DIGITAL GAME-BASED LEARNING AND THE MATHEMATICS ACHIEVEMENT OF GIFTED STUDENTS

by

Lynette Renee Cooper

Liberty University

A Dissertation Presented in Partial Fulfillment

Of the Requirements for the Degree

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ABSTRACT

The purpose of this quasi-experimental non-equivalent control group study was to determine the presence of a statistically significant difference in the mathematics achievement of gifted learners when utilizing digital game-based learning (DGBL) for supplemental mathematics instruction when compared to gifted learners not utilizing DGBL. This study compared the Student Growth Percentile (SGP) of 105 sixth-grade gifted participants from two public middle schools as measured by the Renaissance Learning STAR Math Test. The participants took a pretest, completed 540 minutes of supplemental mathematics instruction over a nine-week period, and took a posttest. Participants were randomly selected for the treatment group who utilized a variety of DGBL activities, or participants were randomly selected for the control group who utilized traditional, paper-based mathematics activities. Independent-samples *t*-tests were used to analyze the SGP between the participants utilizing DGBL and participants not utilizing DGBL, males utilizing DGBL and males not utilizing DGBL, and females utilizing DGBL and females not utilizing DGBL. The importance of this study is to provide educators with knowledge about enhanced instructional technology practices above the prescribed curriculum that may facilitate levels of student achievement for gifted students. No statistical differences in the SGP were found between the treatment group and the control group. Recommendations for further research include the use of specific DGBL games to reduce variations in quality from one publisher to the next, the inclusion of participants from diverse geographic regions, ethnicities, and socioeconomic levels, and data collection over a sustained period of time.

Keywords: digital game-based learning, gifted learners, instructional technology

Dedication

This research is dedicated to my children, Matthew and Brittany, who are my strongest supporters in life. I also thank my parents and my sister, Wanda, who provide continuous encouragement, and my husband, Jerry, for having faith in me throughout this process. Thanks to my colleagues, especially Charlene Stephens, who provided assistance and prayers along the way. Above all, thank you to the Lord for knowing exactly who I am and loving me anyway!

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List of Abbreviations

Computer-Based Instruction (CBI)

Digital Game-Based Learning (DGBL)

Every Student Succeeds Act (ESSA)

Individualized Education Plan (IEP)

National Council of Teachers of Mathematics (NCTM)

No Child Left Behind (NCLB)

Programme for International Student Assessment (PISA)

Student Growth Percentile (SGP)

CHAPTER ONE: INTRODUCTION

Overview

Overcoming the academic barriers of a specific group of learners is a major educational focus especially among those supporting the gifted population. Gifted students have expressed difficulty in amplifying their rates of academic achievement when subjected to instruction presented in traditional teacher-centered, mixed-ability classrooms (Lüftenegger, Kollmeyer, Bergsmann, Jostl, Spiel, & Schober, 2015). Through the implementation of appropriate technology, gifted learners may have their interests stimulated creating an environment that increases motivation and optimizes their learning potential (Jong & Shang, 2015). Technological programs that incorporate digital game-based learning (DGBL) may afford educational institutions the purposeful integration of technology that will satisfy desired technological requirements (Ku, Chen, Wu, Lao, & Chan, 2014) while providing instruction that is individualized and scaffolded for gifted learners (Marklund & Taylor, 2016).

Background

The challenge of implementing new technologies in the classroom has compelled educators to modify their pedagogical practices (Evans, Nino, Deater-deckard, & Change, 2015) while simultaneously reevaluating their provision for differentiated instruction designed to meet the specific needs of gifted learners (Dimitriadis, 2016). The implementation of DGBL may fulfill the requirement for the purposeful utilization of technology in the classroom while concurrently meeting the specialized needs of gifted learners. DGBL may be employed by educators to improve the learning efficiency of gifted students through the establishment of instructional activities that may be individualized or collaborative in a student-centered learning environment (Marklund & Taylor, 2016).

Since limited research has been conducted on methods for increasing the engagement of gifted students in the traditional mathematics classroom (Asmundis, Bitonto, D'Aprile, & Severino, 2015) or on the response of gifted students when DGBL is utilized to supplement mathematics instruction, educators may be afforded with additional instructional tools as a result of this study. Potentially, the benefits of DGBL may be expanded to amend instructional pedagogies beyond the mathematics classroom (Gerber, Abrams, Onwuegbuzie, & Benge, 2014) through the utilization of learning behaviors essential to the establishment of new interdisciplinary learning goals (Ya-Hui Hsieh, Yi-Chun, & Huei-Tse Hou, 2015).

With current advancements in instructional technology, research to evaluate effectiveness for generating academic gains is an essential ingredient for educational leaders as they seek methods for purposely integrating instructional technology into the classroom. To ensure that research on instructional technology is comprehensive, studies should include a variety of educational settings and employ students with a diverse range of academic aptitudes including gifted students (Besnoy, Dantzler, & Siders, 2012). Utilizing instructional technology such as DGBL, student engagement may experience increased levels of sustainment (Martin & Shen, 2014). Furthermore, the versatility of DGBL presents instruction in multiple formats that has the capacity to simulate video games in arcade-style format or simulate tasks that present real-world problems (Ku et al., 2014).

While the amount of research on DGBL is increasing, there is inadequate research concentrating on the success of DGBL to advance the mathematical attainment of gifted learners. Due to the advanced intellectual capacity of gifted learners, their education frequently requires the implementation of innovative approaches to further their learning beyond their existing mastery level (Fisher & Frey, 2012). Since DGBL has the capacity to provide instruction that is individualized based upon the proficiency of the learner, this form of instructional technology may provide gifted learners the capability to exceed the current instructional levels being taught in their classroom environments (Fisher & Frey, 2012). In addition, the format of DGBL is familiar to most learners and may strengthen the enthusiasm of learners to become captivated in their learning programs while simultaneously engaging in mathematical concepts that utilize logical applications (Martin & Shen, 2014).

