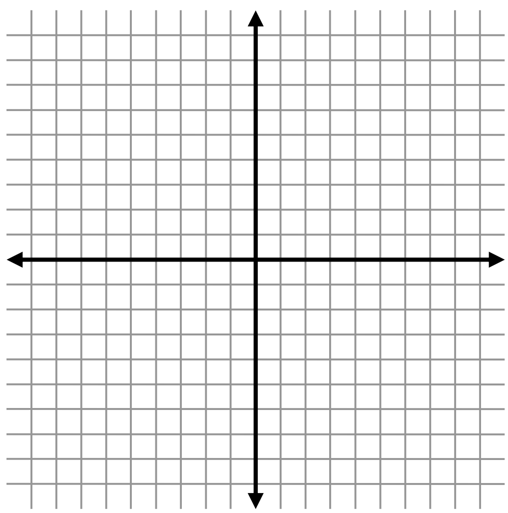
<table>
<tr><td colspan="2"></td></tr>
<tr><td colspan="2">Notes and Nuances: Vocabulary, connections, common mistakes, typical misconceptions, etc.
Parabola, axis of symmetry, vertex, shifts</td></tr>
<tr><td>Resources: What materials or resources are essential for students to successfully complete the lesson tasks or activities?

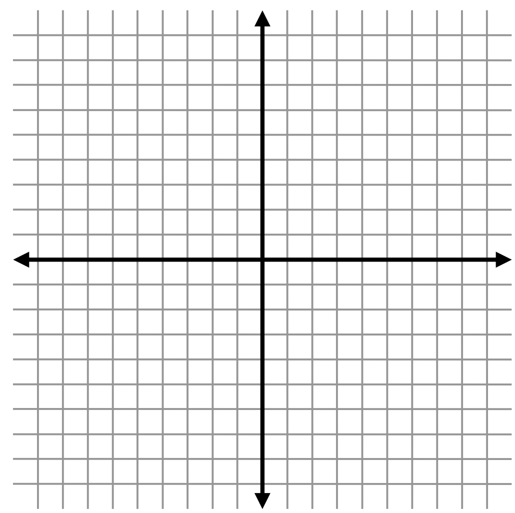
Will be using the graphing calculator, graph paper.</td><td>Homework: Exactly what follow-up homework tasks, problems, and/or exercises will be assigned upon the completion of the lesson?

Pg 254 #20-24, 50 a and b</td></tr>
<tr><td colspan="2">Lesson Reflections: What questions, connected to the lesson objectives and evidence of success, will you use to reflect on the effectiveness of this lesson?</td></tr>
</table>

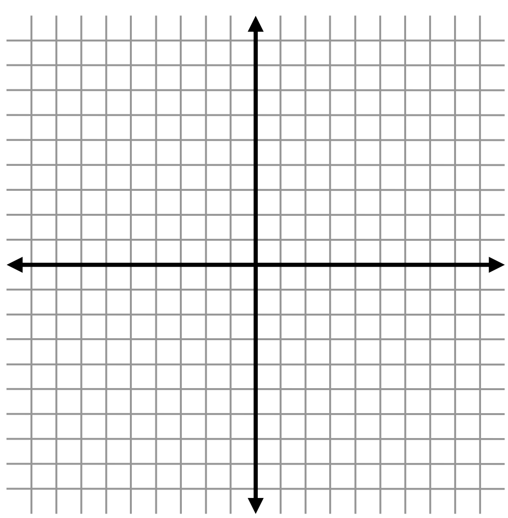
Investigation of Quadratic Functions

1. Sketch the line $y=x^2$ on the grid below.
    a. Use another color to draw what you think $y=2x^2$ will look like.
    b. Use the *Equation Grapher* simulation to check your ideas. Make corrections if necessary.
    c. Design and do experiments to test how changing the number in front of x^2 changes the look of lines. Sketch these graphs on the other grid provided, using different colors. Make sure your graphs are labeled.

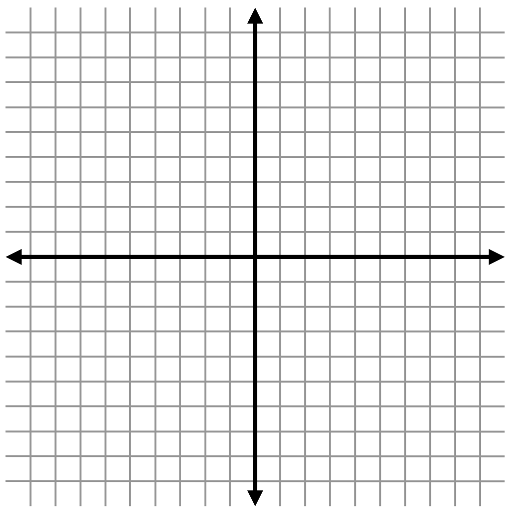


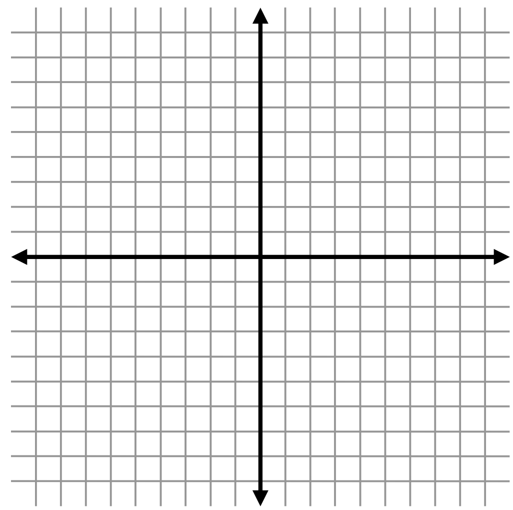


2. Your friend, Eli, asked you to help him with his graphing homework. What would you tell Eli to help him use the number in front of x^2? Draw graphs that would help you explain the idea to Eli.

