MATHEMATICS ACHIEVEMENT WITH DIGITAL GAME-BASED LEARNING IN HIGH SCHOOL ALGEBRA 1 CLASSES

by

Terri Lynn Kurley Ferguson

Liberty University

A Dissertation Presented in Partial Fulfillment

Of the Requirements for the Degree

Doctor of Education

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ABSTRACT

This study examined the impact of digital game-based learning (DGBL) on mathematics achievement in a rural high school setting in North Carolina. A causal comparative research design was used in this study to collect data to determine the effectiveness of DGBL in high school Algebra 1 classes. Data were collected from the North Carolina End-of-Course (EOC) Test for high school Algebra 1. The data collection was broken down by comparison groups based on academic achievement as measured by the North Carolina EOC Test for Algebra 1. The comparison groups were student participants who received digital game-based instruction and tradition instruction in mathematics versus students who only received traditional mathematics instruction over the course of a semester. The results of this study were differing to those in the review of the literature. In this study, the control group was found to be significantly greater than that of the treatment group regarding mathematics achievement.

DEDICATION

I would like to dedicate this paper, first and foremost, to the three loves of my life, my children, Kristin, Steven, and Tori. You all bring meaning and purpose to my life. I would also like to dedicate this paper to my parents, Terry and Patricia, for raising me to believe in myself. Lastly, I would like to dedicate this paper to my dear friend, Hazel; without you and your support, none of this would be possible for me. Thank you and I love you all!

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CHAPTER ONE: INTRODUCTION

It is 2013, and students walk in and out of school carrying the latest technology yet come to school to learn using tools of the past (pencils, paper, and textbooks). Students in this generation have had immediate access to information and technology at their fingertips, just not in the school setting. Most students carry their own cell phones, have video games at home, carry an iPod touch or an iPhone with them wherever they go, socialize on their home computers through Skype or Facebook, or even play online games on their home computer or cell phone. This is truly a different world than that of just a decade ago. The Next Web (2012) reported that of this generation of teenagers, 69% have a home computer, 79% have an iPod or an mp3 player, 75% have their own cell phone, and 80% of them have a gaming console such as the Wii or an Xbox. Even though the world is constantly changing due to technological advances, America's educational system seems to remain stagnant, resistant to these changes. According to the National Center for Education Statistics (2009), 97% of teachers had at least one computer in their classroom, but only 29% reported themselves or their students often using the computer during instructional time. The majority of computer usage time is devoted to teacher use for administrative purposes such as word processing (96%), accessing the Internet (94%), and managing student records (80%).

The students of this generation have grown up in the digital age. Prensky (2001) referred to the youth of today as *digital natives*, meaning that they have been exposed to digital technology since birth. Oblinger and Oblinger (2005) referred to them as the *Net Generation*—growing up in the generation of the Internet. Today's students are often disconnected from school but technologically connected to online tools such as Facebook and Twitter (Prensky, 2001). However, current technology offers students opportunities in an abundance of information and research through the Internet, tools to analyze information and data, tools to create various types of multimedia, and a variety of collaboration tools (Prensky, 2001).

The use of and constant change in technology have caused a tremendous change in the way students think and learn (Prensky, 2001). The rapid changes in computer and Internet technologies allow for greater educational opportunities (Kickmeier-Rust & Albert, 2010). According to Prensky (2001), “Our students have changed radically. Today’s students are no longer the people our educational system was designed to teach” (p. 1).

Digital natives are used to receiving information fast. They like to parallel process and multitask (Prensky, 2001). Digital natives prefer their graphics before their text rather than the opposite. They prefer random access (like hypertext), and they function best when networked. These students thrive on instant gratification and frequent rewards. They prefer games to “serious” work (Prensky, 2002, p. 2). These students are used to the instantaneity of hypertext, downloaded music, phones in their pockets, a library on their laptops, beamed messages, and instant messaging. They have been networked most or all of their lives. Digital natives have little patience for lectures, step-by-step logic, and “tell-test” instruction (Prensky, 2001, p. 3).

Prensky (2001) described the need for educators from previous generations to change their teaching methods to meet the needs of the learners of today if they hope to reach them and teach them. Prensky (2011) stated that the current educational system is not appropriate for 21st-century learners and the skills they need.

Background: Technology in Education

"A defining technology is a technology that results in fundamental changes in how people see themselves and their world" (Norton & Wiburg, 2003, p. 4). There have been many defining technologies throughout history, from the printing press to the radio, the television, and the microcomputer. All technologies have had their place in education throughout history—some have remained while others have faded. However, many electronic technologies still have their place in current education—especially the computer. Computers have been used in education for various reasons. They have been used as drill-and-practice tools, grade and record-keeping tools, information storage, and word processing. Today's computer and electronic technology users are third-stage users—discovering new and inventive ways to use such technologies to meet their own needs (Norton & Wiburg, 2003). Norton and Wiburg (2003) maintained,

> As we learn about their possibilities and how to design learning opportunities that capitalize on those possibilities, the electronic technologies can and are becoming an integral part of the teaching and learning process. They can and are serving as "engines of change." (p. 5)

Norton and Wiburg continued, "To capitalize on the possibilities of using technology to meet the challenge of our technological world, we must embrace new student urgencies, emerging views of learning, and new curricular opportunities as well as a range of technology possibilities" (p. 14).

Problem Statement

Today's students are in need of 21st-century learning and skills for success in their endeavors after high school—college, military, or the workforce. The problem is that most students are taught in a traditional manner without the use of technology (Ahmad, Shafie, & Latif, 2010; Gillispie, Martin, & Parker, 2009; Hiebert et al., 2005; Kikas, Peets, Palu, & Afanasjev, 2009; Koller, Baumert, & Schnabel, 2001; Thompson 2009). The use of technology in schools has increased some within the last few decades but not enough to keep students interested in high school or to prepare them for the technological aspects of the world outside of high school. Research has been conducted in regards to the great benefits of using digital game-based learning (DGBL) in schools (Li & Ma, 2010), but very little has been conducted to show the benefits to high school students, especially in mathematics classes.

Purpose Statement

The purpose of this causal comparative study was to test the theory of the use of DGBL on math achievement in high school Algebra 1, controlling for gender, socioeconomic status, and ethnicity for the participating high school Algebra 1 students at a rural high school in North Carolina. The independent variable, DGBL, is defined as the use of supplemental digital games in the learning environment. The dependent variable (Creswell, 2003), math achievement, is generally defined as the achievement level scored on the North Carolina End-of-Course (EOC) Test for Algebra 1.

Research Question and Hypothesis

The research question guiding this study was the following:

RQ: Is there a difference between students who were taught with traditional math methods and the use of digital-based games versus students who were taught using traditional math methods only? The corresponding null hypothesis was the following:

H_0: There will be no statistically significant difference in student algebra achievement, as measured by the 2012 North Carolina EOC Test for Algebra 1, between students who were taught with traditional math methods and the use of digital-based games versus students who were taught using traditional math methods only.

Definitions

Constructivism: Constructivism maintains the belief that "we construct [build] our knowledge of our world from our perceptions and experiences, which are themselves meditated through our previous knowledge" (Simon, 1995, p. 115).

Digital games: Computer games can be used as a "learning tool" (Ke, 2008, p. 1609) that "simulate real-life social networks" (Neville, Shelton, & McInnis, 2009, p. 410) and motivational situations such as the use of real-world and computer-generated data to perform math operations.

Digital game-based learning (DGBL): DGBL is learning by using computer games for educational purposes. It is a type of game-based learning (GBL).

Flow: The "flow experience could be perceived as a situation of engagement in an activity" (Wang & Chen, 2010, p. 49).

Math achievement: The dependent variable in this study, math achievement, is defined as the achievement level (1–4) scored by the participants on the North Carolina EOC Test for Algebra 1. Level 1 is the lowest score indicating the student is well below proficiency in Algebra 1, Level 2 is below proficiency, Level 3 is proficient, and Level 4 is above proficiency.

Piaget's cognitive development theory: "Jean Piaget's theory of cognitive development in children conceptualizes the process of children's intellectual growth (learning) from a biological perspective" (Jansen, 2011, para. 1).

Play theory: In this educational theory, humans naturally seek play for enjoyment as well as learning opportunities (Grimes & Feenberg, 2009).

Serious games: These are "games designed for educational purposes" (Champion, 2008, p. 216).

Situated cognition: This cognitive means of learning involves "a process of changes in mental models [cognitive maps] that occurs through interaction between individuals within the contexts of a common theme, their prior understandings, social structures, and environmental characteristics" (Goel, Johnson, Junglas, & Ives, 2010, p. 218).

Social learning theory: "Social learning theory states that norms, attitudes, expectations, and beliefs arise from an interaction with the cultural or social environment around and individual" (Hammer, 2011, para. 1).

Traditional math teaching: Traditional mathematics teaching, which is still the norm in our nation's schools, . . . is an endless sequence of memorizing and forgetting facts and procedures" (Battista, 1999, p. 426). Traditional mathematics instruction follows the same routine each day; this includes note taking, guided practice, and independent practice (Battista, 1999).

CHAPTER TWO: REVIEW OF THE LITERATURE

It is 2013 and life as a high school student has changed dramatically. Students carry their own cell phones, iPods, or iPhones with them to school and wherever else they go. Students from this generation have become accustomed to having technology at their fingertips. They use technology to play games, to communicate with friends and family, and for entertainment and informational purposes. *Google* is a common term used not only to identify an Internet search engine but also as a verb referring to finding the answer to a specified question. These students use Google as a means to address any issue they do not understand or know the answer. Facebook is a common Internet website for communicating with others. Smart phones are used to send text messages to friends and family, take pictures, and even log on to the Internet to change Facebook status. The global technology industry targeted to teens is a $360 billion annual market that has become 10 times the size of the music industry (Next Web, 2012). It is truly a different world than what it was just a decade ago.

In January 2002, Congress passed and President George W. Bush signed into law the No Child Left Behind Act (NCLB) as a reauthorization of the Elementary and Secondary Education Act of 1974. NCLB has brought about many advances and changes in education including the integration and use of technology in schools in the United States. The three specific NCLB goals for Title II, Part D—Enhancing Education Through Technology—are (a) "to improve student academic achievement through the use of technology in elementary schools and secondary schools" (§ 2402[b][1]); (b) "to assist every student in crossing the digital divide by ensuring that every student is technologically literate by the time the student finishes the eighth grade, regardless of the student's race, ethnicity, gender, family income, geographic location, or disability" (§ 2402[b][2][A]); and (c) "to encourage the effective integration of technology resources and systems with teacher training and curriculum development to establish research-based instructional methods that can be widely implemented as best practices by State educational agencies and local educational agencies" (§ 2402[b][2][A]).

Background

Theoretical Background

Many theorists and philosophers have paved the way for learning paradigms in American education. Philosophers and theorists include Confucius, Plato, Aristotle, Quintilian, Comenius, and Rousseau. According to Gutek (2005), Confucius described education as the highest philosophical priority. To Confucius, the purpose of education was to acquire new knowledge or a new skill or to get better at an old skill. Confucius held high expectations for his students and believed that learning and knowing were a person's role in the social network (Gutek, 2005). Since technology is already a part of the social network students currently use, the use of computers and DGBL in education can serve students in gaining new knowledge as well as reinforcing previous skills.

Plato (as cited in Gutek, 2005) maintained that knowledge occurs only in the mind of the person seeking it, and it is the teacher who should create the right environment for such learning. DGBL can offer students the opportunity to enhance their current knowledge when teachers provide the right DGBL environment relevant to the curriculum being learned. Aristotle (as cited in Gutek, 2005) stated education was to enable humans to live socially, politically, and economically in the world. All people, according to Aristotle, have the power to reason. Aristotle also claimed that knowledge comes from one's senses carrying information to the brain. The purpose of education, according to Aristotle, is to cultivate human excellence by developing rationality and forming human character (Gutek, 2005). DGBL provides students with opportunities to reason through the use of their senses (i.e., touching, seeing, and hearing) as well as opportunities to develop rational thought and character through interactions with others, even in a virtual setting.