Historically, the introduction of DGBL emerged in the early 1990s when instructional technology began to filter into learning environments (Asmundis et al., 2015). DGBL began as a method for utilizing instructional technology while increasing student engagement to improve instructional practices (Asmundis et al., 2015). Over time, DGBL expanded to encompass a multitude of instructional technology programs and included the integration of new devices and new instructional objectives. With the push to integrate instructional technology into the classrooms, educational leaders could utilize additional research to serve as a foundation for the effective implementation of DGBL. With the hasty implementation of instructional technology and of DGBL in some academic settings, future research should be designed to examine specific DGBL programs grounded on their intended outcomes including components such as gaming experiences, simulations, and virtual learning experiences. For instance, research determining the effectiveness of a specific DGBL program does not ensure that the findings will generalize to imply the effectiveness of a different DGBL program when administered in a comparable setting (Cicchino, 2015). Irrespective of their intended design, the purpose of DGBL should be to promote skills such as critical thinking that presents challenges to learners while utilizing problems based upon their current developmental levels. Furthermore, the design of DGBL should promote the construction of knowledge utilizing scaffolding to achieve the desired learning outcomes (Cicchino, 2015).

This study sought to determine if the use of DGBL impacts mathematics achievement among gifted learners when utilized to supplement traditional mathematics instruction. In previous studies, DGBL has yielded positive implications (All, Castellar, & Van Looy, 2015; Ku et al., 2014; Ya-Hui Hsieh et al., 2015) when used to supplement traditional instruction for the average learner. Historically, DGBL research concentrated on the ability of DGBL to increase academic performance while measuring the levels of student engagement (Alklind & Marklund, 2016). Many of these studies were conducted in carefully monitored environments where learners reviewed previously taught concepts utilizing DGBL. The learners demonstrated academic gains indicating that DGBL may increase academic proficiency (Alklind & Marklund, 2016). However, minimal research has been conducted on the instructional effectiveness of DGBL in authentic educational settings where the integration may be in classrooms that are more disorganized and sometimes chaotic (Alklind & Marklund, 2016).

Problem Statement

The availability of research on the integration of DGBL in the classroom is limited with most research focusing on the outcome of DGBL when utilized with the average learner (Lüftenegger et al., 2015). Minimal research has been conducted on the use of DGBL with the target population of gifted learners. With awareness that learners performing above their grade level peers are not making comparable academic gains in the traditional, mixed-ability classroom, the instruction of gifted learners is becoming a critical educational issue (Lüftenegger et al., 2015). To determine possible causes for the gap between potential academic attainment and actual academic attainment of gifted learners, there is a need for research to support educators in their efforts to promote academic excellence among the gifted learners that will allow alignment of instruction to learners' specific achievement levels (Lüftenegger et al., 2015).

Research on the effectiveness of instructional tools such as DGBL that stimulate sensory inputs to promote the ability to solve mathematical problems may provide educators with insight on improved pedagogical practices (Moyer-Packenham & Suh, 2012). High-stakes testing has resulted in many schools concentrating on learning outcomes in lieu of instructional practices producing limited learner-generated knowledge that is unable to expand beyond the state-dictated grade level curricula (Asmundis et al., 2015). Since DGBL is task-oriented, the games require learners to actively engage in the learning process (Asmundis et al., 2015) while transforming the classroom into a student-centered model that fosters active discovery and collaboration (Chan & Leung, 2014). To solve complex mathematical concepts, the learner must generally progress through sequential steps that activate background knowledge and require the application of newly acquired skills (Moyer-Packenham & Suh, 2012). By researching methods for improving the efficiency of the learning process through the utilization of instruments designed to promote academic achievement, educators may facilitate the learners' ability to progress beyond their current knowledge resulting in the demonstration of greater gains in learning outcomes (Asmundis et al., 2015). The problem that this study seeks to address is the lack of knowledge regarding the ability of DGBL to create gains in the mathematics achievement of gifted learners due to previous research targeting predominantly average learners (Lüftenegger et al., 2015).

Purpose Statement

The purpose of this study employing a quasi-experimental non-equivalent control group design was to determine if there is a statistically significant difference in mathematics achievement when utilizing DGBL between gifted students in the treatment group and gifted students in the control group. The independent variable is the utilization of DGBL programs including Study Island, Calculation Nation, Math Playground, Coolmath, and Sheppard Software in the treatment group. The dependent variable is the mathematics student growth percentile (SGP) scores achieved on the STAR Math assessment by the participants at the conclusion of the study. Subsets of the group were determined by gender. The participants for this study consisted of sixth grade male and female students attending public middle schools. The gifted participants were enrolled in classrooms that specialize in teaching academically gifted students in pullout programs designed to enhance traditional instruction provided in the regular, mixed-ability classroom. The participants were randomly assigned to the treatment group or the control group through a lottery system. The participating teachers held drawings to determine the students that were placed in the treatment group and the control group. Since participants were selected from pre-existing classes, the individual participants varied in academic achievement prior to the administration of the study making them non-equivalent (Warner, 2013).

Significance of the Study

Due to an inadequate number of research studies analyzing the integration of technology and mathematical learning in gifted education, educators may be unable to provide gifted learners with instruction that optimizes mathematics achievement relative to abilities of the gifted learner (Lüftenegger et al., 2015). Therefore, this study on the use of DGBL may provide educators with an additional tool for personalizing mathematics instruction that extends beyond traditional mathematics textbooks and subsequently surpasses the confines of the mathematics classroom (Asmundis et al., 2015). This research is important since the integration of instructional technology in the classroom is yielding growth in mathematics achievement resulting in an increased demand for instructional technology, including DGBL, in the classroom (Lim, Zhao, Tondeur, Chai, & Tsai, 2013).

This current study addressed the gap in existing literature by demonstrating whether or not enhanced instructional practices above the prescribed curriculum will facilitate levels of student achievement that may enrich the potential of students who rank in the upper percentiles of academic abilities. Since gifted learners often achieve higher scores on the mathematical-logical area of the intelligence scale, DGBL may address the need for mathematics instruction utilizing logical applications (Aksoy & Narli, 2015). Furthermore, previous research studies (All, Castellar, & Van Looy, 2015; Ku et al., 2014; Ya-Hui Hsieh et al., 2015) have yielded positive outcomes in student achievement when instructional technology is integrated in the traditional classroom to supplement instruction among average learners.