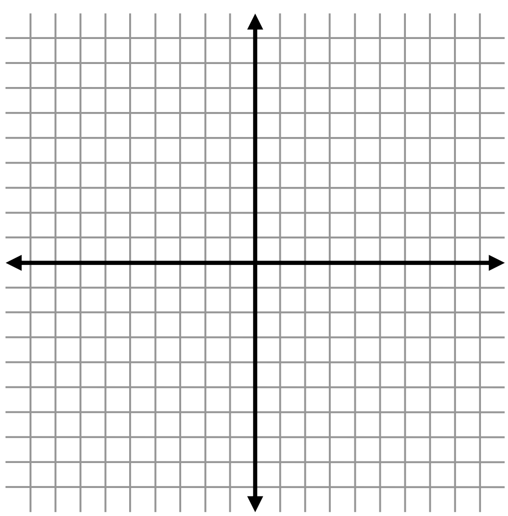


3. Sketch the line $y=x^2$ on your graph paper.
    a. Use another color to draw what you think $y=x^2 + 2$ will look like.
    b. Use the *Equation Grapher* simulation to check your ideas. Make corrections if necessary.
    c. Design and do experiments to test how changing the last number changes the parabola. Sketch these graphs on the other grid provided, using different colors. Make sure your graphs are labeled.

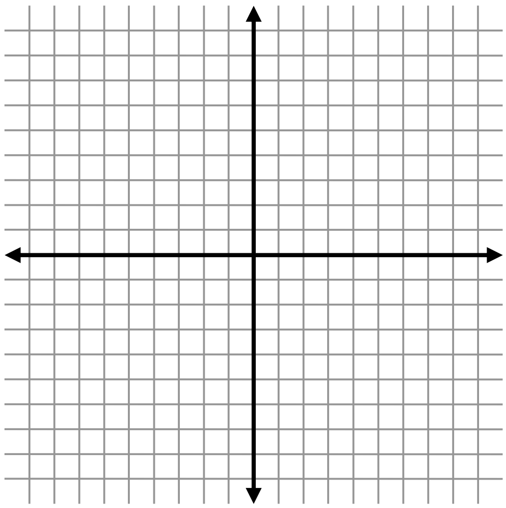


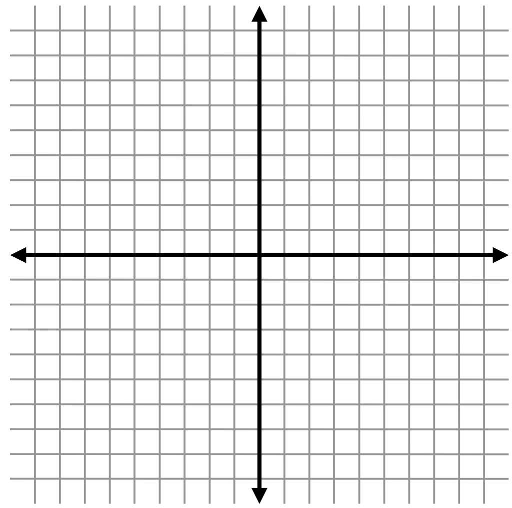


4. Your friend, Vanessa, heard that you helped Eli understand graphing so she asked to you to help her. What would you tell Vanessa to help her use the number at the end of the equation? Draw graphs that would help you explain the idea to Van.

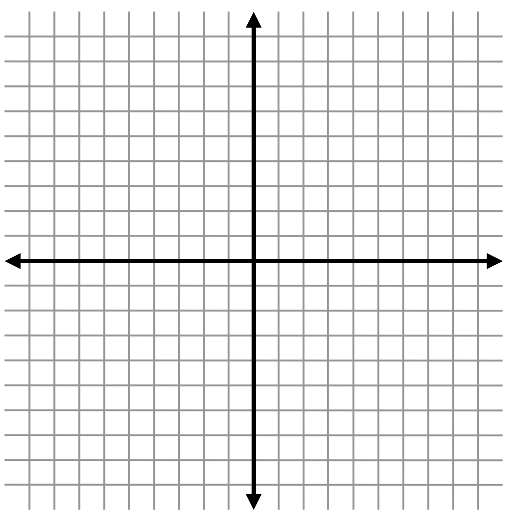


5. Sketch the line $y=x^2$ on your graph paper.
   a. Use another color to draw what you think $y=x^2 + 2x$ will look like.
   b. Use the *Equation Grapher* simulation to check your ideas. Make corrections if necessary.
   c. Design and do experiments to test how changing the number in front of x changes the parabola. Sketch these graphs on the other grid provided, using different colors. Make sure your graphs are labeled.

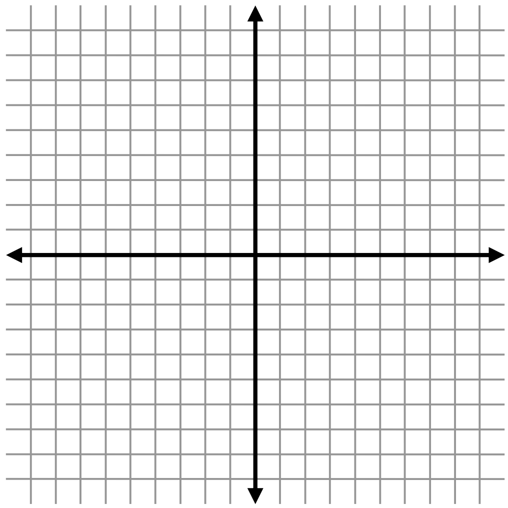




6. Your friend, Ryan, asked to you to help him how to use the number in front of x? Draw graphs that would help you explain the idea to Ryan.