Quintilian (as cited in Gutek, 2005) claimed that all humans possess the power of cognition, all are able to know and form ideas, and the stages of learning need to be based on the readiness of students. Comenius (as cited in Gutek, 2005) described childhood as a crucial part of human growth and development with specific phases conducive to learning efficiently and effectively. Comenius was a proponent of the use of objects and pictures in the educational setting. Gutek (2005) opined, "If Comenius were alive today, he would undoubtedly endorse the effectiveness and efficiency of computer-based instruction" (p. 129).

Rousseau (as cited in Gutek, 2005) described education as an artificial culture that corrupted humans' intrinsically good nature and considered conventional school settings to be wrong and even miseducative. Rousseau also stated that children must be ready to learn based on their own natural stages of development. DGBL opportunities start at various developmental stages and give the players a chance to grow and progress in skill level at their own pace. John Dewey, "one of America's most influential philosophers and educators" (Gutek, 2005, p. 331), stated that a person's social environment plays a huge role in leaning. Dewey (as cited in Gutek, 2005) often referred to this type of learning as experience.

American education has many roots stemming from European education. Although American education has grown and changed many times throughout history, it continues to support the "transmission of the cultural heritage from one generation to the next" (Ornstein & Levine, 1993, p. 113). The aims and goals of American education continue to be influenced by social forces and educational philosophies and theories. The three main influential forces are "changes in society in general, in developments and knowledge, and in the perceived nature of the learner" (Ornstein & Levine, 1993, p. 487). Four main educational philosophies are idealism, realism, pragmatism, and existentialism (Ornstein & Levine, 1993). Each educational philosophy encompasses a specific set of beliefs about life with a particular emphasis on education. Each of the main educational philosophies contains specific metaphysics, epistemology, axiology, and logic beliefs as well as educational beliefs. Educational theories pertain to education and the practices that exist within education. Various theories and philosophies have directly and indirectly influenced the educational practices of the past and those still used today (Ornstein & Levine, 1993).

This paper's theoretical framework is based on the philosophical beliefs of realism and various educational theories. According to Ornstein and Levine (1993), realism is an educational philosophy based on the teachings of Aristotle, in which reality is objective and relative to the person. The values of realists are absolute, eternal, and based on the laws of nature. Realists believe the classroom is a place for academic learning only and the curriculum should focus on teaching skills such as reading and writing as well as specific subject content from mathematics, science, history, and language (Ornstein & Levine, 1993). This paper's educational theories include play theory, Piaget's cognitive development theory, constructivism, and social learning theory.

Historical Background

Mathematics education movement. "At the end of the 20th century, mathematics education policies in U.S. public schools were in a state of flux. Disagreements between parents and mathematicians, on the one hand, and professional educators, on the other, continued without clear resolution" (Klein, 2003, p. 31). In the so-called *Math Wars*, many of the disagreements regarding mathematics education have been due to content and pedagogy—what mathematics to teach and how to teach it (Klein, 2003). According to Klein (2003), William Heard Kilpatrick's view of mathematics education in the early 20th century paved the way for progressive mathematics education. Kilpatrick, an education professor, viewed the study of mathematics for practical use only. He maintained that mathematics did not need to be taught to everyone and had no value as a mental discipline. Kilpatrick (as cited in Klein, 2003) claimed the study of mathematics subjects like Algebra need not exist except to those students who pursued them independently in their studies. Kilpatrick, along with many others, presented the study of mathematics to be a subject of little value for the majority. This public disbelief in the value of mathematics and the teaching of mathematics led mathematicians and teachers of mathematics to publish a contrary report in 1923 entitled *The Reorganization of Mathematics for Secondary Education* (as cited in Klein, 2003). This report was written with the involvement of the National Council of Teachers of Mathematics (NCTM) and outlined the mathematics curriculum necessary for public education, the requirements for being a mathematics teacher, and the value mathematics gives to education itself. However, many sided with Kilpatrick and thus continued the progressive movement of education in the 1920s. The progressive movement was loosely defined as the age in which children were taught and not subjects. Education was based on the developmental needs and interests of children and not specific subject matter (Klein, 2003).

In the 1940s, the U.S. Army noticed the lack of mathematics skills new recruits exhibited and called for a more rigorous mathematics curriculum to be taught at the high school level, with much scrutiny from the public who wanted life skills taught to their children without so much focus on academic subjects (Klein, 2003). Although the so-called life skills movement continued throughout much of the 1940s, it was phased out by 1949 with much resistance from parents. The 1940s also brought about some very significant technological changes like navigation and atomic energy, which sparked the public's interest and showed the importance of mathematics education. Yet, the progressive movement kept on until the 1950s. In the early 1950s when the new math movement erupted, it brought about many changes in high school mathematics curriculum, with mathematicians contributing to the development of the mathematics curriculum and writing mathematics textbooks. At this point courses like calculus were being offered at the high school level. This brought about much controversy among mathematicians due to lack of necessity for such advanced math courses at the high school level (Klein, 2003).

Technology mathematics movement. By the early 1970s, the new math movement had replaced by a call for schools to return to the basics (Klein, 2003). This event sparked the open education movement, a replica of the progressive movement from the 1920s and thus a continuation of the Math Wars (Klein, 2003). The 1970s also brought about standardized testing. Klein (2003) referred to the 1980s as the prelude to national standards. In 1980 the NCTM (as cited in Klein, 2003) published *An Agenda for Action*, a report that called for a different means of teaching mathematics using a problem-solving approach. A few years later, in 1983, Terrell Bell, then U.S. Secretary of Education, formed a commission to write a report about American education (Klein, 2003). This report, entitled *A Nation at Risk*, led the way for many of the changes in education seen today. This report caught the attention of politicians and the public. *A Nation at Risk* (as cited in Klein, 2003) outlined the many shortcomings of education in America, including mathematics education, the lack of qualified mathematics teachers, the use of poor mathematics resources, and the deficiencies in American education of children that stemmed from the open education movement.

In response to *A Nation at Risk*, the NCTM devised a set of national standards in 1989 called NCTM standards—a set of teaching and curriculum guidelines for mathematics in American education (Klein, 2003). These standards proposed specific mathematics guidelines for grade bands kindergarten through Grade 4, Grades 5–8, and Grades 9–12. The NCTM standards reinforced the progressive movement and gave way to a constructivist approach to the study of mathematics through discovery and student-centered learning as well as the use of technology in the study of mathematics (Klein, 2003). This gave rise to the standards-based movement of today. Today, the NCTM (2000) focuses on standards for each strand of mathematics and each grade band. The NCTM has defined not only the concepts to be taught in Algebra 1 (NCTM, 2013) and other math areas but also meaningful teaching methods and the incorporation of technology into the mathematics curriculum at each grade level (Klein, 2003). Subsequently, North Carolina Public Schools (n.d.-b) specifically detailed the areas of focus to be taught in Algebra 1 based on these NCTM Standards. These goals are referred to as the North Carolina Standard Course of Study in Mathematics (see Appendix A).

According to the NCTM (2000), "We live in a mathematical world. . . . The level of mathematical thinking and problem solving needed in the workplace has increased dramatically" (p. 1). Likewise, "in such a world, those who understand and can do mathematics will have opportunities that others do not" (NCTM, 2000, p. 1). The use of technology in the mathematics classroom for teaching and learning can have a tremendous impact on student understanding and problem solving. The NCTM (2000) defined six guiding principles for school mathematics: equity, curriculum, teaching, learning, assessment, and technology. According to the NCTM (2000), "Technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances student learning" (p. 5). Furthermore, "technology can help achieve equity in the classroom" (NCTM, 2000, p. 6) by providing students with opportunities for exploration, practice, and tutorials as well as providing disengaged students a new approach to math and another chance for engagement. It also can support the needs of special-needs students and assist meeting the needs of visually impaired students (NCTM, 2000).

Cantoral and Farfan (2003) stated mathematics is an important teaching concept in society, yet there is a great need for changes in mathematics education due to the many societal changes. Although mathematics has become an important educational focus in society, much attention has been placed on the use of certain tools such as graphing calculators and computers to assist in teaching mathematics. Mathematics is an academic discipline that requires and permits social construction of knowledge as well as thinking and reasoning skills (Cantoral & Farfan, 2003).

MacNab (2000) said that thinking mathematically is more important than mathematical knowledge, and mathematics education thus needs an emphasis on real-life contexts. MacNab also stated that the lack of interest and the nonuse of real-life settings are common reasons for the differences in performance in mathematics between the United States and other countries. Teaching strategies, flow of learning mathematics, and active engagement can all make a great difference in students' mathematics achievement (MacNab, 2000).

> Mathematics is often seen as a very difficult subject in which motivational factors are particularly important for the enhancement of learning. Prior research . . . has suggested that, compared to other subjects, there is a relatively strong relationship between interest and achievement in mathematics. (Koller et al., 2001, p. 452)

On the other hand, Koller et al. (2001) pointed out, "achievement has a significant influence on the development of interest" (p. 453).

Theoretical Framework

Patanella (2011) stated, "Learning refers to changes in behavior and cognition as a result of experience" (para. 1). The beliefs in this paper are built upon many theories, paradigms, and forms of learning associated with mathematics and DGBL that are outlined within this literature review. These include play theory, Piaget's cognitive development theory, constructivism, and social learning theory.

Play Theory

Constructive play is the use of materials, objects, or tools to achieve a certain outcome (Pender, 2011). The process of doing or creating is the critical component of play theory. Constructive play is a necessary aspect of life; it aids in the development of children physically, emotionally, socially, spatially, mathematically, and linguistically. Constructive play inspires learning in children and allows them to make meaning of their own world and themselves. Play is something all humans aspire to do in one form or another. It makes learning fun and allows children to learn their own potential (Pender, 2011).

> For the school child, play becomes a more limited form of activity. . . . Play does not die away but permeates the attitude toward reality. It has its own inner continuation in school instruction and work (compulsory activity based on rules). It is the essence of play that a new relation is created between the field of meaning and the visual field—that is, between situations in thought and real situations. (Vygotsky, 1978, p. 104)

According to Ortlieb (2010), humans are meant to play and even have a need to play. "Play is a minimally scripted, open-ended exploration in which the participant is absorbed in the spontaneity of the experience" (Ortlieb, 2010, p. 241). Ortlieb recommended that educators use the opportunity to allow students to play because of its many benefits, especially since the passive means of instruction are not meeting the needs of technological students. Many of the benefits of play include effective learning capabilities, learning engagement, freedom to make mistakes and learn from those mistakes, the ability to heighten skills through engagement, and active participation that leads to increased knowledge retention. "Children are born to be discoverers, thinkers, and problem-solvers" (Ortlieb, 2010, p. 244), and play offers such opportunities. Play can have long-lasting positive effects for children (Ortlieb, 2010). DGBL provides opportunities for educational play.

Piaget's Cognitive Development Theory

Piaget's cognitive development theory focuses on the intellectual growth and development of children biologically (Jansen, 2011). The four stages of Piaget's theory are sensorimotor, preoperational, concrete, and formal. Each of the four phases contains specific identifiers of childhood development based on the age of the child, regardless of intelligence (Jansen, 2011). Children also tend to move from one stage to the next through organization and adaptation. Piaget's last period of development, the formal operational stage, ranges from age 11 to adulthood. This stage specifically describes the abilities and capabilities of high school students. At this phase of development, adolescents "engage in abstract thinking, using skills such as deductive and hypothetical reasoning" (Jansen, 2011, para. 6). Adolescents at this stage "learn and begin to solve complex problems through cautious and systematic processes, share and propose their own ideas and as well as go through the process of evaluating their opinion being proposed" (Jansen, 2011, para. 6). Moreover, they learn to form their own identity as well as how to relate to others (Jansen, 2011). DGBL can provide students with opportunities for problem solving and collaborative interactions with others.