The outcome of this study may impact instructional decisions made by educators, curriculum specialists, and online game designers through the integration of DGBL into mathematics instruction that may increase the motivation of learners through the utilization of programs that require active participation (Perini, Margoudi, Oliveira, & Taisch, 2017) while providing timely, accurate feedback that encourages mastery learning (Yang, 2017). Additionally, this study adds to the current body of knowledge by providing proven alternatives to the current classroom environment where the curriculum is generally the same for all learners in a specific grade level with little or no differentiation for learners that have demonstrated mastery of grade-level objectives (Ku et al., 2014). The results of this study may inform educators of gifted learners about various components of DGBL and demonstrate the use of DGBL as a means to encourage learners to examine problems from diverse perspectives while facilitating the acquisition of complex thinking competencies (Besnoy et al., 2012). With current accountability models, gifted learners may receive less differentiated instruction as schools may opt to focus on the growth of struggling learners and minimize their attention on high-achieving learners such as gifted learners (DeNisco, 2015). As a result, gifted learners may spend the greater part of the academic year exposed to previously mastered objectives and may not fulfill their academic potential or achieve academic gains comparable to the gains obtained by their non-gifted peers (Ku et al., 2014). Incorporating tasks such as DGBL to frame the classroom may increase the likelihood that instruction will correspond with the competence level of learners while increasing learner involvement in decision-making, encouraging self-evaluation, and increasing mastery learning (Lüftenegger et al., 2015). While learning outcomes from the utilization of DGBL are deliberately designed to facilitate the academic achievement of learners through increased levels of learner interest and subsequent engagement in specific educational objectives, the outcomes associated with this study on DGBL may also include the transferability of new knowledge to other situations while enhancing the classroom environment through efficient time management and cost effective instructional practices (All et al., 2015).

This study addresses a gap in existing literature by providing information on whether or not the integration of DGBL as a supplemental tool for mathematics instruction will facilitate academic achievement among students whose academic abilities measure in the upper percentiles. As a result of this study, educators may be provided with an additional means for offering flexible, individualized instruction for gifted students that extends beyond their grade level curriculum and may broaden into other academic disciplines.

Research Question

The research question for this study is:

RQ1: Is there a statistically significant difference between the mathematics student growth percentile scores of gifted learners who utilize digital game-based learning in comparison to gifted learners who do not utilize digital game-based learning?

Definitions

1. *Digital game-based learning* – Technological programs designed to increase the academic achievement of students through the use of applications presented in gaming formats (Lee & Hao, 2015).
2. *Gifted learners* – Students exhibiting the potential for outstanding achievement in academics (Landis & Reschly, 2013) and that frequently score in the top 10% on standardized assessments (Lüftenegger et al., 2015).
3. *Instructional technology* – Tools systematically designed to provide instructional sequences and simulated learning activities (McEneaney, 2016).
4. *Student-centered learning environment* – A classroom environment where the teacher assumes the role of facilitator as students engage in the acquisition of their own knowledge (Marklund & Taylor, 2016).
5. *Underachievement of gifted students* – The discrepancy between the exceptional academic potential of learners and the actual academic performance exhibited by the learners (Snyder & Linnenbrink-Garcia, 2013).

CHAPTER TWO: LITERATURE REVIEW

Overview

Chapter two commences with theoretical frameworks related to the broad range of ideas and concepts utilized during DGBL including the works of Confucius (Tan, 2016), John Dewey (Tan, 2016), Jean Piaget (Gilakjani, Leong, & Ismail, 2013), Lev Vygotsky (Asmundis et al., 2015), and Albert Bandura (All, Castellar, & Van Looy, 2015). The theoretical frameworks presented in this study are followed by a comprehensive review of related literature. Major topics discussed in the literature review include the background of DGBL, overview of the definition of DGBL, the needs of gifted learners, deficits of gifted education, No Child Left Behind Act and Every Student Succeeds Act, factors impacting mathematics achievement, and the role DGBL may play in education.

Introduction

Historically, mathematics instruction has been delivered in classrooms with educators conveying factual information followed by assessments that measure the ability of learners to recall concepts (Hallström, Hultén, & Lövheim, 2013). Such pedagogical practices deny learners the opportunity for meaningful educational experiences that increase engagement through the use of motivating lessons where learners actively participate in collaborative educational activities (Nel, 2017). As learners progress from concrete to abstract mathematical concepts, an increased number of instructional tools, pedagogical practices, and learner models should accompany the shift to ensure meaningful student engagement (Hallström et al., 2013). One such tool is the implementation of instructional technology. By increasing levels of academic engagement, instructional technology is yielding improvements in mathematics achievement increasing the demand for additional forms of technology such as DGBL in the classroom (Lim et al., 2013).

Mathematical learning can be complex with mathematical concepts requiring a specific combination of sensory inputs including dominant, multiple, and combined senses for the development of solutions to problems (Katai, Toth, & Adorjani, 2014). Dominant senses vary by student with some learners responding favorably to one specific sense such as visual learners or auditory learners (Katai et al., 2014). Furthermore, research has shown that learning may occur simultaneously from several senses using multiple senses or combined senses (Katai et al., 2014). Multiple senses refer to the pathways utilized by the learner to locate information storage in the brain, and combined senses refer to the stimulation of specific senses to maximize learning (Katai et al., 2014). These pathways provide a multi-sensory approach for learners as they follow through a series of developmental progressions where learners connect isolated mathematics skills to larger, overarching concepts while simultaneously applying pertinent background knowledge (Moyer-Packenham & Suh, 2012). As more senses are stimulated, the efficiency of learning is improved due to the increased level of information processing (Katai et al., 2014). Consequently, the use of DGBL may remove learners from the traditional role of passively acquiring knowledge to the center of the instructional process where they are the active participants exploiting the benefits of instructional technology while allowing for experiential learning that may permit knowledge to transfer to contexts outside of the mathematics classroom (Asmundis et al., 2015).