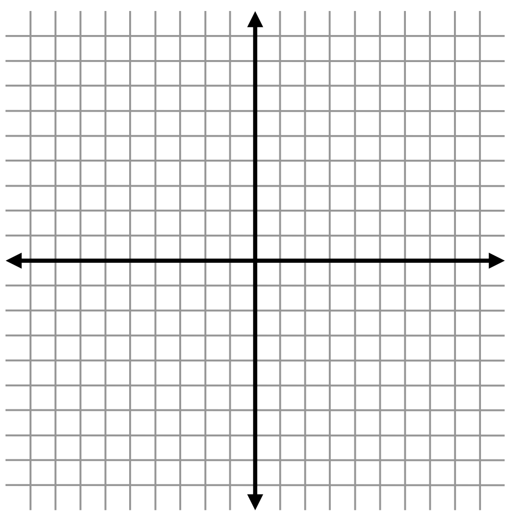


7. Now put all three ideas together to sketch $y=3x^2+2x+4$. Check your sketch and make corrections if necessary.

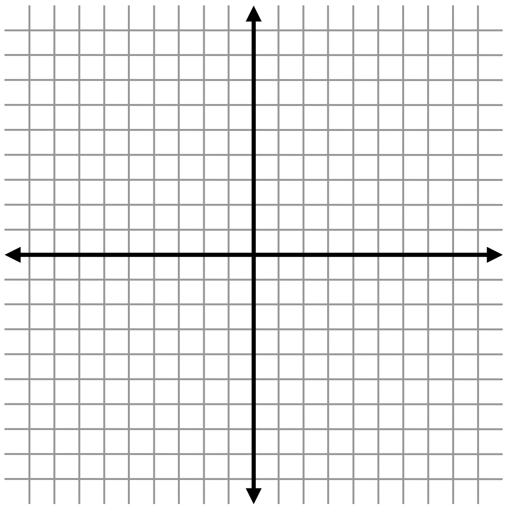
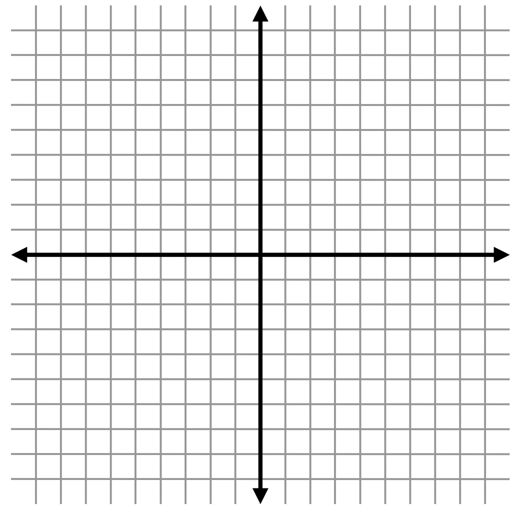
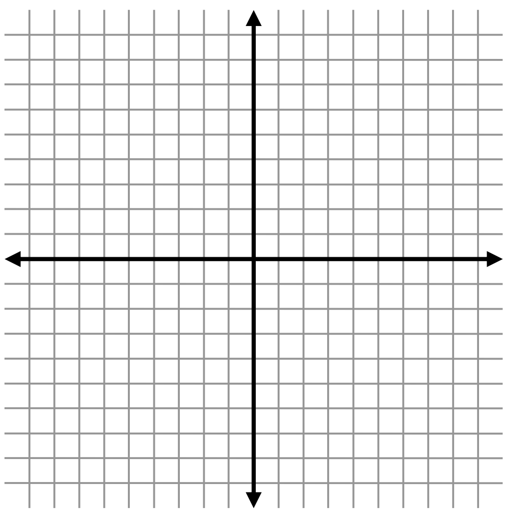
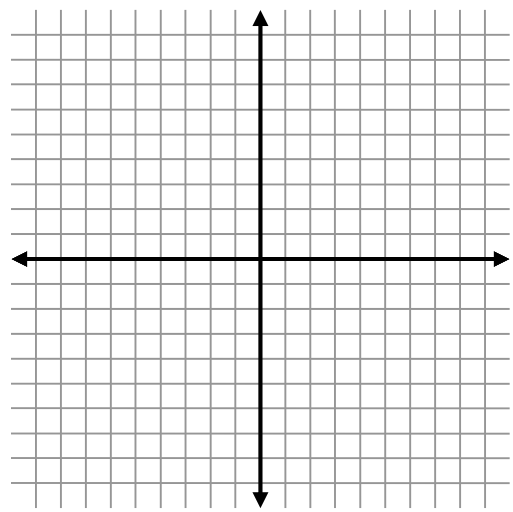


8. Bob is trying to graph the line $y = 2 -.3x^2 + 1/2x$. He can't understand how this problem fits with the lesson because the x^2 isn't at the beginning of the equation.

   a. What could you tell Bob to help him?
   b. Sketch what you think the graph will look like.
   c. Use the sim to check your graph and then make any corrections.



9. Sketch graphs for the following, checking your work.
   a. $y = 2x^2+3x-2$
   b. $y = -1x^2+2x+3$
   c. $y = 3x^2+1/3x -1$
   d. $y= 3x^2-2x + 4$

Appendix H

Lesson #3: Exponential (Control/Treatment)

Lesson Title: __Exponential Graphs___(Treatment)_________________ Course: _Algebra 2________
Date: ______________ Teacher(s): ___________________ Start/end times: ___50 mins

Lesson Objective(s): *What mathematical skill(s) and understanding(s) will be developed?*

Students will be able to:

- For a function that models a relationship between two quantities, interpret key features of a graphs and tables in terms of the quantities, and sketch graphs showing key features given a verbal description of the relationship. *Key features include: intervals where the function is increasing, decreasing, positive, or negative and end behavior.*

Lesson Launch Notes: *Exactly how will you use the first five minutes of the lesson?*

Have the students graph the following linear function: $f(x) = 2x - 3$ and determine the domain and range.

Lesson Closure Notes: *Exactly what summary activity, questions, and discussion will close the lesson and provide a foreshadowing of tomorrow? List the questions.*

Lesson Tasks, Problems, and Activities (attach resource sheets): *What specific activities, investigations, problems, questions, or tasks will students be working on during the lesson?*

Warm-up:

Have the students write a model for the following situation: Describe the end behavior of the graph $f(x) = x(x - 6)(x + 2)$

Procedures/Development:

***Students will be working in pairs to understand characteristics of exponential functions. Students will use the guided notes provided by the teacher and (http://www.simulation-math.com/GraphingCalculator1/AGraphingCalculator.cshtml). ***

1. Administer the pre-quiz and collect it once finished. This will test the students' prior knowledge on the subject matter.

2. Distribute the worksheet on exponential functions characteristics. Students will experiment looking at the exponential functions.

3. Students will work in pairs. They will follow along on the guided worksheet. The teacher can assist with any questions.

4. Working with a partner, the students will work through the "Exploring Exponential Graphs" worksheet. This worksheet will allow students to explore the properties of piecewise functions. They will also develop knowledge on what will be the most important parts of graphing piecewise functions.