Piaget (as cited in Jansen, 2011) maintained that children go through three stages of maintaining a balanced equilibrium: adaptation, assimilation, and accommodation. Adaptation is when a child learns to adapt to his or her surroundings. Assimilation is when a child incorporates newly learned ideas into existing knowledge. Accommodation is when a child modifies existing knowledge to accommodate newly learned knowledge and understanding. Humans organize their worlds into systems. Disequilibrium happens when humans are unable to fit information into one of their systems. When disequilibrium occurs, humans either assimilate this new information into an existing system or accommodate by changing the system to fit the new information (Atherton, 2011). Because students are accustomed to technology at this age anyway, they can readily adapt to the use of DGBL, assimilate to a method of learning that fits their lifestyle, and accommodate their knowledge of technology to acquire new knowledge in mathematics and other disciplines.

Constructivism

Constructivism is a learning theory in which learners construct or build their own knowledge for themselves based on their own experiences (Hein, 1991). Interaction and experience create understanding for people, even those with varying abilities and interests (Champion, 2008). Connolly, Stansfield, and Hainey (2007) addressed two types of constructivism, cognitive and social. Cognitive constructivism pertains to the active learning process of an individual based on current and past knowledge. Social constructivism is based on an individual's learning through cultural experiences and interactions with others (Connolly et al., 2007). The constructivist theory

> holds that learners construct knowledge by understanding and expertise. Constructivism contradicts the idea that learning is the transmission of content to a passive receiver. Instead, it views learning as an active process, always based on the learner's current understanding or intellectual paradigm. A learner does

not come to a classroom or a course Web site with a mind that is tabula rasa, a blank slate. Each learner arrives at a learning "site" with some preexisting level of understanding. (Brown, 2005, p. 12.4)

Table 1 outlines the differences in teaching and learning paradigms between traditional teaching and constructivist learning.

Table 1

Differences in Teaching and Learning Paradigms

Traditional paradigm: Teaching	Constructivist paradigm: Learning
Memorization	Understanding
Recall	Discovery
One size fits all	Tailored; option rich
Talent via weeding out	Talent cultivated and sought out
Repetition	Transfer and construction
Acquisition of facts	Facts + conceptual framework
Isolated facts	Organized conceptual schemas
Transmission	Construction
Teacher = master and commander	Teacher = expert and mentor
Fixed roles	Mobile roles
Fixed classrooms	Mobile, convertible classrooms
Single location	Plurality of locations and space types
Summative assessment	Summative and formative assessments

Note. From "Learning Spaces," by M. Brown, 2005, in D. G. Oblinger and J. L. Oblinger (Eds.), *Educating the Net Generation,* p. 12.6, Washington, DC: EDUCAUSE. Reprinted with permission.

Constructivism has been a focus in mathematics education and reform. The NCTM (as cited in Simon, 1995) has endorsed the use of constructivism as a means of mathematics education and reform in schools. Simon (1995) explained that because constructivism is not a teaching method but a teaching perspective, educators need to provide students the means to investigate and explore mathematics using a constructivist purpose by designing tasks that utilize structure, provide a set of guidelines, and stimulate thought for students. Thus, the role of the teacher is facilitator—the one who provides the learning tasks and inquiry for students to construct their own knowledge (Lerman, 1989; Simon, 1995). DGBL readily provides constructive learning experiences because it actively engages the learner and allows collaborative interactions.

Social Learning Theory

Social learning theory focuses on the learning that occurs within a social context. Learning takes place in natural contexts and in everyday situations and is relative to the environment (Dede, 2005). Social learning theory considers that people learn from one another, including such concepts as observational learning, imitation, and modeling (Ormrod, 1999). Social learning theory is

> the belief that humans are unique in our abilities to symbolize experiences, to develop forethought about consequences for our actions, to learn vicariously through the actions of others, to be able to change our behaviors through self-regulation, and to self-reflect. (Bozack, 2011, para. 3)

Social cognitive learning theory is often seen as an alternative to Piaget's cognitive development theory. This theory states that people learn best by observing and being exposed to other people and information (Bozack, 2011; Hammer, 2011). Learning takes place in real situations that are meaningful to the learner. Learning is culturally based and dependent upon interactions with other people and contexts (Tarng & Tsai, 2010). Bozack (2011) claimed, "People are both products and producers of their environments and social systems" (para. 4).

Self-efficacy is a major component of social learning theory. Self-efficacy is a person's belief about his or her abilities to do something but can change over time and with experience (Bozack, 2011). DGBL is conducive to meeting the needs of students through a social learning perspective because it allows for social interactions with others in a method that is already natural to students (e.g., the use of technology).

Twenty-First-Century Skills

Since the turn of the century, educational policy makers have loosely defined their expectations for 21st-century learning skills and mandated public school changes to address the needs of 21st-century learners. To many, learning in the 21st century has come to mean using technology to prepare the youth of today for the world of tomorrow as well as creating globally competitive and responsible citizens (North Carolina Public schools, n.d.-a). Students should leave high school prepared to go to college, enter the workforce, or join the military. Students should be readily prepared in technology and information usage, core subjects like math and reading, and innovation of ideas for a global world. "The guiding mission of the North Carolina State Board of Education is that every public school student will graduate from high school globally competitive for work and postsecondary education and prepared for life in the 21st century" (North Carolina Public Schools, n.d.-a, para. 1).

"While schools are aimed at the education of pupils and qualifications of pupils for the labour market, they are not always successful today" (Huizenga, Agmiraal, Akkerman, & ten Dam, 2009, p. 332). Therefore, Ramaley and Zia (2005) stated, "we must prepare all young people for lives of creativity, citizenship, and social responsibility as well as success in the workplace increasingly shaped by science and technology" (p.

8.5). Students need to be prepared for life in a global world. Consequently, the International Society for Technology in Education (2007) provided a detailed set of expectations for students' use of technology in schools for workplace and future readiness.

The 21st Century Skills Incentive Fund Act (2009) was introduced to encourage states to adopt a 21st-century framework of skills, including problem solving and critical thinking. The Partnership for 21st Century Skills (2009) developed a framework for 21st-century learning in response to the bill. "This Framework describes the skills, knowledge and expertise students must master to succeed in work and life; it is a blend of content knowledge, specific skills, expertise and literacies" (Partnership for 21st Century Skills, 2009, p. 1). This framework (see Figure 1) includes four main student outcomes: (a) core subjects and 21st-century themes; (b) learning and innovation skills; (c) information, media, and technology skills; and (d) life and career skills (Partnership for 21st Century Skills, 2009).

Core subjects and 21st-century themes involve students mastering core subjects such as mathematics, English, world languages, science, arts, economics, geography, history, and government and civics with the incorporation of 21st-century interdisciplinary themes like global awareness; financial, economic, business, and entrepreneurial literacy; civic literacy; health literacy; and environmental literacy (Partnership for 21st Century Skills, 2009). Learning and innovation skills include creativity and innovation, critical thinking and problem solving, and communication and collaboration. Information, media and technology skills pertains to accessing, evaluating, using, and managing information as well as analyzing media, creating media products, and applying technology effectively.

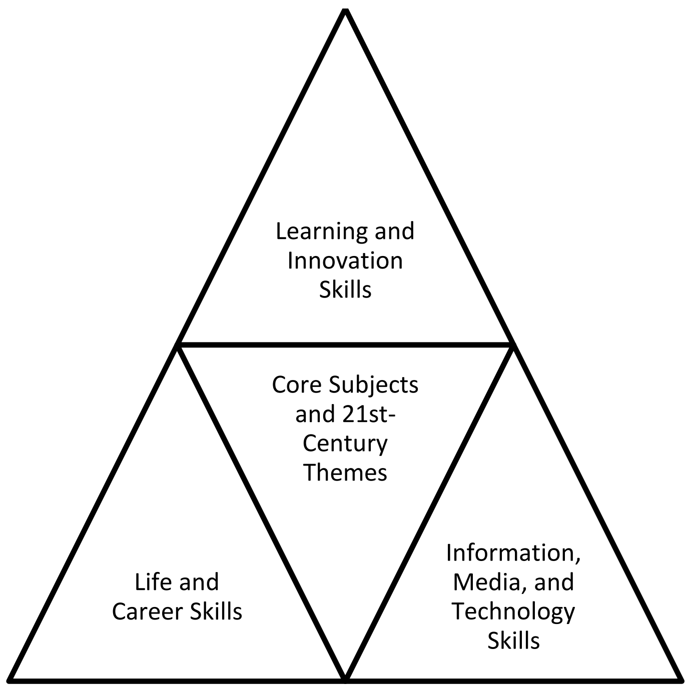

Figure 1. Twenty-first-century skills in the framework for 21st-century learning. Adapted from *Framework for 21st Century Skills*, by the Partnership for 21st Century Skills, 2009, available from http://www.p21.org/storage/documents/P21_Framework.pdf

Life and career skills include flexibility, adaptability, initiative, self-direction, social and cross-cultural skills, productivity, accountability, leadership, and responsibility (Partnership for 21st Century Skills, 2009). "Student mastery of 21st century skills should be recognized as one of the most critical outcomes of the teaching and learning process. Therefore, it is necessary to develop and implement curriculum and instructional strategies that—by design—enhance these skills" (Partnership for 21st Century Skills, 2009, p. 3).

According to the Project Tomorrow (2010) national report, students demand three essential components in their education for 21st learning: (a) social-based learning, (b) untethered learning, and (c) digitally rich learning. Social-based learning involves students' use of collaboration tools like wikis, tweets, and even videoconferencing to assist in their own learning and connecting with other students for assistance. Untethered learning is essentially allowing students to have choice regarding learning modalities. Students want to be able to use the tools they currently have, like their iPhones, iPods, or netbooks to access information that schools do not have readily available. Students want a digitally rich learning environment full of technological tools they already have much experience with, like online tools and interactive textbooks and digital learning games. Students in this generation are used to performing many tasks using such tools, and their parents are even accustomed to utilizing many of the same tools to communicate with their children or in their own work environment (Project Tomorrow, 2010). Yet, students come to school not being allowed to use their own tools (iPhones, netbooks, etc.) to accommodate their own learning.

Math Education

There is a great need for teachers to make math fun and meaningful for their students to motivate them to want to learn and study mathematics (Ahmad et al., 2009). Ahmad et al. (2009) also noted in their study that many students have problems learning mathematics for the following reasons: lack of motivation, boredom, little encouragement for self-learning, lack of personal meaning to them, and lack of continuity and focus. Arbaugh et al. (2008) ascertained a great need to improve mathematics education in American schools today, and improving student learning should be the main focus. They also stated that maximizing the use of technology in schools and classrooms could help to improve student learning. Mathematical and collaborative or communicative technologies are two technology types Arbaugh et al. described as being useful tools for the teaching and learning of mathematics in today's classrooms. "Mathematical technologies allow the user to operate on mathematical entities . . . [and] provide people with a range of mathematical activities and forms of mathematical representations" (Arbaugh et al., 2008, p. 20). Arbaugh et al. continued, "Collaborative and communicative technologies allow users to create, manipulate, edit, communicate, and share experiences, ideas, and products using words, numbers, symbols, images, audio, and video" (p. 20).

Twigg (2011) declared a need for integration of technology into math curricula because technology is necessary for student learning in society. Accordingly, interactive software and computers are the keys to helping students learn math by doing (Twigg, 2011). In an interview for *Harvard International Review*, U.S. Secretary of Education Margaret Spellings (2010) noted that for the United States to keep up with other countries in math, it must be taught with real-world intentions and career outlooks. Spellings stated that "math and science is the way forward" (p. 68) in education as well as for the United States to keep up with a global society.