Philosophically, schools have endeavored to align theories that will facilitate the conveyance of knowledge to learners. One of the greatest challenges for educational leaders is determining the presentation of curriculum utilizing a methodology that is most applicable to the learners to promote greater rates of academic success (Asmundis et al., 2015). DGBL provides a mode of instructional technology that integrates several approaches to learning including experiential, constructivist, and social (Asmundis et al., 2015). The major theory that supports the use of DGBL is constructivism developed by Jean Piaget (Gilakjani et al., 2013). Constructivism is the development of the learner's conceptual framework that provides a knowledge structure where current knowledge is established into a prearranged system in the learner's mind, and new knowledge is assimilated into this existing structure (Gilakjani et al., 2013). For new knowledge to be properly assimilated, constructivism necessitates interaction between the learner and the new information for the development of the desired conceptual understanding. Engagement is a key concept that refers to the motivation, overall attitude, and interest level of the learner (Hui Hsieh et al., 2015). Engagement promotes learning through broadening learner knowledge while simultaneously expanding the reality of the learner (Gilakjani et al., 2013). The scaffolded design of DGBL promotes the acquisition of knowledge as learners build upon previously learned concepts. Additionally, instructional technology, such as DGBL, further aligns with the constructivist approach as the learner must manipulate tools and apply knowledge to progress from one level to the next promoting increased levels of learner engagement (Gilakjani et al., 2013). Moreover, DGBL requires a transformation in the educational environment to a student-centered classroom where the educator facilitates learning by shifting students from passively receiving knowledge to creating and discovering their own knowledge (International Society for Technology in Education, 2017). This student-centered classroom corresponds with the constructivist theory where learners must be active participants in the learning process (Ku et al., 2014). By empowering learners with the ability to make academic decisions such as task choice and time management, the student-centered classroom may foster confidence and academic risk-taking in a supportive environment facilitated by the teacher (Bohlman & Weinstein, 2013). Prior to implementing DGBL in the student-centered classroom, educators must determine the learner's level of academic readiness to ensure the presence of necessary background knowledge to maximize academic achievement (Avci, Keene, McClaren, & Vasu, 2013).

Gifted learners are frequently identified as those learners possessing the capacity to employ higher order thinking as they develop academic skills in preparation for future accelerated programs (Landis & Reschly, 2013). While the education of gifted learners requires specialized services, they are often placed in mixed-ability classrooms under the guidance of teachers with no training in gifted education who lack the strategies necessary to adequately service gifted learners (Benny & Blonder, 2016). With appropriate supports, gifted learners have demonstrated high levels of academic achievement, but the lack of support has resulted in underachievement relative to abilities from causes such as boredom and the inability to make purposeful connections to the content (Kroesbergen, Hoojdonk, Van Viersen, Middel-Lalleman, & Reijnders, 2015).

In mathematics, gender differences are present when considering the lower number of females in finance, science, technology, and engineering fields in comparison to the number of males in the same fields (Joensen & Nielsen, 2015). Finding methods for fostering the ability of females to perform high-level mathematics could provide an expanded labor force of qualified professionals in these mathematics-based fields (Joensen & Nielsen, 2015). Also, gender differences may hinder the optimization of DGBL in the classroom based upon the preference for males to engage in digital games more frequently than females. While the benefits of DGBL may be similar for males and females, males may be more likely to engage in digital games minimizing the positive impact DGBL may provide for females (Admiraal, Huizenga, Heemskerk, Kuiper, Volman, & Dam, 2014).

Theoretical Framework

As learners acquire new knowledge, they often develop an understanding of the structural conceptions of advanced comprehension allowing for the transfer of information to future learning models (Holma & Hyytinen, 2015). This acquisition of knowledge is often derived from the active participation of the learner while engaged in instructional technology such as DGBL. There are multiple education theorists whose work correlates to the learning process utilized during DGBL including Confucius (Tan, 2016), John Dewey (Tan, 2016), Jean Piaget (Gilakjani et al., 2013), Lev Vygotsky (Asmundis et al., 2015), and Albert Bandura (All, Castellar, & Van Looy, 2015). Confucius proposed that the purpose of education is to enlighten students as they interact with the universe, and learning experiences should take an interdisciplinary approach including positive experiences that encourage diversity for the development of all aspects of the learner (Gutek, 2011). Socrates believed that learning should encompass many subjects simultaneously while providing positive learning experiences (Gutek, 2011). John Dewey encouraged the exploration of the environment so that learners could develop a foundation of truth that was distinctly their own endorsing the belief that learners' natural curiosities should spark their own natural questioning while promoting thinking and problem-solving skills (Gutek, 2011). DGBL presents learners with many of the components that align with this broad range of educational theorists.

Confucius

Insight on how learners obtain knowledge was addressed by Confucius who related the acquisition of knowledge to the purposeful quest for enlightenment to facilitate interaction with the universe (Tan, 2016). According to Confucius, learners acquire knowledge through a dynamic process that requires active involvement in learning followed by a time of reflection.

Additionally, Confucius emphasized the function of positive learning experiences to serve as the foundation for education that develops all aspects of the learner including the disciplines of music and science. Confucius promoted that learning is a holistic process where all aspects of a human are related including feelings, perceptions, and thinking (Tan, 2016). In accordance with the teachings of Confucius, DGBL promotes engaged, positive learning experiences. According to Ya-Hui Hsieh et al. (2015), engagement may be divided into three dimensions consisting of cognitive, affective, and behavioral. The dimension of cognitive engagement refers to self-regulated learning including the application of specific learning strategies and the establishment of learning goals (Hui Hsieh et al., 2015). The dimension of affective engagement correlates to the learner's attitude including the motivation and interest level of the learner to perform a task. Observable levels of participation or the level of inquiry during a task is related to the dimension of behavioral engagement (Hui Hsieh et al., 2015). Furthermore, increased engagement by learners may be associated with increased fluency enabling learners to respond flexibly and apply knowledge to a variety of scenarios (Pasztor, Gyongyver, & Csapo, 2015). DGBL utilizes instructional components such as a competitive format to increase the level of learner engagement while allowing the learner to track progression through a series of stages throughout the application heightening learner interest (Musti-Rao, Lynch, & Plati, 2015).