5. Administer the post quiz and collect it once the students have completed. This will measure the knowledge gained by the students.
Evidence of Success: *What exactly do I expect students to be able to do by the end of the lesson, and how will I measure student mastery? That is, deliberate consideration of what performances will convince you (and any outside observer) that your students have developed a deepened (and conceptual) understanding.* At the end of this lesson, students should be able to draw, interpret, and evaluate a piecewise function. Students should be able to graph given the certain constraints for each function.
Notes and Nuances: *Vocabulary, connections, common mistakes, typical misconceptions, etc.* Piecewise function, function, domain, range

Resources: *What materials or resources are essential for students to successfully complete the lesson tasks or activities?* Worksheet, transparent paper	**Homework:** *Exactly what follow-up homework tasks, problems, and/or exercises will be assigned upon the completion of the lesson?* Pg 117 #21-26, all

Lesson Reflections: *What questions, connected to the lesson objectives and evidence of success, will you use to reflect on the effectiveness of this lesson?*

Lesson Title: __Exponential Graphs___(Control)________________ Course: _Algebra 2________
Date: _____________ Teacher(s): __________________ Start/end times: ___50 mins____

Lesson Objective(s): *What mathematical skill(s) and understanding(s) will be developed?*

Students will be able to:

- For a function that models a relationship between two quantities, interpret key features of a graphs and tables in terms of the quantities, and sketch graphs showing key features given a verbal description of the relationship. *Key features include: intervals where the function is increasing, decreasing, positive, or negative and end behavior.*

Lesson Launch Notes: *Exactly how will you use the first five minutes of the lesson?*

Have the students graph the following linear function: $f(x) = 2x - 3$ and determine the domain and range.

Lesson Closure Notes: *Exactly what summary activity, questions, and discussion will close the lesson and provide a foreshadowing of tomorrow? List the questions.*

Lesson Tasks, Problems, and Activities (attach resource sheets): *What specific activities, investigations, problems, questions, or tasks will students be working on during the lesson?*

Warm-up:

Have the students write a model for the following situation: Describe the end behavior of the graph $f(x) = x(x - 6)(x + 2)$

Procedures/Development:

***Students will be working in pairs to understand characteristics of exponential functions. Students will use the guided notes provided by the teacher and there graphing calculator. ***

1. Administer the pre-quiz and collect it once finished. This will test the students' prior knowledge on the subject matter.

2. Distribute the worksheet on exponential functions characteristics. Students will experiment looking at the exponential functions.

3. Students will work in pairs. They will follow along on the guided worksheet. The teacher can assist with any questions.

4. Working with a partner, the students will work through the "Exploring Exponential Graphs" worksheet. This worksheet will allow students to explore the properties of piecewise functions. They will also develop knowledge on what will be the most important parts of graphing piecewise functions.

5. Administer the post quiz and collect it once the students have completed. This will measure the knowledge gained by the students.

<table>
<tr><td colspan="2"></td></tr>
<tr><td colspan="2">Evidence of Success: What exactly do I expect students to be able to do by the end of the lesson, and how will I measure student mastery? That is, deliberate consideration of what performances will convince you (and any outside observer) that your students have developed a deepened (and conceptual) understanding.

At the end of this lesson, students should be able to draw, interpret, and evaluate a piecewise function. Students should be able to graph given the certain constraints for each function.</td></tr>
<tr><td colspan="2">Notes and Nuances: Vocabulary, connections, common mistakes, typical misconceptions, etc.
Piecewise function, function, domain, range</td></tr>
<tr><td>Resources: What materials or resources are essential for students to successfully complete the lesson tasks or activities?

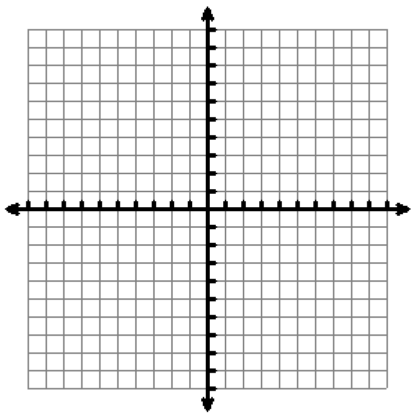
Worksheet, transparent paper</td><td>Homework: Exactly what follow-up homework tasks, problems, and/or exercises will be assigned upon the completion of the lesson?

Pg 117 #21-26, all</td></tr>
<tr><td colspan="2">Lesson Reflections: What questions, connected to the lesson objectives and evidence of success, will you use to reflect on the effectiveness of this lesson?</td></tr>
</table>

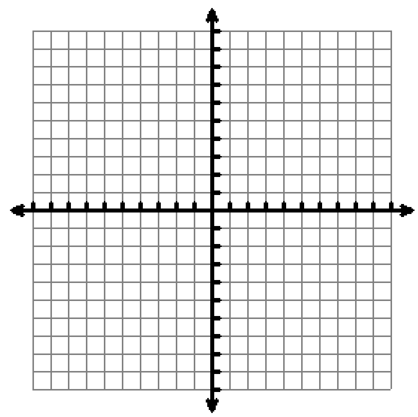
Exploring Exponential Graphs

- How are the equations listed below similar? How are they different?
- Type the parent function $y = 2^x$ into y_1, the type each transformed equation into y_2 and compare.
- Fill in a table of values for each and sketch the graph. Be sure to sketch the parent function on each graph.
- Give similarities and differences between the parent function and the transformed function. Be sure to include
    - Where the graph level off
    - The range and horizontal asymptote for each.
    - Where the graph crosses the *y*-axis
    - How the graph is changing.
- Relate the changes in the equations to what you see in the graph.