Taylor (2010) noted that the United States is behind other countries in math for two reasons: Students are becoming less interested in math, and they lack proficiency in math. However, mathematics is a core skill necessary to live and work in society. The President's Council of Advisors on Science and Technology (2010) stated,

> As the world becomes increasingly technological, the value of these national assets will be determined by the effectiveness of science, technology, engineering, and mathematics (STEM) education. STEM education will determine whether the U.S. will remain a leader among nations and whether we will be able to solve

> immense challenges in such areas as energy, health, environmental protection, and national security. It will help produce the workforce needed to compete in a global marketplace. It will ensure our society continues to make fundamental discoveries and advance our understanding of ourselves, our planet, and the universe. It will generate the scientists, technologists, engineers, and mathematicians who will create new ideas, products, and industry of the 21st century. It will provide the technical skills and quantitative literacy needed for individuals to earn livable wages and make better decisions. And it will strengthen our democracy by preparing all citizens to make informed choices. (p. 42)

Khan and Chishti (2011) conducted a one-shot case study to determine whether students' active participation affected math achievement. Their participants included 27 ninth-grade math students, and their study design included a posttest only. The study found that students' active participation in math class played a tremendous role in their math achievement.

Hiebert et al. (2005) conducted a qualitative study to determine what processes support student learning and how. The authors used the 1999 TIMSS Video Study, which is a video of national participants from the United States, Australia, Czech Republic, Hong Kong, Japan, the Netherlands, and Switzerland. The video coding was based on the daily structure of lessons, the nature of the math presented in class by the teacher, and the method of instructions and practice of math. Hiebert et al. found the use of material to engage students is necessary to support specific learning goals, more engagement was needed as well as the use of prioritized learning, and the emphasis on conceptual learning was necessary instead of basic skills as a route to higher achievement.

Koller et al. (2001) conducted a longitudinal study to determine whether interest played a role in academic achievement. They used achievement scores and coursework selection with interest surveys with 602 students in Germany from Grades 7, 10, and 12. The authors determined that the higher the grade level, the more academic interest affected motivation to learn, that younger students desired more feedback than older students, and that interest in math decreased substantially from Grade 7 to Grade 12. Furthermore, academic interest in mathematics achievement was due to a change in the instructional setting (Koller et al., 2001).

Ke (2008) conducted a mixed-methods study to determine math achievement and increase in positive attitudes about mathematics among 15 students in Grades 4 and 5. Ke used a case-study approach and collected data from observations; document analysis; participant comments; and a 30-item, game-skills, arithmetic test. The study revealed that there was an overall increase in positive attitudes about learning mathematics, there is value in situated learning activities, and not all computer math drills increase engagement for students (Ke, 2008).

Thompson (2009) conducted a mixed-methods study to determine what standards-based instruction practices are effective for students' math and science achievement. The method of study included student observation forms and a norm-referenced test, the Iowa Test of Basic Skills. Participants included 10,000 Oklahoma public school students and 408 teachers from Grades 6–9. Thompson determined that computer technology, group projects, manipulatives, and self-assessment were effective contributors to student math achievement.

GBL

DGBL or GBL takes place in a virtual environment with fantasy elements while engaging players in a learning activity through the use of a technological tool such as a computer (Teed, 2012). DGBL is the use of digital games to spark competition, engage learners, and challenge and motivate learners (Teed, 2012). Prensky (2001) defined six key structural elements of digital games necessary for learning engagement: (a) rules; (b) goals and objectives; (c) outcomes and feedback; (d) conflict, competition, challenge, or opposition; (e) interaction; and (f) a storyline.

According to Bloom (2009), "The underlying principles of video game design parallel the learning process" (p. 18). Game design must meet the needs of the learner by being relevant to the learner, understanding the educational needs of the learner, appealing to various types of learners, being user-friendly, and being easily played (Moschini, 2006). Teed (2012) stated that a continuous challenge, an interesting storyline, flexibility, immediacy, useful rewards, and the combination of fun and being realistic define a good game.

Prensky (2009) stated, "Digital technology . . . can be used to make us not just smarter but truly wiser" (p. 1). Prensky (2009) defined this digital wisdom as complex problem solving in which the learner has "the ability to find practical, creative, contextually appropriate, and emotionally satisfying solutions to complicated human problems" (p. 2). Students in this generation have been raised using technology and have been constantly exposed to numerous forms of changing technology since birth. These students are "'native speakers of the digital language of computers, video games, and the Internet" (Prensky, 2001, p. 1).

Today's students may be disconnected from school but technologically connected to social media such as Facebook and Twitter (Prensky, 2001). Subsequently, today's technology offers students opportunities in an abundance of information and research through the Internet, tools to analyze information and data, tools to create various types of multimedia, and a variety of collaboration tools (Prensky, 2001).

Many have come to believe that games play a vital role in education because they are engaging, motivational, and academically effective (Van Eck, 2006). "Recently computer games have been proposed as a potential learning tool by both educational researchers and game developers" (Ke, 2008, p. 1609). Digital games have become a popular source of learning various strategies and acquiring new knowledge (Gros, 2007). Digital games create a virtual world that promotes necessary social and community skills and can create real-life simulations for learning. Previous game studies noted various aspects of games that make them engaging and appealing to both male and female students. These characteristics include "the feeling of working toward a goal; the possibility of attaining spectacular successes; the ability to problem-solve, collaborate with others, and socialize; an interesting story line; and other characteristics" (Johnson, Smith, Willis, Levine, and Haywood, 2011, p. 20).

Tarng and Tsai (2010) claimed that DGBL is motivational for students, involves active participation and involvement for students, simulates real situations, is used to aid current teaching practices, and promotes problem solving. The diagram in Figure 2 illustrates Tarng and Tsai's view of GBL for students and how student input creates a cyclic process to promote a learning achievement output.

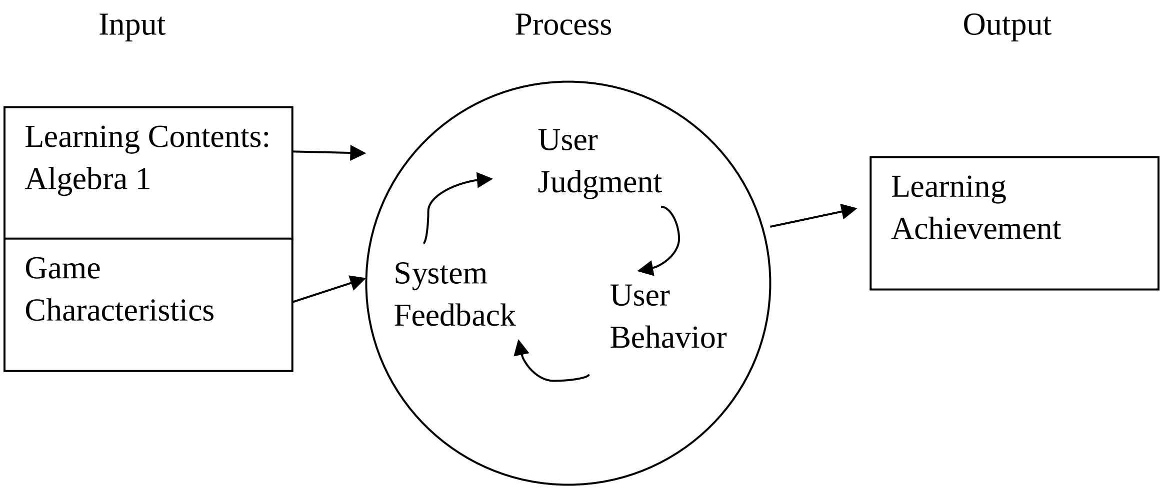

Figure 2. Game-based-learning model of learning output. Adapted from "The Design and Analysis of Learning Effects for a Game-Based Learning System," by W. Tarng and W. Tsai, 2010, *World Academy of Science, Engineering and Technology, 61,* p. 338. Reprinted with permission.

Impact of GBL

According to Trybus (2009), GBL has many advantages. It is cost effective, has low physical risk or liability to the learner, has standardized assessments for student-to-student comparisons, is highly engaging, has a learning pace tailored to the individual needs of the student, affords immediate feedback responses for students' mistakes, can easily transfer learning to a real-world environment, and is engaging for the learner (Trybus, 2009). GBL promotes "the skills and thought processes needed to respond appropriately under pressure, in a variety of situations" (Trybus, 2009, p. 1). It teaches students "how to think and perform in the face of real-world challenges" and provides "interactive experiences that motivate and actively engage us in the learning process" (Trybus, 2009, p. 1). According to Johnson et al. (2011), GBL provides many benefits to learners such as active engagement, information-based skills, decision-making skills, innovation, problem-solving skills, knowledge construction, and discovery learning. "Digital games are user-centered; they promote challenges, co-operation, engagement, and the development of problem-solving strategies" (Gros, 2007, p. 23). Digital video games not only promote student engagement and motivation but also can be used in various other educational ways to promote student learning. Such games benefit learners in other ways such as introducing computer literacy, science and technology preparation, improved spatial skills, verbal and iconic skills, increased visual skills, increased attention span, and increased response time (Gros, 2007).

Hong, Cheng, Hwang, Lee, and Chang (2009) stated that GBL provides learners with mentality changes; emotional fulfillment; knowledge enhancement; as well as the development of thinking skills, interpersonal skills, spatial ability, and bodily coordination. GBL allows the learner to interact in and master a virtual learning environment through imagination while helping learners to "establish values and knowledge of the world" (Hong et al., 2009, p. 425). It also provides learners with opportunities to improve learning accuracy, increase memory, stimulate critical thinking, assist in information gathering and retention, introduce new and solidify current knowledge, discover new ideas and concepts, simulate real-life experiences, learn by testing hypotheses, and solve real problems (Hong et al., 2009).

According to Kickmeier-Rust and Albert (2010), there are many advantages to teaching with the technology, such as "the rich potential of visualizations and animations that provide new insights and perspectives, the ubiquitous access to information, the possibilities for self-directed and self-regulated learning, or the possibilities for exchange and collaboration" (p. 95). Huizenga et al. (2009) ascertained that GBL is highly motivational and engaging to learners, causing learners to become completely immersed in their learning. Huizenga et al. referred to this engrossed engagement as "flow" (p. 333)—an absorption of a learning goal in which all teachers desire their students to achieve and where the learner cannot seem to stop.

GBL "actively engages the participant" (Bloom, 2009, p. 19). According to Teed (2012), GBL is fun, motivating for learners, and encourages learners to learn from their mistakes along the way. GBL provides learners with opportunities for competition and engagement and provides immediate rewards to the learner (Teed, 2012). Huang's (2011) quantitative GBL study showed that learners maintained a high level of confidence while experiencing learning using games as a result of being highly motivated to play. Reasons for using digital games in education include learner engagement, the use of learning tools, and encouragement of peer collaboration (Ke, 2008). Digital games promote learning by doing (Huang, 2011), multitasking abilities, strategic thinking, collaboration, and leadership (Kickmeier-Rust & Albert, 2010).