John Dewey and Experiential Education

Similar to Confucius, John Dewey focused his work on promoting the acquisition of knowledge utilizing a two-step process composed of thinking and reflecting (Tan, 2016). Dewey endorsed that learners seek their own truths through environmental exploration and that perceived truth is provisional based upon personal experience. Also, Dewey promoted that learners should be able to utilize their natural curiosities to seek answers to self-developed questions (Tan, 2016). According to Dewey, the learning environment should provide a child-centered curriculum where learners engage in an interactive environment filled with obstructions that challenge the learner to generate a series of questions (Waddington, 2015). As learners progress through the questioning process, experimental learning promotes interaction and allows for the development of socialization (Tan, 2016).

Similar to Dewey's beliefs, a major function of instructional technology is the ability to engage learners by utilizing software applications that require learners to respond to stimuli while answering probing questions in a student-centered classroom (Musti-Rao et al., 2015). As a major component of instructional technology, DGBL contains graphics and vibrant colors that sustain learner attention, provide immediate feedback for self-monitoring progress, and maintain engagement throughout the experience while providing multiple examples. Additionally, sound plays an important role in maximizing engagement while graphics provide incentive through instant rewards for correct answers (Musti-Rao et al., 2015). DGBL programs require learners to provide input while progressing through scaffolded levels of instruction. Forms of scaffolding include differentiated instruction based upon learner's prior knowledge and the learner's academic readiness followed by tiered activities. The tiered activities promote mastery of the academic objective with activities ranging in complexity from simplest to more difficult, from concrete to more abstract, and from highly structured to minimally structured (McCoach, Gubbins, Foreman, Rubenstein, & Rambo-Hernandez, 2014). Additionally, the learners conduct digital experimentation while experiencing minimal penalty for incorrect answers producing results that may be clearly interpreted (Waddington, 2015). Many of the digital games are adaptive allowing the game to adjust to the ability of the learner addressing academic gaps while maximizing the academic challenge for the learner as discussed by Dewey (Sampayo-Vargas, Cope, He, & Byrne, 2013).

Jean Piaget and Constructivism

Similar to John Dewey's theory promoting explorative learning, Jean Piaget's theory on constructivism requires the learner be actively engaged in the learning process (Gilakjani et al., 2013). According to Piaget, learning occurs most efficiently when instruction is presented in context while utilizing an instructional design that requires the learner to engage with the concept (Gilakjani et al., 2013). In accordance with the constructivist belief that learning should transpire in the appropriate context, instructional technology provides learning experiences in context while utilizing an engaging learning environment (Gilakjani et al., 2013). Additionally, instructional technology provides learning experiences aligned with the constructivist framework through layered lessons that utilize scaffolding allowing learners to progress at individual rates (Gilakjani et al., 2013). DGBL provides learners the opportunity to interact with abstract concepts utilizing concrete visualizations through the use of advanced graphics and visual models providing the learners with multiple ways for relating with the concepts (Moyer-Packenham & Suh, 2012). Additionally, virtual manipulatives may be included to provide learners with instructional tools that are more engaging than traditional illustrations included in textbooks (Moyer-Packenham & Suh, 2012).

Lev Vygotsky and Activity Theory

The activity theory developed by Lev Vygotsky proposes that learning occurs while performing activities that promote social interaction such as working in collaborative groups and communicating ideas that may lead to the development of complex problem solving skills (Asmundis et al., 2015). The process of learning and the creation of knowledge are social processes resulting from interaction within the learning community. According to Vygotsky, learners are attempting to achieve balance between individuality and their sense of community while reaching beyond traditional limitations in learning to support the construction of collaborative, concrete outcomes (Asmundis et al., 2015). Research conducted by Gerber et al. (2014) demonstrates that DGBL is capable of surpassing traditional instructional models because of the simultaneous stimulation of multiple senses as learners pursue video and sound cues while manipulating avatars. In accordance with Vygotsky's Activity Theory, avatars provide a method for engaging in collaborative working environments that allow learners to interact with the game community, real and virtual, and establish global connections that extend beyond the perimeters of the classroom (Novak, Mladenow, & Strauss, 2014). As players continuously decode the game while reacting to the prompts, the edges separating knowledge from application become less distinct (Gerber et al., 2014).

Albert Bandura and Social Cognitive Theory

According to Bandura, social cognitive theory establishes a framework for self-evaluation where learners are capable of observing their behavior and the outcomes resulting from that behavior (All et al., 2015). Based upon their evaluation, learners will continue their behavior, alter their behavior, or discontinue their behavior (All et al., 2015). As learners establish goals, behaviors are determined based upon their ability to meet established goals, and effectiveness is determined by competence to meet the goals reinforcing the chosen behavior. As a result, outcomes become a benchmark for judging effective behaviors (All et al., 2015). Similarly, the learner's evaluation of DGBL will be judged against the ability of the learner to meet a desired goal. While environmental determinants influence a human's personal standards, aspirations, and self-efficacy, outcomes will be the primary determinant when judging effectiveness (All et al., 2015).