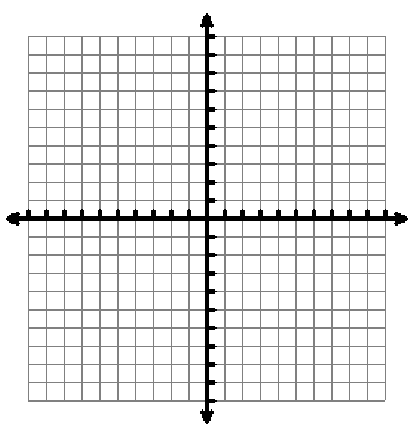
$y = 2^x$



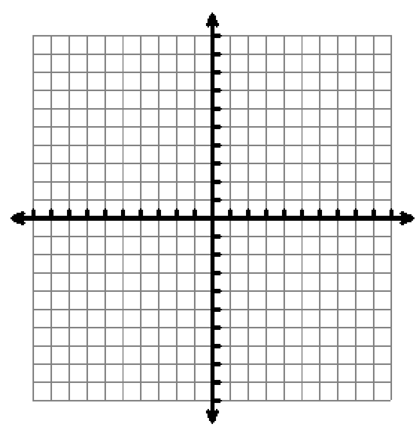
$y = 3(2)^x$



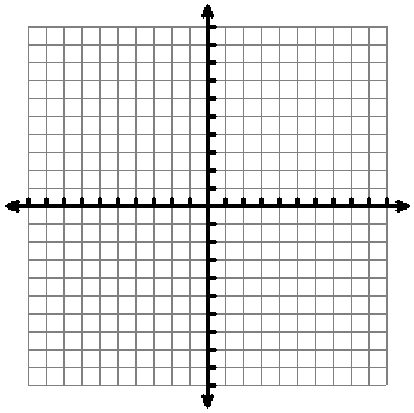
$y = -2(2)^x$



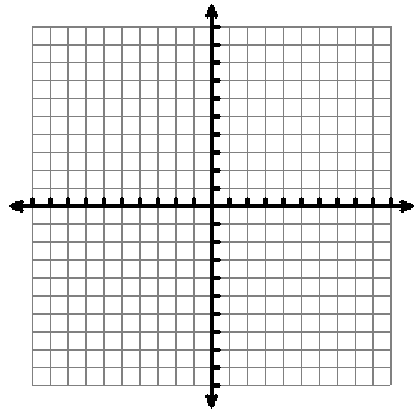
$y = 2^x + 3$



$y = 2^x - 1$

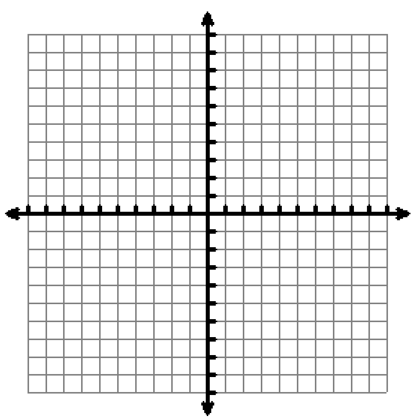


$y = 2^x - 4$

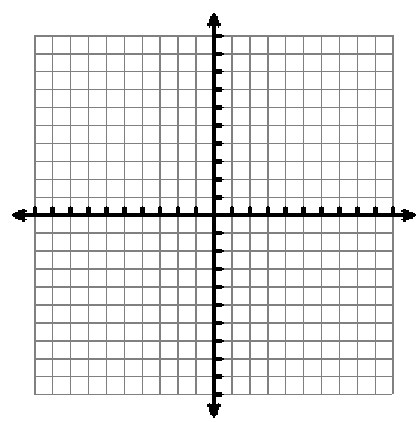


- How are the equations listed below similar? How are they different?
- Type the parent function $y = \left(\frac{3}{4}\right)^x$ into y_1, the type each transformed equation into y_2 and compare.
- Give similarities and differences between the parent function and the transformed function. Be sure to include
    - Where the graph level off
    - The range and horizontal asymptote for each
    - Where the graph crosses the *y*-axis
    - How the graph is changing.
- Relate the changes in the equations to what you see in the graph.

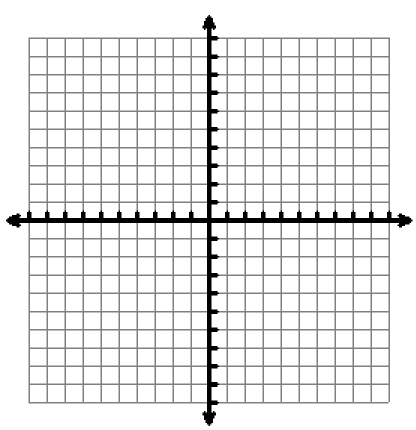
$y = \left(\frac{3}{4}\right)^x$



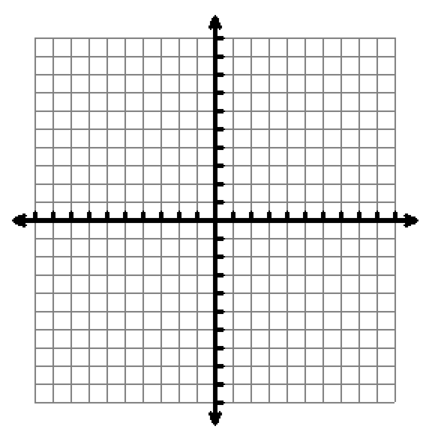
$y = 3\left(\frac{3}{4}\right)^x$



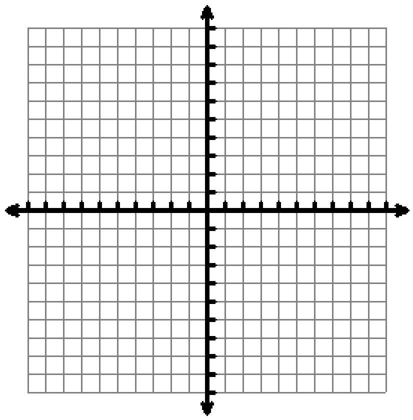
$y = -2\left(\frac{3}{4}\right)^x$



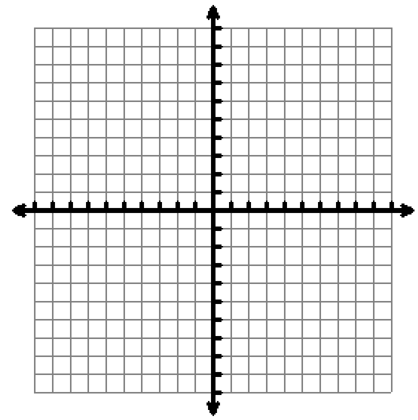
$y = \left(\frac{3}{4}\right)^x + 3$



$y = \left(\frac{3}{4}\right)^{x} - 1$



$y = \left(\frac{3}{4}\right)^{x-4}$



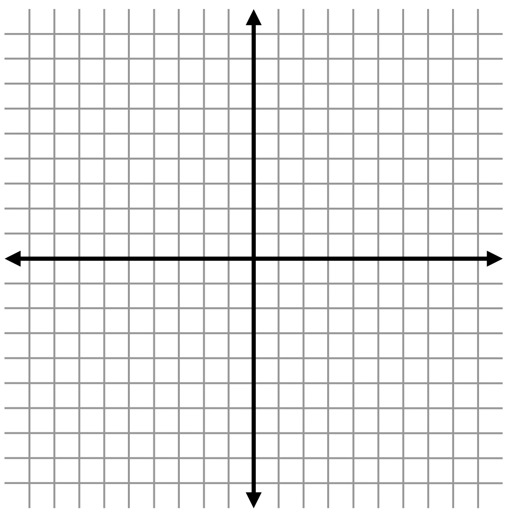
Appendix I

Pre/Post-Assessment Algebra 2 (Control/Treatment)

Pre-Assessment /Post-Assessment

Sketch the following quadratic functions. State the Domain, Range, and y-intercepts.