Digital games enhance the memory of learners and extend the cognitive capabilities of learners (Hong et al., 2009). DGBL has positive effects on learning across various subjects and for different types of learners. It is intrinsically motivating to learners. It supports, reinforces, and accelerates the process of learning as well as helps to develop higher order cognitive skills (Hong et al., 2009). "The nature of utilizing (computer) games for education is that playing games is one of the most natural forms of learning" (Kickmeier-Rust & Albert, 2010, p. 96). Some of the educational benefits of game use identified by Mitchell and Savill-Smith (2004) were the following:

1. Computer games are valuable tools in enhancing learning.
2. They are means of encouraging learners who may lack interest or confidence.
3. Computer games can reduce training time and instructor load.
4. They enhance knowledge acquisition and retention.
5. They allow manipulation of objects, supporting development towards levels of proficiency.
6. Computer games are particularly effective when designed to address a specific problem or to teach a certain skill.
7. Such games are relevant to specific learning activities and goals.
8. They can be used to facilitate tasks appropriate to learners' level of maturity in the skill.
9. They are designed to enhance specific learning outcomes such as recall of factual content or as the basis for active involvement and discussion.
10. They are good vehicles for embedding curriculum content such as math and science concepts that may be hard to visualize or manipulate with concrete materials.
11. Computer games enhance creative and other forms of critical thought.
12. They have the potential to support cognitive processing and the development of strategic skills.
13. They can encourage greater academic, social, and computer literacy skills.

Hong et al. (2009) conducted a qualitative case study to determine the value of various types of educational games. They used research teams comprised of educational psychology scholars and game designers plus game participants in their research study. The methods used were observations and discussions with the research participants to determine the educational value of games. They found that games must be fun, have clear goals and rules, and provide gain values for the player. Hong et al. also noticed that game players exhibited mentality changes, emotional fulfillment, knowledge enhancement, thinking-skills development, interpersonal skills, spatial abilities, and bodily coordination. Mentality changes include a level of adventure, game trade-offs for wrong answers, and efficient game strategies. Emotional fulfillment includes the player having a sense of belonging, social interactions and collaboration, concentration, and game fairness. Acquisition of knowledge and knowledge reinforcement are both part of knowledge enhancement. Thinking skills development consists of strategic thinking, memory enhancement, observation and perception skills, and flexible thinking. Negative emotional management and mutual support are part of interpersonal skills. Bodily coordination includes hand-eye coordination and quick reaction time (Hong et al., 2009).

Tarng and Tsai (2010) performed a quantitative, quasi-experimental study with a pre- and posttest design to analyze student learning with the use of a digital world geography game. Their study participants included 60 ninth-grade students in world geography classes. The experimental group in the study used a world geography GBL system at home, while the control group used their own methods of learning at home for world geography study. Tarng and Tsai found there was a significant difference in learning with the experimental group using the digital games in world geography. They also found there was no significant difference on learning based on gender, students' prior use of the games, or Internet use. In their attitude survey, Tarng and Tsai discovered that most students were satisfied with the use of the games for learning and the context in which the games were used to support their learning.

Li and Ma (2010) conducted a meta-analysis to determine kindergarten through Grade 12 students' learning of mathematics with the use of computer technology. Their meta-analysis included doctoral dissertations and research articles from 1990–2010. They used a three-step approach as well as a 100% interrater agreement coding criteria to determine the articles and dissertations to be used in the meta-analysis. Li and Ma found "overall positive effects of computer technology on mathematics achievement" (p. 232) and noticed the results were "significantly enhanced when computer technology was used (a) on special needs students, (b) in elementary mathematics classrooms, and (c) where a constructivist approach to teaching was practiced" (p. 233). Li and Ma noted that short interventions with technology of 6 months or less were more effective in regards to mathematics achievement than interventions of 6–12 months.

Camli and Bintas (2009) conducted a quantitative experimental study with a pre- and posttest design to determine the academic achievement of students using computers. Their study included 102 sixth-grade students in a public elementary school over a 5-week period. They used computer software designed to assist students in mathematics problem solving. Camli and Bintas found the experimental group that used the computer software for mathematics problem-solving support performed significantly higher on the posttest than the control group, which had no computer usage.

Wang and Chen (2010) conducted a quantitative study to analyze the flow experience, motivational level, and academic performance of learners. They used 150 junior high school students from four classes in their study. The method of study involved junior high school students playing the digital games and then answering a questionnaire based on game preference, game flow experience, and motivation. Wang and Chen determined that games need to pose a challenge in order to enhance student learning.

Brom, Sisler, and Slavik (2010) conducted a mixed-methods study to determine the effectiveness on student learning of Europe 2045, a digital history game. Their research methods included the use of pretests, videos, field notes, posttests, and teacher and student interviews. Participants included 220 students aged 16–18 from eight secondary schools in the Czech Republic. Brom et al. determined the games were easy for students to use, students enjoyed role-playing with the game, students appreciated real data use and the storytelling feature, and the game offered support for teachers.

Kanthan and Senger (2011) conducted a quantitative study to determine the effect of use of games in learning on student satisfaction by conducting a satisfaction survey on undergraduate medical students. They learned that games are effective for teaching and learning even for adults. Likewise, games support multiple intelligences and are motivating and engaging. "Digital games effortlessly and seamlessly integrate vital concepts necessary for learning within safe, virtual, mystical worlds" (Kanthan & Senger, 2011, p. 140).

Huizenga et al. (2009) conducted a quantitative study to determine the motivational and learning aspects of the game Frequency 1550. The participants of the study included 458 students aged 12–16. Three surveys were conducted to determine engagement, determinations, and knowledge. Their study showed that GBL combines situated and active learning with fun for the players. Huizenga et al. also found that GBL is authentic, engaging, and fosters learning untraditionally and constructively.

Neville et al. (2009) performed a mixed-methods study to evaluate knowledge retention and attitudes of university students who used DGBL to learn German vocabulary, reading, and culture. The research methods used included the observation of students playing games as well as the test results of retention of information. The study confirmed that DGBL assists students in learning a foreign language. DGBL maintains an immersive learning environment and is student centered (Neville et al., 2009).

Mitchell and Savill-Smith (2004) developed a list of DGBL elements that contribute to the engagement of computer games for students. The game characteristics and basis for student engagement are shown in Table 2.

Table 2

Digital Game-Based Learning Engagement Elements

Characteristics of game	Contribution to players' engagement
Fun	Enjoyment and pleasure
Play	Intense and passionate involvement
Rules	Structure
Goals	Motivation
Interaction	Doing (i.e., the activity)
Outcomes and feedback	Learning
Adaptive	Flow
Winning	Ego gratification
Conflict, competition, challenge, opposition	Adrenaline
Problem solving	Sparks creativity
Interaction	Social groups
Representation and a story	Emotion

Note. From *The Use of Computer and Video Games for Learning: A Review of the Literature*, by A. Mitchell and C. Savill-Smith, 2004, p. 18, London, England: Learning and Skills Development Agency. Reprinted with permission.

GBL in Schools

In an interview with Foreman (2004), Gee stated,

> It is amazing to me that in the modern age, when we have technologies like the Internet and the hand-helds and the computers and computer games, we are still teaching inside four walls, where all the information is coming from within those walls and where all students, regardless of the amount of preparation they have, are sitting together. (p. 53)

Gee (as cited in Foreman, 2004) also stated that the greatest aspect of games is that they allow users to take on any identity they desire. Foreman also interviewed Sawyer, who mentioned that games are simulations, which allow a person to become engrossed in and construct knowledge. Modeling through the use of simulations creates a visual representation of the concepts and makes them more real. In Foreman's interview, Prensky stated that games are one of the greatest things created, and children become totally engaged in playing them. Gee (as cited in Foreman, 2004) mentioned that videogames are a great way of learning and are indicative of the idea of cognitive science. Gee also maintained that young people are very familiar with games already, and they are a "very powerful form of learning" (Foreman, 2004, p. 58) for students.

Oblinger and Oblinger (2005) reported responses high school students gave when asked why technology was important to their education:

- It's part of our world.
- Technology is so embedded in our society; it'd be hard not to know how to use it.
- It's really helpful—it makes things faster.
- Abstract concepts are often easier to grasp when technology is used effectively as a teaching tool.
- Some students at my school who weren't great students are better one now thanks to computers.
- Technology allows us to learn as much as we want to about virtually any topic.
- I usually connect with friends to get help or to help others. (p. 2.3)

Oblinger and Oblinger reported that 20% of Net Generation students started using computers between the ages of 5 and 8. Further, over 2 million American children aged 6–17 have their own websites. According to Oblinger and Oblinger, 94% of teens use the Internet for research, and 78% believe the Internet is a useful tool for schoolwork.

Oblinger and Oblinger (2005) also stated that Net Generation students deal with information much differently than students of previous generations. Differences include the ability to read visual images; visual-spatial skills, perhaps due to expertise with games; inductive discovery; attentional deployment, shifting attention rapidly and ignoring things that do not interest them; and fast response time (Oblinger & Oblinger, 2005). Net Generation students are digitally literate and have always known the world as being digitally connected. They are used to immediate gratification and responses, they prefer to learn by doing, they seek out social interactions with others, and they prefer to work in teams. Likewise, they seek to achieve, seek interactivity, learn visually and kinesthetically, and prefer to perform tasks that matter to them (Oblinger & Oblinger, 2005).

> The emergence of new technology challenges our assumptions about the nature and locus of learning. In turn, advances in the learning sciences reveal new possibilities for the application of technology in support of educational goals centered on the engagement of the learner. (Ramalay & Zia, 2005, p. 8.4)

The use of technology in instruction is not meant to replace traditional forms of learning but to enhance learning (Ramalay & Zia, 2005).

Wager (2005) stated, "The Net Generation cares about the activity technology enables, not the technology, per se. . . . Technology is a tool—it represents the means not the desired outcome. Students will use technology; in fact, they will expect services delivered through technology" (p. 10.4). Wager referred to this as "a symbiotic relationship between a basic need and the technology that delivers a response to that need" (p. 10.6).

Computer and Internet technologies have given rise to more educational opportunities (Kickmeier-Rust & Albert, 2010). According to Prensky (2001), "Our students have changed radically. Today's students are no longer the people our educational system was designed to teach" (p. 1). The use of and constant change in technology have caused a tremendous change in the way students think and learn (Prensky, 2001).

Digital natives are used to receiving information quickly. They like to parallel process and multitask. They prefer their graphics before their text rather than the opposite. They prefer random access (like hypertext). They function best when networked. They thrive on instant gratification and frequent rewards. They prefer games to "serious" work (Prensky, 2001, p. 2). They are used to the instantaneity of hypertext, downloaded music, phones in their pockets, a library on their laptops, beamed messages and instant messaging. They have been networked most or all of their lives. They have little patience for lectures, step-by-step logic, and "tell-test" instruction (Prensky, 2001, p. 3).

Prensky (2001) described the need for educators from previous generations to change their teaching methods to meet the needs of the learners of today if they hope to reach them and teach them. Prensky (2011) maintained that the educational system of today is not appropriate for 21st-century learners and the skills they need. The current pedagogy of the educational system is ineffective and needs to be future oriented and engaging for the students of today, including problem-based, inquiry-based, and student-centered learning using a variety of technological tools relating to real life and the quickly changing future. Gros (2007) maintained, "We need to change our teaching methods to enhance the skills that future citizens will need in a digital society" (p. 23). Students are bored with the way school is conducted without the use of technology because they are readily equipped to use and are already using this technology outside of school (Prensky, 2008).

"Technology's role—and its only role—should be to support students teaching themselves (with, of course, their teachers' guidance)" (Prensky, 2008, p. 1). Gillispie et al. (2009) observed, "Traditional classroom teachers are faced with the challenge of delivering instruction that competes with the media-rich and interactive experiences the typical student is exposed to daily" (p. 68). Technology (i.e., digital games) can contribute to learning in the following areas: personal and social development, language and literacy, mathematical development, creative development, knowledge and understanding of the world, and physical development (McFarlane, as cited in Gros, 2007).