Related Literature

The conception of learning involves a system of reasoning that consists of historically founded cultural implications that allow learners to develop a progressive awareness when presented with new knowledge (Laina & Monaghan, 2014). However, establishing a classroom that lays the foundation for learners to become receptive to instructional content presented via technology is not a straightforward task. Young teachers and students born since 1980 have been immersed in technology most of their lives and may be referred to as digital natives, a name coined by Marc Prensky in 2001 (Echenique, 2014). For this group, technology is a source of communication and recreation that has redefined how they communicate resulting in the exponential growth of internet use (Lim et al., 2013). Unfortunately, these digital natives may fail to associate the integration of instruction utilizing digital devices with a meaningful educational experience (Garrido, 2012). As a result, the adoption of instructional technology does not always serve as a precursor for increased levels of academic achievement (Lim et al., 2013). To increase the likelihood of success, implementation of instructional technology should be prefaced with strategic planning, professional development, and careful alignment with specific academic objectives (Lim et al., 2013). The use of games as educational instruments should be focused on specific content to create maximum impact on learners whether they are learning collaboratively or independently (Chen, Wang, & Yu-Hsuan, 2015). Additionally, implementing DGBL must generate learner attention, maintain focus and engagement, and sustain the self-paced learning necessary to maximize the potential offered by this form of instructional technology (Katai et al., 2014).

Background

Defining technology is difficult due to the presence of contradictory concepts that hinder the development of one universally accepted definition (Hallström et al., 2013). Educational technology has been defined as the use of technology and technological processes for the facilitation of learning and for improvements in learner performance (Reeves & Oh, 2017). The terms educational technology and instructional technology have been utilized in research without distinction. The components of technology began advancing as industries sought ways to develop machines to complete tasks previously completed by humans resulting in increased output and reduced number of employee hours (Hallström et al., 2013). These developments led to technological advancements including devices capable of operating software applications such as computers and mobile devices (Musti-Rao et al., 2015).

Computer-based instruction (CBI) was introduced into classrooms in the latter part of the 1950s (Sözcü, İpek, & Taşkın, 2013). The use of computers in the educational setting was primarily the result of government funding allocated to determine the efficiency of computers used in instruction. In 1960, the University of Illinois' PLATO project established one of the first learning environments that integrated the use of text and graphics in CBI (Sözcü et al., 2013). The educational use of technology continued during the 1960s and was predominantly focused on acquiring manufacturing skills for males enrolled in vocational courses (Hallström et al., 2013). As vocational courses continued to transform workers to fulfill the needs of industry, the academic success of the advancements began to build a strong foundation for the integration of technological devices into other disciplines in schools (Hallström et al., 2013).

Originating in the 1960s, one of the first, mainstream instructional technology devices was the development of affordable, handheld calculators that consisted of single-line displays

(Hillman, 2014). The handheld calculator facilitated mathematical problem solving by increasing the speed and efficiency of computational fluency. In the 1980s, the development of advanced graphing calculators could perform functions similar to desktop computers (Hillman, 2014). Transformations to instructional practices were instituted in response to the greater flexibility calculators afforded the mathematics classroom (Hillman, 2014). Utilizing the calculator to aid in mathematical computation required humans to input desired operations and monitor the functioning of the device. Simultaneously, the acceptance of multiple methods for solving mathematical problems began gaining popularity (Hillman, 2014). As with all instructional technology, calculators depend upon human interaction to serve any purpose. The interaction between the calculator and the operator serves as the foundation for the application of this form of instructional technology to improve the efficiency of mathematics computation (Hallström et al., 2013).

The adoption of personal computers for individual learners in the classroom began during the 1980s. During this time, required courses in technology began emerging but were taught in isolation of other disciplines. The World Wide Web began reinforcing academic objectives during the 1990s (Sözcü et al., 2013). As a result, technology expanded into other disciplines and began facilitating problem solving and analytical thinking skills in all subject areas. Consequently, academic institutions increased the investment in instructional technology during the 1990s creating a generation of technologically proficient learners (Hallström et al., 2013). The integration of technology in the classroom continued in the 2000s with the proliferation of mobile devices and widespread wireless access (Sözcü et al., 2013).

During the 1990s, one major aspect of technology designed for instruction was the replication of some features of popular digital games designed for entertainment (Spires, 2015).

Digital games have captivated the attention of large numbers of children by providing elements of challenge and fantasy (Mavridis, Katmada, & Tsintsos, 2017). Some of the basic components of instructional games are the inclusion of instructional goals, clear rules, single or multi-player capabilities, concise directions, constraints, rewards and penalties, and the provision of player choices. DGBL gained recognition and acceptance as a viable education tool by the Federation of American Scientists in 2005 (Spires, 2015). Key components of DGBL are the ability to provide learners with skill mastery by activating higher level thinking skills such as strategic thinking, problem solving, and adaptability (Spires, 2015). Consequently, the Federation of American Scientists recognized digital learning games as having the capacity to prepare students for highly skilled occupations with above average earning potential (Spires, 2015).

Gifted Learners

The definition of giftedness varies, but the generally accepted definition includes learners that have the capacity to perform at high levels in comparison to peers (Landis & Reschly, 2013). Some general characteristics of gifted students may include a willingness to work hard to achieve above the ordinary, determination to exert effort to obtain a goal, and an openness to learn new knowledge and skills (Gallagher, 2015). As gifted students develop, the process is often asynchronous with middle school gifted students demonstrating higher cognitive abilities and exhibiting characteristics that indicate a higher mental age in comparison to their grade-level peers (Ritchotte, Rubenstein, & Murry, 2015). Data have demonstrated that gifted students have a higher incidence of traits that may provide advantages throughout their lives on academic performance and in the job market. These traits include personality and social factors that distinguish gifted students from the general population (Gallagher, 2015).

In the absence of a federally established guideline, identification of gifted learners varies by state and by district. According to the National Association for Gifted Children (2017), gifted students in grades kindergarten through 12th grade comprise an estimated six percent of the public school population. Achievement tests are frequently used to identify gifted learners, but methods such as teacher nomination, observations, and student work are also used in some areas (DeNisco, 2015). Common characteristics identified by teachers as good indicators of giftedness include a good working memory, creative thinking, and innovative problem solving approaches (Güçyeter, 2015). Using multiple sources to identify giftedness is recommended to overcome bias of a single method (Kroesbergen et al., 2015). While many gifted learners are easy to recognize based upon their behavioral characteristics such as reading or competing beyond the expected level for their age, further efforts should be made to identify those with superior potential that have not been discovered (Gallagher, 2015). Categorizing gifted learners by those with high performance and those with high potential may produce more equitable results in gifted identification (Kroesbergen et al., 2015). The age of identification of giftedness also varies, but the majority of students who are classified as gifted are identified by the third grade (DeNisco, 2015).