1. $y = x^2 - 4x + 3$

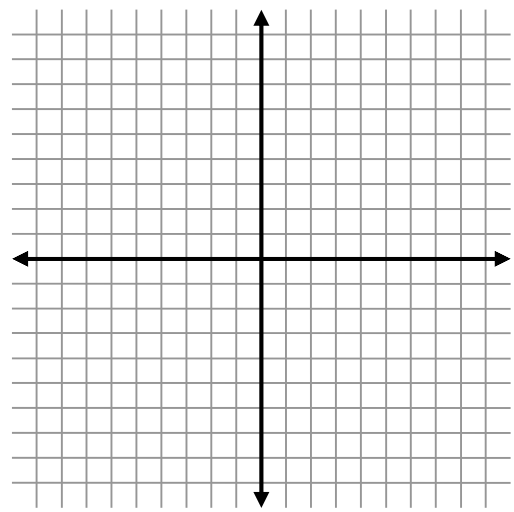


Domain:____________________

Range:_____________________

y-intercepts: _____________

2. $y = -2x^2 - 8x - 5$



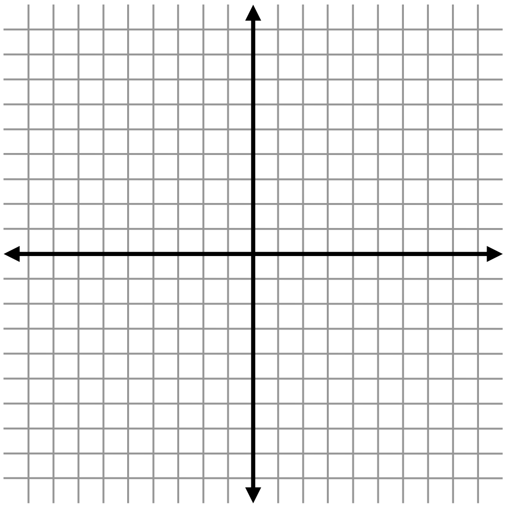
Domain::_________________

Range: __________________

y-intercepts:____________

Graph each piecewise function below.

3. $f(x)=\begin{cases} 2x+3, [0,\infty) \\ x+4, (-\infty,0] \end{cases}$

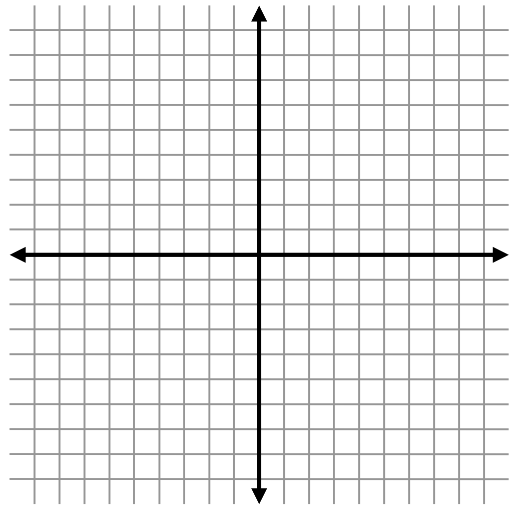


Evaluate:

f(3): ______________

f(-3): ______________

4. $f(x)=\begin{cases} 2x, [-1,\infty) \\ 3x, [-2,-1] \\ -x, (-\infty,-2] \end{cases}$



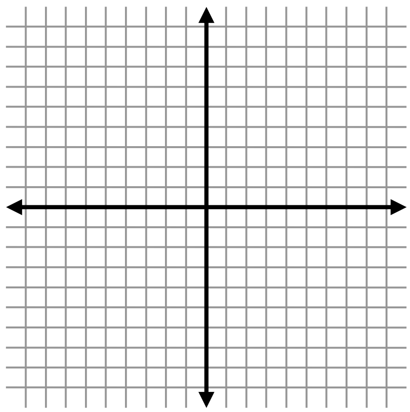
Evaluate:

f(-1): ______________

f(5): ______________

Given the following graphs answer the follow questions.

5. $f(x) = 2^{x-4} + 3$



Domain: ______________________________

Range: ______________________________

Asymptote: ______________________________

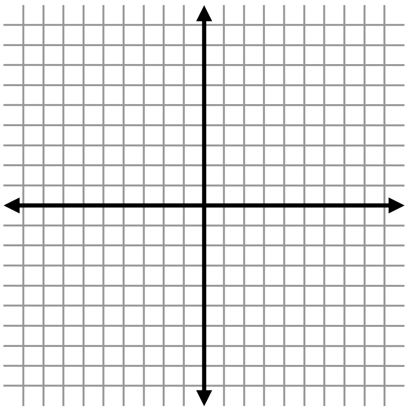
y-intercept: ________________________

End Behavior: _______________________

____

How is the graph changing?

6. $f(x) = -3^{x+2} - 5$



Domain: ________________________

Range:__________________________

Asymptote:______________________

y-intercept: ___________________

End Behavior: __________________

____

How is the graph changing?

Appendix J

Demographic Survey (Control/Treatment)

Please take a moment to complete this demographic survey. No personal information will be attached to the results. Information gathered from this survey is used only for the purpose of demographic record keeping. Completion of this survey is important, and all responses are anonymous.