According to Trybus (2009), DGBL tools are becoming increasingly accepted in educational settings due to the changing workforce and the many advances in technology. "Computer games have been particularly effective in raising achievement levels of both children and adults in areas such as math and language, where specific objectives can easily be stated" (Mitchell & Savill-Smith, 2004, p. 25). GBL applies to a plethora of learning theories like Piaget's cognitive disequilibrium, "anchored instruction, feedback, behaviorism, constructivism, [and] narrative psychology" (Van Eck, 2006, p. 20). There is also research-based evidence for the support of social learning theory in the use of educational GBL activities (Mitchell & Savill-Smith, 2004). Huizenga et al. (2009) noted that the use of such GBL activities utilize behavioral, cognitive, and social learning theories. According to Kim and Chang (2010), research has shown that the use of GBL contributes to significantly higher achievement in student learning as compared to the use of traditional instruction. Ahmad et al. (2009) noted in their study that many students have problems with the learning of mathematics due to lack of motivation, boredom, little encouragement for self-learning, lack of meaning to them, and lack of continuity and focus.

GBL "can be a very efficient tool if it is designed to reflect pedagogical and learning needs in a real educational setting" (Hong et al., 2009, p. 431). Huang (2011) explained, "The game playing process therefore supports the learning process by allowing players to acquire learning experiences in games, encouraging interactions between learners and the game system, and situating learners in complex learning environments" (p. 694). According to Ahmad et al. (2009), "Game-based learning can be used as a teaching tool in the classroom to facilitate learning mathematics" (p. 185). GBL "can stimulate the enjoyment, motivation and engagement of users, aiding recall and information retrieval, and can also encourage the development of various social and cognitive skills" (Ahmad et al., 2009, p. 185).

Brom et al. (2010) generalized the following aspects of GBL based on their review of Europe 2045. GBL should adhere to five recommendations (Brom et al., 2010):

1. Ground the game content in everyday context, which helps with formulating learning objectives and offers students options for solving nearly real-world problems.

2. Integrate appealing game play directly into formal lectures without compromising the learning or gaming aspects of the game; debriefing and classroom lectures are directly relevant to the game and partially take place in the game.
3. Exploit information-seeking behavior, helping students to contextualize gaming materials with a real-world context and vice versa, enabling the transfer of knowledge.
4. Create supplementary materials and courses for teachers.
5. Describe the learning environment in terms of what it visibly offers students.

Trybus (2009) described four key learning principles and the applications of each of these principles to GBL. First, she found that students' prior knowledge may enhance or hinder the ability to learn. GBL provides immediate positive or negative nonthreatening consequences to correct misconceptions or reward correct responses. Next, the degree to which students are motivated affects not only what they do and how they do it but also how long they retain what they have learned. GBL creates a nonthreatening environment by providing instant feedback for students' accomplishments and thereby increasing motivation. The third principle maintains that students must learn the skill, practice the skill, and apply the skill in order to develop mastery (Trybus, 2009). In GBL, students have the opportunity to practice learned skills by applying their knowledge within the context and timeframe of the game. Finally, the quality of student learning is directly affected by the goals and purpose of the practice of a particular skill targeted in a game and by feedback specific to that skill. Educational games offer feedback, by way of scores and rewards, within the context of a game. This motivates students to continue with the game until they master the targeted goals (Trybus, 2009).

Kickmeier-Rust and Albert (2010) suggested recommendations for making GBL pedagogically sound. Designers and researchers need to assure the development of such games meet the challenges of (a) an appropriate balance between gaming and learning activities, (b) a balance between game challenges and the learner's abilities, (c) educational objectives being convincingly embedded in the game scenario, and (d) the cost of developing high-quality games (Kickmeier-Rust & Albert, 2010).

Achievement and GBL

Ke (2008) conducted a mixed-methods case study using qualitative and quantitative data to determine the effectiveness of game use in learning math at the upper elementary school level. Ke determined that students' attitudes were positively enhanced from using games to learn mathematics. The author also determined that the game design plays a significant role in student interaction with the game.

Kim and Chang (2010) performed a quantitative study to determine the effectiveness of digital math games for fourth-grade students. The authors used data from the 2005 National Assessment of Educational Progress data and item response theory scale scores to measure math achievement. They found a greater overall math achievement level for male students than for female students. They also found that English-language learners had higher math performance than non-English-language-learner students who did not play games prior to this experience. They also noted that students receiving free lunch performed significantly lower than noneligible students.

Roschelle et al. (2010) performed a quantitative experimental study to determine whether the use of computer technology software increased student engagement in math class and consequently increased student learning. Their study took place in the San Francisco Bay Area in California at three local elementary schools using fourth-grade students from three classes. They used a pre- and posttest design with random assignment to the treatment and control groups. The researchers found that students in the treatment group achieved more on the posttest than those students in the control group.

Yien, Hung, Hwang, and Lin (2011) conducted a quantitative study to determine the influence of GBL on knowledge of nutrition, attitude, and habits of students via computer game usage. Their participants included 66 third-grade students from two elementary schools in Taiwan. They discovered a significant difference in achievement for the experimental group on nutrition knowledge. However, they found no significant difference in student attitudes or gender performance.

Beal, Qu, and Lee (2008) conducted a study to determine high school students' motivation and achievement with using instructional software and the help tool versus random guessing. The participants in this study included 90 high school students from four geometry classes within three high schools in California public schools. Beal et al. found that students with low math achievement used the help options from the computer more than others. Students with low math self-efficacy guessed more than others.

Maloy, Edwards, and Anderson (2010) studied the use of a computer-based math tutoring and teaching system called 4-Coach Mathematics Active Learning Intelligent Tutoring System to determine its effectiveness in elementary school student performance.

The system makes use of student hint tools, virtual coaches, and supportive test practices. Maloy et al.'s study proved a significant growth in posttest scores from pretest scores. The researchers' data were limited because the study did not use a control group to determine whether the system was the only factor in the increase in student performance.

Van Eck (2006) expressed the need to match DGBL with the needs and experiences of the learner to maintain the effectiveness desired in the learning experience. Van Eck also suggested the need to align GBL experiences with the necessary curriculum and the content being learned. "Games are effective not because of what they are, but because of what they embody and what learners are doing as they play a game" (Van Eck, 2006, p. 18). Van Eck emphasized that games should "embody well-established principles and models" of learning (p. 18). Such digital games provide opportunities for situated cognition for learners and apply play theory as a means of learning.

Brom et al.'s (2010) study of a digital game called Europe 2045 found it effective for learners because it has intelligibility, promotes social role-playing, makes use of real data, incorporates storytelling, and provides teacher support. Likewise, Huizenga et al. (2009) discovered that learners were highly motivated, had fun, and gained knowledge in playing the project-based history game, Frequency 1550.

Kim and Chang's (2010) study showed gains in math achievement for elementary school students. Their study showed increased math achievement for male students who did not play video games extensively and for male English-language learners. "The study suggests that various learner characteristics should be considered when attempting to explore the effects of computer games" (Kim & Chang, 2010, p. 231).

Gillispie et al. (2009) studied 500 middle school students in rural North Carolina and their achievement and attitudes of using the games Dimension-M and Xeno Island. These games are problem-based, digital games utilizing concepts in prealgebra and algebra. The researchers used a pre- and posttest design as well as an attitude survey to formulate results. Students increased in math achievement an average of 17%. Gillispie et al. also noted that students were willing to repeat the GBL missions to make improvements in their scores on the computer.

Mitchell and Savill-Smith (2004) noted numerous incidents in the literature about the increase in student achievement in various disciplines, including mathematics, as well as an increase in the engagement of students. Computer games can "stimulate the enjoyment, motivation and engagement of users, aiding recall and information retrieval, and can also encourage the development of various social and cognitive skills" (Mitchell & Savill-Smith, 2004, p. 1). Mitchell and Savill-Smith also noted that boys and girls both tend to enjoy playing computer games. Boys tend to play more regularly than girls, and girls tend to favor games with less aggression and demand than boys do. Although extensive playing of video games can cause eye strain and dependence and even depression, they can be a valuable tool for learning and actually benefit the school performance of students.

Sardone and Devlin-Scherer (2010) performed a mixed-methods study with 25 undergraduate students in teacher education to determine the 21st-century skills utilized in educational games. The participants reviewed 50 games for specific criteria of motivation, critical thinking, problem solving, collaboration, and communication. The researchers discovered that digital games possess many of these 21st-century skills (Sardone & Devlin-Scherer, 2010).

Summary

In this ever-changing world of technology, education must keep up with the trends in order to fully support the needs of the stakeholders—the students. Technology requirements are not only mandated from NCLB (2002) but also recommended in accordance with standards set forth by federal and state education agencies. According to many researchers, the use of 21st-century skills is lacking in the educational system to meet the needs of these digital natives; the use of technology is one method of meeting their needs and instilling mandated, 21st-century skills. As shown in this literature review, there are many theories of learning and research-based studies that have demonstrated the use of technology as a means of accomplishing this task. Research has shown that the use of DGBL is not only a much-needed practice in math education but also significantly increases mathematics achievement.

This chapter has outlined the current literature on educational theories and learning paradigms; the mathematics education movement; the technology mathematics movement; the background of mathematics education and DGBL; as well as the impact, use of, and achievement findings of DGBL. Chapter Three, Methodology, will highlight the chosen research methodology—causal comparative—as well as describe the characteristics of the study and the participants.

CHAPTER THREE: METHODOLOGY

The purpose of this chapter is to explain the methodology used to complete this causal comparative research study. This study examined the use of DGBL and the possible effects of DGBL on math achievement in high school Algebra 1 classes. This chapter includes a description of the research design, the research context, the instrument used, research participants, and how the data were analyzed to answer the research question.

Design

This research used a causal comparative research design. This methodology was chosen because the researcher sought to identify a comparative relationship on an event that had already happened (ex post facto) for math achievement based on the methods of math instruction. The researcher used two comparison groups in the study. One group (the control group) received traditional math instruction only, and the other group (the treatment group) received traditional and DGBL math instruction. Students participating in this study were previously assigned to high school Algebra 1 classes using a computer-generated program called the North Carolina Window of Information on Student Education (NC WISE, 2013).

There was no attempt to randomize the students because they already had been placed in preset classes for their mathematics instruction and already differed on the instruction used in the classroom. However, the use of homogeneous subgroups strengthened the research design and controlled for the extraneous variables of gender, socioeconomic status, and ethnicity. Because the research was designed to determine a relationship between two preset groups that lacked variable control and random assignment for an event that had already occurred, the use of the causal comparative research design was appropriate (Gay, Mills, & Airasian, 2006).

Quantitative data were obtained as standardized test scores from the 2012 North Carolina EOC Test for Algebra 1. Descriptive statistics such as the mean and standard deviation were used to describe the comparison groups and subgroups. Inferential statistics such as the *t* test were used to determine whether differences in mean scores for each group were statistically significant (Gay et al., 2006). In this study, the initial group differences not only included traditional math instruction versus traditional and DGBL math instruction but also differences in teachers delivering the instruction and their various teaching styles. The conventional alpha level of .05 was used to determine statistical significance from the independent *t* test (Gall, Gall, & Borg, 2007).

Research Question and Hypothesis

This study was guided by a single research question:

RQ1: Is there a difference between students who were taught with traditional math methods and the use of digital-based games versus students who were taught using traditional math methods only? The corresponding null hypothesis was the following:

H_0: There will be no statistically significant difference in student algebra achievement, as measured by the 2012 North Carolina EOC Test for Algebra 1, between students who were taught with traditional math methods and the use of digital-based games versus students who were taught using traditional math methods only.

Participants

The participants for this study consisted of 222 ninth-grade students enrolled at a high school in a rural school district in North Carolina. Ninth graders constituted 306 of the total 960 students at the school. All students were preassigned for the researcher as intact groups of ninth-grade math classes of Algebra 1 by the administration of the high school. All students had completed the ninth-grade math course of Foundations of Algebra prior to enrollment in Algebra 1, unless they were repeating the class due to not passing the class the previous time taken, which would account for a small percentage of students. All Algebra 1 students were placed in either Algebra 1 or Foundations of Algebra based on their score on their eighth-grade end-of-grade math test. Students scoring Levels 1–3 on the four-level test were placed in the Foundations of Algebra class in the first semester prior to going to Algebra 1 in the second semester. Students enrolled in these ninth-grade Algebra 1 classes for the second semester had a mixture of aptitudes and abilities in mathematics education.