Generally, gifted learners have a greater propensity for utilizing skills associated with higher-ordered thinking (Besnoy et al., 2012). Skills such as the ability to recall, think creatively, and engage in complex, abstract thought are more prevalent in gifted learners, but these skills must be acquired through exposure to sound instruction and engaging educational experiences (Besnoy et al., 2012). Gifted students are often placed in mixed-ability classrooms for most of the school day with teachers that have little or no training in the education of gifted learners (Benny & Blonder, 2016). Effective gifted learning programs should encompass instructional strategies that challenge gifted learners while offering meaningful instruction with programs that foster academic exploration, curiosity, and creativity while providing tasks that are authentic and meaningful (Beasley, Briggs, & Pennington, 2017).

Deficits in Gifted Education

Currently, there are multiple problems plaguing efforts to educate gifted students in the United States. According to Callahan, Moon, Oh, Azano, and Hailey (2015), gifted learners have typically mastered 50% of the content prior to presentation by educators. Gifted learners report spending less than an hour daily studying academic material (Gallagher, 2015). Additionally, an estimated 80% of the time gifted learners spend in the classroom is utilized to cover the same instructional content as their grade-level peers resulting in minimal opportunities to extend current knowledge (Callahan et al., 2015). In comparison, most European countries require a specialized approach to gifted education. Teachers undergo mandatory training for the education of gifted students, and the implementation of advanced programs include differentiated instruction and specialized classes or schools (Sękowski, & Łubianka, 2013). Similarly, China has key-point schools for students demonstrating exceptional intelligence and abilities (Ye, 2015). The key-point schools have distinct advantages over traditional schools with higher quality teachers and facilities. Students graduating from the key-point schools have advantages for university admission and future marketability (Ye, 2015). In contrast, cultural beliefs in Japan encourage egalitarianism discouraging the implementation of a formal gifted program, but there are extensive afterschool and private programs for gifted students that provide intensive, accelerated instruction (Sumida, 2013).

In most states in the United States, teachers of gifted learners are not required to hold any special certifications or undergo training for teaching gifted learners (DeNisco, 2015). Teachers may lack content knowledge, might underestimate the importance of student engagement, could lack familiarity with the use of data to drive instruction, and may be deficient in implementing differentiated instruction (Beasley et al., 2017). Due to the small number of gifted learners in a class, some educators may overlook them due to time constraints or the lack of knowledge in how to foster their needs (Benny & Blonder, 2016). Additionally, the establishment of a learning environment that constructs the challenges and simulations necessary to service gifted learners may be viewed as impractical due to large class sizes and inadequate funding (Waddington, 2015). According to Gallagher (2015), for every $100 dollars spent on education, approximately two cents is spent providing instruction for gifted students. Consequently, classrooms are unlikely to have adequate instructional materials or instructional supports to provide an intense gifted curriculum resulting in modifications for gifted learners that involve slight variations of the current grade-level curriculum producing negligible differences in achievement (Callahan et al., 2015). Furthermore, grade-level standards, including Common Core State Standards, are inadequate to address the needs of gifted learners due to the lack of content depth and acceleration (Beasley et al., 2017), and many schools fail to establish observable outcome measures for determining the effectiveness of gifted education efforts (Callahan et al., 2015).

Adding to these difficulties, teaching mathematics to a group of students can be an intimidating task for teachers because the needs of students may vary greatly in one classroom. The variability that exists in how students understand mathematical concepts and how they apply the mathematical knowledge requires modifications by the teacher. From lesson design to textbook content, adjustments in the presentation of mathematical concepts should be customized to meet the needs of the individual learners (McCoach et al., 2014). Providing differentiated instruction daily is daunting for teachers despite the presence of technology and assistance from curriculum developers. As a result, teachers may become overwhelmed due to time constraints, lack of knowledge and teaching skills, and absence of the desire to overcome these deficiencies to provide differentiated instruction (McCoach et al., 2014).

Gifted Learners, No Child Left Behind, and Every Student Succeeds Act

No Child Left Behind (NCLB) is an accountability system that measures the overall achievement level of schools (McCoach, Rambo, & Welsh, 2012). NCLB does not measure the growth of individual students in a particular school but focuses on raising the number of students that are proficient on state assessments. NCLB uses static measures that look at each school as one unit without examination of individual scores with no model included to provide an adequate evaluation of growth of specific students. These static measures provide snapshots of achievement at one moment and do not capture growth over time (McCoach et al., 2012). As a result, many schools have focused diligently on raising the scores of low-achieving students to ensure they reach the designated target prior to state assessments without safeguarding adequate growth of high-achieving students (McCoach et al., 2012).

The adoption of NCLB has produced a shift in funding for many schools districts resulting in a sharp decrease in gifted education support as money is transferred to at-risk learners (Haberlin, 2016). Examples include the state of Oregon that has decreased funding for gifted programs from $800,000 to $100,000, Michigan that has decreased funding from $19 million to $5 million, and Illinois that has cut all $16 million in funding for gifted education (Haberlin, 2016). With the absence of incentives to enhance gifted education under NCLB, educational trends focused on creating equity have resulted in the denial of innovative instructional practices to satisfy the special needs of gifted learners (Gallagher, 2015). Since gifted learners are capable of mastering grade-level content without instructional supports, the elimination of specialized instruction deters gifted learners from developing the skills necessary to embrace challenges or the persistence to achieve excellence (DeNisco, 2015). Consequently, the accountability system of NCLB has coincided with lower achieving students demonstrating academic improvements while higher-performing learners are demonstrating lower academic gains than in previous years (DeNisco, 2015).