1. Gender (Select One): Male _____ Female ______

2. Age (Specify in years): ______

3. Class Standing (Select One): Freshman Sophomore Junior Senior

4. Ethnicity (Select One):

   ______ African American
   ______ Asian or Pacific American
   ______ Hispanic, Latino, or Chicano
   ______ Native American, Alaskan Native
   ______ White (Non-Hispanic)
   ______ Other (Specify): ___________________________

5. List previous High School Mathematics Classes Taken: ______________________

6. Do you receive any outside mathematics help? (e.g. tutor) __________________

If you have answered yes to question 6, then please list what kind of help you receive and how often you receive it.

---

7. Do you have a computer at your home? ______ Yes ______ No

8. If you do have a computer, how often do you use it during a typical week? (Check one)

   _____ Never

   _____ More then six times a week

   _____ Four to six times a week

   _____ One to three times a week

9. What do you use your computer for at home? (Check all that apply)

_____ Games _____ Homework

_____ Internet _____ Homework Hotline

_____ Watch Movies _____ I never use the computer

_____ Music ______ other

If other is selected please list (ex. Facebook, twitter, instagram, tumbler, etc….)

____
____

10. How often do you use a computer in mathematics class during one week? (Check one)

_____ Never One to three times a week

_____ One to ten times a week

_____ Ten to twenty times a week

_____ More then twenty times a week

Appendix K

Attitudes Toward Mathematics Inventory (ATMI)

Directions: This inventory consists of statements about your attitudes towards mathematics. There are no correct responses. Read each item carefully. Please think about how you feel about each item. Enter the letter that most closely corresponds to how each statement best describes your feelings. Use the following response scale to respond to each item.

PLEASE USE THESE RESONSE CODES: A- Strongly Disagree
B- Disagree
C- Neutral
D- Agree
E- Strongly Agree

1. Mathematics is a very worthwhile and necessary subject.	
2. I want to develop my mathematical skills.	
3. I get a great deal of satisfaction out of solving a mathematics problem.	
4. Mathematics helps me develop the mind and teachers a person to think.	
5. Mathematics is important in everyday life.	
6. Mathematics is one of the most important subjects for people to study.	
7. High school math courses would be very helpful no matter what I decide to study.	
8. I can think of many ways that I use math outside of school.	
9. Mathematics is one of my most dreaded subjects.	
10. My mind goes blank and I am unable to think clearly when working with mathematics.	
11. Studying mathematics makes me feel nervous.	
12. Mathematics makes me feel uncomfortable.	
13. I am always under a terrible strain in a math class.	
14. When I hear the word mathematics, I have a feeling of dislike.	
15. It makes me nervous to even think about having to do a mathematics problem,	
16. Mathematics does not scare me at all.	
17. I have a lot of self-confidence when it comes to mathematics.	
18. I am able to solve mathematics problems without to much difficulty.	
19. I expect to do fairly well in any math class I take.	
20. I am always confused in my mathematics class.	
21. I feel a sense of insecurity when attempting mathematics.	
22. I learn mathematics easily.	
23. I am confident that I could learn advanced mathematics.	
24. I have usually enjoyed studying mathematics in school.	
25. Mathematics is dull and boring.	
26. I like to solve new problems in mathematics.	
27. I would prefer to do an assignment in math than to write and essay.	
28. I would like to avoid using mathematics in college.	
29. I really like mathematics.	
30. I am happier in a math class than in any other class.	
31. Mathematics is a very interesting subject.	
32. I am willing to take more than the required amount of mathematics.	

33. I plan to take as much mathematics as I can during my education.	
34. The challenge of math appeals me.	
35. I think studying advanced mathematics is useful.	
36. I believe studying math help me with problem solving in other areas.	
37. I am comfortable expressing my own ideas on how to look for solutions do a difficult problem in math.	
38. I am comfortable answering questions in math class.	
39. A strong math background could help me in my professional life.	
40. I believe I am good at solving math problems.	

Appendix L

Mathematics and Technology Attitude Scale (MTAS)

Directions: This scale consists of statements about your attitudes towards mathematics and technology. There are no correct responses. Read each item carefully. Please think about how you feel about each item. Circle the choice that most closely corresponds to how the statements best describes your feelings.

	Hardly Ever	Occasionally	About Half the Time	Usually	Nearly Always
1. I concentrate hard in mathematics.	HE	OC	HA	U	NA
2. I try to answer questions the teacher asks.	HE	OC	HA	U	NA
3. If I make mistakes, I work until I have corrected them.	HE	OC	HA	U	NA
4. If I can't do a problem, I keep trying different ideas.	HE	OC	HA	U	NA
	Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
5. I am good at using computers.	SD	D	NS	A	SA
6. I am good at using things like VCRs, DVDs, MP3s and mobile phones.	SD	D	NS	A	SA
7. I can fix a lot of computer problems.	SD	D	NS	A	SA
8. I can master any computer program needed for school.	SD	D	NS	A	SA
9. I am interested to learn new things in mathematics.	SD	D	NS	A	SA
10. In mathematics you get rewards for your effort.	SD	D	NS	A	SA
11. Learning mathematics in enjoyable.	SD	D	NS	A	SA
12. I get a sense of satisfaction when I solve mathematics problems.	SD	D	NS	A	SA
13. I like using simulations for mathematics.	SD	D	NS	A	SA
14. Using simulations in mathematics is worth the extra effort.	SD	D	NS	A	SA
	Hardly Ever	Occasionally	About Half the Time	Usually	Nearly Always
15. Mathematics is more interesting when using simulations.	SD	D	NS	A	SA
16. Simulations help me learn mathematics better	SD	D	NS	A	SA

Appendix M

ANCOVA Tables

Tests of Between-Subjects Effects: Algebra 2 Final

Dependent Variable: PostTestFinal

Source	Type I Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1430.002[a]	2	715.001	9.652	.000	.083
Intercept	549769.228	1	549769.228	7421.381	.000	.972
PreTestFinal	328.514	1	328.514	4.435	.036	.020
learningmethod	1101.488	1	1101.488	14.869	.000	.066
Error	15704.770	212	74.079			
Total	566904.000	215				
Corrected Total	17134.772	214				

a. R Squared = .083 (Adjusted R Squared = .075)

Tests of Between-Subjects Effects: Algebra 2 Exponential

Dependent Variable: PostTestExp

Source	Type I Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	454.527[a]	2	227.263	11.041	.000	.094
Intercept	67445.879	1	67445.879	3276.777	.000	.939
PreTestExp	.945	1	.945	.046	.831	.000
learningmethod	453.582	1	453.582	22.037	.000	.094
Error	4363.594	212	20.583			
Total	72264.000	215				
Corrected Total	4818.121	214				

a. R Squared = .094 (Adjusted R Squared = .086)