The sample consisted of all students enrolled in Algebra 1 in the second semester. Of these students, two comparison groups were formed based on math instruction received. The first comparison group was a group of 112 students who received traditional math instruction and DGBL instruction for the second semester in Algebra 1. The second comparison group consisted of the remaining 110 students enrolled in second semester Algebra 1 who only received traditional instruction. Normal math class sizes at the high school are approximately 25 students. All classes were randomly assigned at the beginning of the second semester of the 2011–2012 school year by the NC WISE coordinator and the administration of the high school. Each class at this high school follows a 90-minute block schedule.

The teachers involved in the math instruction for these Algebra 1 students differed as well. These differences included teacher instruction style, personality, and years of teaching experience (ranging from 10–25 years of teaching experience), for which the research could not control. Among the five teachers of Algebra 1 in the Spring 2012 semester, four used only traditional math instruction that follows the same routine each day; this includes note taking, guided practice, and independent practice (Battista, 1999). The fifth teacher (having the least number of years of teaching experience) used a combination of traditional math instruction with DGBL instruction, defined as learning by using computer games for educational purposes. Each of the five teachers followed the same school pacing guide for instructional sequencing. The teachers using traditional math instruction only followed a very similar format as seen in the lesson plan (Appendix B), whereas the teacher using the combination of traditional math instruction and DGBL instruction used an altered lesson plan (Appendix C). The teachers who followed the traditional math instruction path followed this same format daily, whereas the teacher who used the combination of DGBL with traditional math instruction followed the same format on certain days. This teacher replaced classroom seatwork time with taking her students to the computer lab to utilize DGBL activities two to three times a week for approximately 30-minute periods. The same textbook and workbook assignments were used on a regular basis with each teacher. However, the teacher who used DGBL and traditional math instruction used some of the assignments as homework instead of class work.

Setting

This study was conducted in ninth-grade classrooms during the second semester of the 2011–2012 school year in a rural school district in the state of North Carolina. The county within this school district consists of 25 elementary schools, five middle schools, five high schools, and three alternative schools. This school district reported a graduation rate of over 70% in 2010. This particular school had 960 students and a student–teacher ratio of 16.4:1. The school's reported combined free and reduced-price lunch eligibility was 34% of the student population, which is much lower than the only feeder middle school's reported free and reduced-price lunch eligibility rate of 52%. The administration of the school stated this decrease was a result of students coming to the high school not wanting to apply for free and reduced-price lunches out of possible embarrassment. The ethnic composition of the school student population was 70% White, 20% Black, 6% Hispanic, 4% Asian, and less than 1% other. The ethnic composition of the participants was closely related to that of the entire school: 70% White, 20% Black, 5% Hispanic, 5% Asian, and less than 1% other. All classes at the high school are randomly assigned by the school NC WISE coordinator and approved by the school administration. The gender and academic abilities of the students are heterogeneous. Students are randomly assigned to 90-minute block classes until maximum class limits are achieved.

Instrumentation

Achievement levels in mathematics were reported using the results from the 2012 North Carolina EOC Test for Algebra 1 at the end of the second semester. Comparisons were made using descriptive statistics of mean and standard deviation of each comparison group's scale score. Group 1 received traditional and DGBL math instruction in Algebra

1 second semester, and Group 2 received only traditional math instruction in Algebra 1 second semester. These statistical measures revealed the answers to the research question of this study. The hypothesis was tested through statistical analyses of collected test data for all participants using an independent-samples *t* test at a significance level of $\alpha = .05$ and a confidence level of 95%.

Reliability and Validity

Reliability was based on the reliability measures determined by North Carolina for the EOC Tests. "Reliability refers to the consistency of a measure when the testing procedure is repeated on a population of individuals or groups" (Bazemore, Van Dyk, Kramer, Yelton, & Brown, 2006, p. 62). The coefficient alpha (α) is used to determine internal consistency with any alpha coefficient over .85 being highly reliably. Having an alpha coefficient of .94, "the North Carolina . . . EOC Tests of Mathematics are highly reliable as a whole. In addition, it is important to note that this high degree of reliability extends across gender, ethnicity, LEP [limited English proficient] status, and disability" (Bazemore et al., 2006, p. 62).

"Coefficient alpha sets the upper limit to the reliability of tests constructed in terms of the domain-sampling model" (Bazemore et al., 2006, p. 44). The North Carolina EOC Test for Algebra 1 has a coefficient $\alpha = .94$ (Bazemore et al., 2006).

"The validity of a test is the degree to which evidence and theory support the interpretation of test scores. Validity provides a check on how well a test fulfills its function" (Bazemore et al., 2006, p. 87). All North Carolina EOC Tests, including the EOC Test for Algebra 1, are designed based on three validity checks—content validity, criterion-related validity, and construct validity (Bazemore et al., 2006). In regards to content validity, the North Carolina EOC Test for Algebra 1 is aligned to the North Carolina standard course of study in Algebra 1 as well as reviewed by North Carolina teachers of Algebra 1 (Bazemore et al., 2006). Criterion-related validity of the North Carolina EOC Test for Algebra 1 is determined by the use categories of performance standards known as achievement levels, ranging from Level 1 to Level 4. Each of these levels was determined using field testing of more than 90,000 students statewide. "The [Pearson] correlation coefficients for the North Carolina…EOC Tests of Mathematics range from 0.49 to 0.89 indicating a moderate to strong correlation between EOC scale scores and its associated variables" (Bazemore et al., 2006, p. 89).

Procedures

Upon completion of the Algebra 1 course for all second semester Algebra 1 students, each student was given the North Carolina EOC Test for Algebra 1 to determine his or her scale score and level of proficiency, ranging from Level 1 to Level 4. Level 1 indicates students do not have sufficient knowledge and mastery of skills in Algebra 1 required for success in the next-level mathematics course. Students performing at Level 2 demonstrate inconsistent knowledge and mastery of skills in Algebra 1 required for success in the next-level mathematics course. Students performing at Level 3 consistently demonstrate knowledge and mastery of skills in Algebra 1 required for success in the next-level mathematics course. Level 4 indicates students consistently perform in a superior manner and in Algebra 1 required for success in the next-level mathematics course (Bazemore et al., 2006). Student demographics such as gender, socioeconomic status, and ethnicity as well as test-score data were collected for analysis to determine the results based on the research question.

Data Analysis

Statistical analyses were performed using SPSS for Windows. Descriptive statistics including the mean and standard deviation for the two comparison groups were calculated to describe the groups individually as well as the subgroups within each group. Homogeneous subgroups were used as a control procedure for the extraneous variables of gender, socioeconomic status, and ethnicity. The *t* test for independent samples was used to test for statistical significance of achievement gains between and within the two comparison groups. This study was designed to link the independent variable, DGBL, to the dependent variable, student math achievement as measured by the North Carolina EOC Test for Algebra 1. The researcher tested the hypothesis by statistically analyzing the collected test data for all participants using an independent-samples *t* test at a significance level of $\alpha = .05$ and a confidence level of 95%. Subsequently, a Mann Whitney U test was used to confirm the results of the independent-samples *t* test.

CHAPTER FOUR: FINDINGS

The purpose of this chapter is to provide the results of the data collection and analysis of the study. The purpose of this study was to test the theory of the use of DGBL on math achievement in high school Algebra 1, controlling for gender for the participating high school Algebra 1 students at a rural high school in North Carolina. The independent variable, DGBL, is defined as the use of supplemental digital games in the learning environment. The dependent variable (Creswell, 2003), math achievement, is generally defined as the achievement level scored on the North Carolina EOC Test for Algebra 1.

The research question guiding this study was the following: Is there a difference between students who were taught with traditional math methods and the use of digital-based games versus students who were taught using traditional math methods only? The corresponding null hypothesis was the following: There will be no statistically significant difference in student algebra achievement, as measured by the 2012 North Carolina EOC Test for Algebra 1, between students who were taught with traditional math methods and the use of digital-based games versus students who were taught using traditional math methods only.

Initially, a series of descriptive statistics was conducted on scores for the North Carolina Algebra 1 EOC test on the basis of respondent group. As shown in Table 3, average scores were found to be slightly higher in the control group as compared with the treatment group, while standard deviations were generally found to be low. Individuals in the control group were found to have scores ranging from 131–167, whereas individuals in the treatment group had scores ranging from 127–166.

Table 3

Descriptive Statistics by Group

Group	*N*: valid	*N*: missing	*M*	*Mdn*	Mode	*SD*	Variance	Range	Min.	Max.
Control	110	1	146.57	149	149	7.71	59.42	36	131	167
Treatment	112	4	143.48	144	144	9.80	96.04	39	127	166

Table 4

Means, Standard Deviations, and t-test (EOC Test Scores)

Group	N	M	SD	t	p<
Control	110	146.57	7.71	2.614	.010
Treatment	112	143.48	9.80		

Table 5

Means, Standard Deviations, Mann-Whitney U Test (EOC Test Scores)

Group	n	M	SD	U	z	p<
Control	110	146.57	7.71	4901	2.635	.010
Treatment	112	143.48	9.80			

Following this, initially, an independent-samples *t* test was conducted focusing upon differences in EOC Test scores on the basis of respondent group. Levene's test for the equality of variances was conducted in order to determine whether the assumption of equal variances was violated in this analysis. Levene's test was found to achieve statistical significance, $F = 5.105$, $p = .025$, indicating that the assumption of equal variances was violated here. For this reason, the independent-samples *t* test conducted was calculated without assuming the equality of variances. The results of this test were found to achieve statistical significance, $t(210.026) = 2.614$, $p = .010$. These results indicated that the control group had significantly higher scores on the EOC Test as compared with respondents in the treatment group. The mean difference found comparing these two groups was 3.091 points, with the 95% confidence interval of this mean difference ranging from 0.760–5.421. Additionally a Mann-Whitney *U* test was conducted in order to confirm these results. With regard to EOC test scores, the control group was found to have a mean rank of 122.95 ($N = 110$), while the treatment group was found to have a mean rank of 100.26 ($N = 112$). This analysis was found to achieve statistical significance, $U = 4901$, $z = 2.635$, $p < .01$. This result indicates that the control group had significantly higher EOC test scores as compared with the treatment group, which confirms the results found in the independent-samples *t*-test.

CHAPTER FIVE: DISCUSSION

Students in this generation have grown up with technology at their fingertips. They have been accustomed to using technology for a variety of aspects in their lives from entertainment to learning. The use of and constant change in technology have caused a tremendous change in the way students think and learn (Prensky, 2001).

Today's students are in need of 21st-century learning and skills for success in their endeavors after high school—college, military, or the workforce. The problem is that most students are taught in a traditional manner without the use of technology (Ahmad et al., 2010; Gillispie et al., 2009; Hiebert et al., 2005; Kikas et al., 2009; Koller et al., 2001; Thompson, 2009). The use of technology in schools has increased some within the last few decades but not enough to keep students interested in high school or to prepare them for the technological aspects of the world outside of high school. Research has been conducted in regards to the great benefits of using DGBL in schools (Li & Ma, 2010), but very little has been conducted to show the benefits to high school students, especially in mathematics classes.

In this ever-changing world of technology, education must keep up with the trends in order to fully support the needs of the stakeholders—the students. Technology requirements are not only mandated from NCLB (2002) but also recommended in accordance with standards set forth by federal and state education agencies. According to many researchers (e.g., Huizenga et al., 2009; Prensky, 2011), the use of 21st-century skills is lacking in the educational system to meet the needs of these digital natives; the use of technology is one method of meeting their needs and instilling mandated, 21stcentury skills. As shown in the literature review, many theories of learning and research-based studies have demonstrated the use of technology as a means of accomplishing this task. Research has shown that the use of DGBL is not only a much-needed practice in math education but also significantly increases mathematics achievement (Ahmad et al., 2009; Camli & Bintas, 2009; Gillispie et al., 2009; Hong et al., 2009; Ke, 208; Kim & Chang, 2010; Li & Ma, 2010).

The teacher who used DGBL in this study used a variety of games from different online resources. This teacher used teacher created mathematics practice games modeling game shows such as *Millionaire* and *Rags to Riches* from http://www.Quia.com. Mathematics simulation and exploration games from http://www.shodor.org/ were used as well. In this study mathematics strategy games were also used from http://www.coolmath.com/ and http://hotmath.com/. Each online game had a different purpose and covered a variety of topics from the Algebra 1 curriculum.

This chapter provides a summary of the research findings and a discussion of those findings relative to the review of related literature. This chapter also outlines future implications of the research, conclusions about the methodology used in this study, and recommendations for future study.

Summary and Discussion of Findings

In light of the literature review, positive gains in achievement were seen in every study discussed. In the quasi-experimental study on the achievement gains in world geography from Tsarng and Tsai (2010), they found a significant difference in learning using game-based learning [GBL] in their experimental group as compared to their control group. However, they noticed no significant difference in learning gains based on gender, prior use of games, or Internet usage. Li and Ma (2010) conducted a meta-analysis to determine kindergarten through grade 12 students' learning of mathematics with the use of computer technology and found an overall positive association between students' achievement and the use of GBL especially with special needs students, elementary math students, and with those students in a constructivism classroom. Camli and Bintas (2009) conducted an experimental study to determine the academic achievement of sixth-grade students using computers and found that the experimental group scored significantly higher on the posttest than those students in the control group. Neville et al. (2009) performed a mixed-methods study to evaluate knowledge retention and attitudes of university students who used GBL to learn German vocabulary, reading, and culture and revealed that GBL assists learning of a foreign language. Kim and Chang (2010) performed a quantitative study on fourth-grade students to determine the effectiveness of digital math games. They found a greater overall math achievement level for male students than for female students, for English-language learners than for non-English-language learners, and for noneligible free lunch students than for students receiving free lunch. In an experimental study conducted by Roschelle et al. (2010) to determine whether the use of computer technology software increased student learning in math, they discovered that students in the experiment group achieved more on the posttest as compared to those students in the control group. Yien, Hung, Hwang, and Lin (2011) conducted a quantitative study to determine the influence of GBL on knowledge of nutrition, attitude, and habits of students via computer games. They found a significant difference in achievement for the experimental group as compared to the control group.

This causal comparative study examined the achievement scores for 222 students in ninth grade at a rural high school in the state of North Carolina. The *t* tests presented findings in reverse of what was expected based on the current related literature on DGBL and math achievement (Ahmad et al., 2009; Camli & Bintas, 2009; Gillispie et al., 2009; Hong et al., 2009; Ke, 208; Kim & Chang, 2010; Li & Ma, 2010). The literature reviewed in this dissertation presented a variety of statistical significance for the use of DGBL opportunities in an educational setting. However, this study presented statistical significance for the use of traditional mathematics teaching methods over the use of DGBL in combination with traditional mathematics teaching methods.

This study was guided by a single research question: Is there a difference between students who were taught with traditional math methods and the use of digital-based games versus students who were taught using traditional math methods only? The corresponding null hypothesis was the following: There will be no statistically significant difference in student algebra achievement, as measured by the 2012 North Carolina EOC Test for Algebra 1, between students who were taught with traditional math methods and the use of digital-based games versus students who were taught using traditional math methods only.

Descriptive statistics of the data showed that the treatment group had a significantly lower mean than the control group for the study. However, the standard deviation for the treatment group was higher than that of the control group. The range of student scale scores also showed that students in the treatment group scored lower than the students in the control group. The analysis of the data showed that the control group's scale scores were significantly higher than those of the treatment group.

Implication of Findings and Research Study Limitations

All of the literature reviewed for this study showed statistical significance for the use of DGBL in one form or another (e.g., Brom et al., 2010; Huang, 2011; Huizenga et al., 2009; Johnson et al., 2011; Kanthan & Senger, 2011; Kickmeier-Rust & Albert, 2010; Mitchell & Savill-Smith, 2004; Neville et al., 2009; Tarng & Tsai, 2010; Trybus, 2009) and specifically in mathematics (Ahmad et al., 2009; Camli & Bintas, 2009; Gillispie et al., 2009; Hong et al., 2009; Ke, 208; Kim & Chang, 2010; Li & Ma, 2010). However, this particular study could not determine any statistical significance based on the data given. The results of this study seem to provide a positive stance on traditional teaching methods in mathematics; however, many factors such as student population, instructional time in class, access to technology, curriculum, and teacher experience and efficacy could also play a major role in the outcome of this study. The student population could affect the outcome of the results if certain classes were not equally weighted in regards to the achievement levels of students. The instructional time in class could also have an effect on the results in the teacher using DGBL had less instructional time with the students. Access to technology or the lack thereof for all teachers could have played a role in the outcome as well. The curriculum and the current teaching practices of mathematics teachers could have had an effect in the outcome since teachers have the prerogative to teach the curriculum as they see fit. Lastly, teacher experience and efficacy could contribute to the outcome of this study. Theoretically, the more experience a teacher gains the better his or her ability to produce desired results in the classroom.

There are several limitations of this study. These limitations include the design of the study, the selection of participants, lack of a pre-test, and the instrument used for data collection. The causal comparative study was limited because of the lack of randomization of the participants, which was out of the control of the researcher. The selection of the participants for the study was limited because the participants included only those students in one school from one rural area of one state in the United States. Thus, sample selection narrowed down the possibilities that might exist from other regions. This study was also limited due to the lack of having a pre-test to control for external factors. Lastly, the instrument used to collect data, the North Carolina EOC Test of Algebra 1, is limited in that it only tests those students within the state of North Carolina, excluding the possibilities from other regions in the United States as well.

Recommendations for Future Study

In light of the limitations of this study, the researcher recommends the following for future research. Clearly, the need for further research in the use of DGBL in mathematics at the high school level is needed. This study was conducted at a particular region of North Carolina and at only one school. Future research could be done in other areas of North Carolina and other regions of the United States. The number of participants could be increased and even compared from schools within a broader area of the state of North Carolina or among numerous states within the United States or other countries. Finally, research designs other than causal comparative should be considered in future research. Causal comparative has its place in research, but other research designs may prove to be more comprehensive for DGBL. A longitudinal study may offer a clearer view of the extended use of DGBL in education.

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APPENDIX A: NORTH CAROLINA STANDARD COURSE OF STUDY: ALGEBRA 1

North Carolina STANDARD COURSE OF STUDY

MATHEMATICS :: 2003 :: TO BE IMPLEMENTED 9-12 :: ALGEBRA I

High School Grades

Algebra 1 continues the study of algebraic concepts. It includes operations with polynomials and matrices, creation and application of linear functions and relations, algebraic representations of geometric relationships, and an introduction to nonlinear functions. Students will be expected to describe and translate among graphic, algebraic, numeric, tabular, and verbal representations of relations and use those representations to solve problems. Appropriate technology, from manipulatives to calculators and application software, should be used regularly for instruction and assessment.

Prerequisites

- Operate with the real numbers to solve problems.
- Find, identify, and interpret the slope and intercepts of a linear relation.
- Visually determine a line of best fit for a given scatterplot; explain the meaning of the line; and make predictions using the line.
- Collect, organize, analyze, and display data to solve problems.
- Apply the Pythagorean Theorem to solve problems.

Number and Operations	
Competency Goal 1	The learner will perform operations with numbers and expressions to solve problems.
	Objectives 1.01 Write equivalent forms of algebraic expressions to solve problems. a. Apply the laws of exponents. b. Operate with polynomials. c. Factor polynomials. 1.02 Use formulas and algebraic expressions, including iterative and recursive forms, to model and solve problems. 1.03 Model and solve problems using direct variation.
Geometry and Measurement	

Competency Goal 2	The learner will describe geometric figures in the coordinate plane algebraically.
	Objectives 2.01 **Find the lengths and midpoints of segments to solve problems.** 2.02 **Use the parallelism or perpendicularity of lines and segments to solve problems.**
Data Analysis and Probability	
Competency Goal 3	The learner will collect, organize, and interpret data with matrices and linear models to solve problems.
	Objectives 3.01 Use matrices to display and interpret data. 3.02 Operate (addition, subtraction, scalar multiplication) with matrices to solve problems. 3.03 Create linear models for sets of data to solve problems. a. Interpret constants and coefficients in the context of the data. b. Check the model for goodness-of-fit and use the model, where appropriate, to draw conclusions or make predictions.
Algebra	
Competency Goal 4	The learner will use relations and functions to solve problems.
	Objectives 4.01 Use linear functions or inequalities to model and solve problems; justify results. a. Solve using tables, graphs, and algebraic properties. b. Interpret constants and coefficients in the context of the problem. 4.02 Graph, factor, and evaluate quadratic functions to solve problems. 4.03 Use systems of linear equations or inequalities in two variables to model and solve problems. Solve using tables, graphs, and algebraic properties; justify results. 4.04 Graph and evaluate exponential functions to solve problems.

APPENDIX B: TRADITIONAL MATH INSTRUCTION LESSON PLAN

Subject: Algebra 1	Topic: Slope of a Line
Teacher: S****	Date: / /2012

NC Objective:
4.01 Use linear functions or inequalities to model and solve problems; justify results.
a) Solve using tables, graphs, and algebraic properties.
b) Interpret constants and coefficients in the context of the problem.

Activity	Description	Materials/Time
Focus/Review (Establish prior knowledge)	Warm-up problems in book page 127 (2-5)	Textbook 10 min
Statement of Objectives (Inform students of objectives)	What is slope? What is special about the slope of a line (linear function)?	5 min
Teacher Input (Present tasks, information, and guidance)	Teacher notes on slope Slope formulas	30-40 min
Guided Practice (Elicit performance, provide assessment, and feedback)	Sample problems from textbook section Students work out problems individually then compare with partner (Think-pair-share) Student volunteers to work out problems on the board	Textbook 15-20 min
Independent Practice (Seatwork/homework-retention and transfer)	Workbook page	Workbook Remainder of class and finish for homework
Closure (Plan for maintenance)	What is slope? What is special about the slope of a line? Class recap discussion	5 min

APPENDIX C: DIGITAL GAME-BASED MATH INSTRUCTION LESSON PLAN

Subject: Algebra 1	Topic: Slope of a Line
Teacher: J****	Date: / /2012

NC Objective:
4.01 Use linear functions or inequalities to model and solve problems; justify results.
a) Solve using tables, graphs, and algebraic properties.
b) Interpret constants and coefficients in the context of the problem.

Activity	Description	Materials/Time
Focus/Review (Establish prior knowledge)	Warm-up problems in book page 127 (2-5)	Textbook 10 min
Statement of Objectives (Inform students of objectives)	What is slope? What is special about the slope of a line (linear function)?	5 min
Teacher Input (Present tasks, information, and guidance)	Teacher notes on slope Slope formulas	30-40 min
Guided Practice (Elicit performance, provide assessment, and feedback)	Sample problems from textbook section Students work out problems individually then compare with partner (Think-pair-share) Student volunteers to work out problems on the board	Textbook 15-20 min
Independent Practice (Seatwork/homework-retention and transfer)	Computer lab/Internet game at http://www.crctlessons.com/slope-game.html Workbook page for Homework	Computer lab Workbook
Closure (Plan for maintenance)	What is slope? What is special about the slope of a line? Class recap discussion	5 min