Tests of Between-Subjects Effects: Algebra 2 Piecewise

Dependent Variable: PostTestPiece

Source	Type I Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	28.437[a]	2	14.219	.534	.587	.005
Intercept	34919.070	1	34919.070	1310.587	.000	.861
PreTestPiece	21.397	1	21.397	.803	.371	.004
learningmethod	7.040	1	7.040	.264	.608	.001
Error	5648.493	212	26.644			
Total	40596.000	215				
Corrected Total	5676.930	214				

a. R Squared = .005 (Adjusted R Squared = -.004)

Tests of Between-Subjects Effects: Algebra 2 Quadratics

Dependent Variable: PosttestQuad

Source	Type I Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	209.626[a]	2	104.813	6.850	.001	.061
Intercept	86962.679	1	86962.679	5683.668	.000	.964
PreTestQuad	143.578	1	143.578	9.384	.002	.042
learningmethod	66.048	1	66.048	4.317	.039	.020
Error	3243.695	212	15.300			
Total	90416.000	215				
Corrected Total	3453.321	214				

a. R Squared = .061 (Adjusted R Squared = .052)

Tests of Between-Subjects Effects: ATMI Enjoyment

Dependent Variable: post_atmi_eng

Source	Type I Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	2528.452[a]	2	1264.226	52.496	.000	.331
Intercept	231568.074	1	231568.074	9615.647	.000	.978
pre_atmi_eng	2268.775	1	2268.775	94.209	.000	.308
learningmethod	259.677	1	259.677	10.783	.001	.048
Error	5105.474	212	24.082			
Total	239202.000	215				
Corrected Total	7633.926	214				

a. R Squared = .331 (Adjusted R Squared = .325)

Tests of Between-Subjects Effects: ATMI Self-Confidence

Dependent Variable: post_atmi_self

Source	Type I Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	8337.451[a]	2	4168.726	67.188	.000	.388
Intercept	600864.912	1	600864.912	9684.269	.000	.979
pre_atmi_self	6551.018	1	6551.018	105.584	.000	.332
learningmethod	1786.433	1	1786.433	28.792	.000	.120
Error	13153.637	212	62.045			
Total	622356.000	215				
Corrected Total	21491.088	214				

a. R Squared = .388 (Adjusted R Squared = .382)

Tests of Between-Subjects Effects: ATMI Value

Dependent Variable: post_atmi_value

Source	Type I Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	3307.472[a]	2	1653.736	72.924	.000	.408
Intercept	288737.865	1	288737.865	12732.264	.000	.984
pre_atmi_value	2746.260	1	2746.260	121.100	.000	.364
learningmethod	561.212	1	561.212	24.747	.000	.105
Error	4807.663	212	22.678			
Total	296853.000	215				
Corrected Total	8115.135	214				

a. R Squared = .408 (Adjusted R Squared = .402)

Tests of Between-Subjects Effects: ATMI Self-Confidence

Dependent Variable: post_atmi_self

Source	Type I Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	8337.451[a]	2	4168.726	67.188	.000	.388
Intercept	600864.912	1	600864.912	9684.269	.000	.979
pre_atmi_self	6551.018	1	6551.018	105.584	.000	.332
learningmethod	1786.433	1	1786.433	28.792	.000	.120
Error	13153.637	212	62.045			
Total	622356.000	215				
Corrected Total	21491.088	214				

a. R Squared = .388 (Adjusted R Squared = .382)

Tests of Between-Subjects Effects: ATMI Enjoyment

Dependent Variable: post_atmi_eng

Source	Type I Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	2528.452[a]	2	1264.226	52.496	.000	.331
Intercept	231568.074	1	231568.074	9615.647	.000	.978
pre_atmi_eng	2268.775	1	2268.775	94.209	.000	.308
learningmethod	259.677	1	259.677	10.783	.001	.048
Error	5105.474	212	24.082			
Total	239202.000	215				
Corrected Total	7633.926	214				

a. R Squared = .331 (Adjusted R Squared = .325)

Tests of Between-Subjects Effects: MTAS Behavioral Engagement
Dependent Variable: postBE

Source	Type I Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	202.162[a]	2	101.081	17.722	.000	.145
Intercept	49333.755	1	49333.755	8649.354	.000	.976
preBE	182.904	1	182.904	32.067	.000	.133
learningmethod	19.258	1	19.258	3.376	.068	.016
Error	1192.084	209	5.704			
Total	50728.000	212				
Corrected Total	1394.245	211				

a. R Squared = .145 (Adjusted R Squared = .137)

Tests of Between-Subjects Effects: MTAS Technology Confidence
Dependent Variable: postTC

Source	Type I Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	519.559[a]	2	259.780	40.351	.000	.280
Intercept	44232.346	1	44232.346	6870.558	.000	.971
preTC	497.114	1	497.114	77.216	.000	.271
learningmethod	22.445	1	22.445	3.486	.063	.016
Error	1339.095	208	6.438			
Total	46091.000	211				
Corrected Total	1858.654	210				

a. R Squared = .280 (Adjusted R Squared = .273)

Tests of Between-Subjects Effects: MTAS Affective Behavior
Dependent Variable: postAE

Source	Type I Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	572.689[a]	2	286.345	44.377	.000	.297
Intercept	37282.272	1	37282.272	5777.900	.000	.965
preAE	449.653	1	449.653	69.686	.000	.249
learningmethod	123.036	1	123.036	19.068	.000	.083
Error	1355.039	210	6.453			
Total	39210.000	213				
Corrected Total	1927.728	212				

a. R Squared = .297 (Adjusted R Squared = .290)

Tests of Between-Subjects Effects: MTAS Attitude Towards Learning Mathematics with Technology

Dependent Variable: postMT

Source	Type I Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	478.533[a]	2	239.266	29.888	.000	.223
Intercept	34575.360	1	34575.360	4319.046	.000	.954
preMT	473.267	1	473.267	59.119	.000	.221
learningmethod	5.265	1	5.265	.658	.418	.003
Error	1665.107	208	8.005			
Total	36719.000	211				
Corrected Total	2143.640	210				

a. R Squared = .223 (Adjusted R Squared = .216)

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