In 2015, the Every Student Succeeds Act (ESSA) replaced NCLB providing state governments with more authority over education and placing greater emphasis on college and career readiness (Malin, Bragg, & Hackmann, 2017). As a result, states have greater focus on preparing students with rigorous courses that may prepare students for college and vocational programs. ESSA encompasses a broader approach to student achievement in comparison to NCLB with accountability extending to the academic attainment of all learners including the higher-achieving students. While the impact for gifted education has yet to be determined, ESSA provides expanded flexibility to state and local districts to make educational decisions in lieu of the prescriptive requirements of NCLB (Ferguson, 2016).

Gifted Learners and Underachievement

Underachievement may be defined as the variance between exceptional academic potential and actual academic performance (Snyder & Linnenbrink-Garcia, 2013). Underachievement does not indicate that a learner is not performing on grade level, but the learner is not reaching optimal academic potential without the presence of a learning disability. With the great contributions gifted students may make to society, researching how to transform their potential into actual achievement is critical (Landis & Reschly, 2013). Additionally, identifying potential causes for underachievement may equip educators with improved tools for offering interventions to gifted learners at earlier ages (Obergriesser & Stoeger, 2015). A study conducted by Obergriesser & Stoeger (2015) determined that underachievement may result from several factors associated with self-regulated learning including emotional concerns, learning behavior, and learner motivation. Research by Landis and Reschly (2013) determined that student engagement is a key element of underachievement. The lack of engagement may be the result of an academic curriculum that is unchallenging or fails to attach significant value to education (Snyder & Linnenbrink-Garcia, 2013). In either scenario, the causes for a lack of motivation or a lack of student engagement may vary depending upon the circumstances. Underachievement may be the result of gifted learners experiencing a poor self-concept in the academic environment based upon how they compare themselves to their peers (Obergriesser & Stoeger, 2015). Additionally, self-efficacy may impact the achievement of gifted learners as they attempt specific tasks. Unlike self-concept, self-efficacy refers to the goals the individual desires to achieve and does not rely on comparisons to peers (Obergriesser & Stoeger, 2015).

Gifted middle school students may experience underachievement as the result of the transition from elementary school to middle school where many gifted students begin a downward cycle in academic achievement with no specific intervention used in isolation successfully deterring this downward academic trend (Ritchotte et al., 2015). There are several characteristics that underachieving middle school gifted students share including increased social pressure, higher expectations from those around them, and added responsibility for individual actions (Ritchotte et al., 2015). The extent of underachievement is the determining factor in how educators and parents react. A gifted learner scoring in the average range may not cause major concern, but the long-term result of underachievement may alter future outcomes (Ritchotte et al., 2015).

Gifted learners experiencing underachievement may become disengaged in the learning process or exhibit disruptive behavior. Often during middle school, the social group begins demanding more time and attention replacing time previously spent on academic pursuits (Landis & Reschly, 2013). Social status and attention to appearance may interfere with learning and the development of new concepts. Addressing underachievement early is critical because the consequences of declined academic performance may continue throughout a lifetime resulting in decreased earnings (Landis & Reschly, 2013). In extreme cases, the result of underachievement may be failure or dropping out of school altogether (Ritchotta et al., 2015). Academic skills, such as mathematics, have important foundational concepts taught in the middle school years that make future educational pursuits more challenging or impossible if not mastered. For example, advanced mathematics courses taken in middle school are intended to prepare the students to take accelerated algebra classes at the next level. Gaps in foundational knowledge during the early mathematics courses may result in lower scores in high school that may result in lower scores in college or in failure (Ritchotta et al., 2015).

Socioeconomic Levels' Impact on Mathematics Achievement

The socioeconomic status of learners has provided a reliable predictor for mathematics achievement with learners from higher socioeconomic levels attaining higher scores on mathematics achievement tests than those learners from low socioeconomic levels (Valero & Meaney, 2014). In low socioeconomic areas, the occurrence of giftedness among minorities is approximately half as prevalent in comparison to the general population (Gallagher, 2015). Valero and Meaney conducted a study (2014) comparing international learners from various socioeconomic backgrounds that completed the Programme for International Student Assessment (PISA). The PISA ranges in scores up to 650 possible points. Valero and Meaney's findings indicated a 39-point advantage out of a possible 650 points between scores for learners from high socioeconomic homes in comparison to those from low socioeconomic homes. According to the assessment measures, 39 points are equivalent to the growth expected in one school year (Valero & Meaney, 2014). The reasons for the score discrepancy between the two socioeconomic groups is difficult to ascertain, but one accepted theory is the lack of environmental exposure to educational concepts for many of the low socioeconomic level learners (Valero & Meaney, 2014). In some impoverished areas, there are negative consequences for those excelling in school including harassment and peer rejection (Gallagher, 2015). While living in neighborhoods where the lack of personal security consumes the thoughts of learners, irrelevant academic information may be impertinent and inconsequential to the learners (Gallagher, 2015). Distractions deprive some learners of the opportunity to immerse their minds into concepts such as the solar system and hinder them from developing their intellectual potential.

In most schools, minority or economically disadvantaged students are not proportionally represented among the gifted population (DeNisco, 2015). Frequently, schools utilize scores from standardized tests to determine gifted eligibility placing some students at a disadvantage. Difficulty identifying gifted learners that are economically disadvantaged or are from a minority group may require multiple assessment formats to meet their individualized needs (DeNisco, 2015). Additionally, services rendered by public schools are often inadequate by reaching only small segments of the population and even fewer of the subpopulations (Gallagher, 2015).

Gender Gap

Mathematics has been considered a subject stereotypically dominated by males (Jackson, Brummel, Pollet, & Greer, 2013), and the gender gap between males and females has been the subject of research studies for many years (Bohlmann & Weinstein, 2013; Casad, Hale, &

Wachs, 2015; Nollenberger, Rodriguez-Planas, & Sevilla, 2016). In a study by Güçyeter, (2015), surveyed teachers reported that they observed perceived mathematical giftedness in males more frequently than females. While females have been making gains in closing the achievement inequality, a gap is still present (Jackson et al., 2013). Understanding the disparities in mathematical performance requires that researchers examine differences in gender, especially among middle school learners. For example, females frequently use language-based strategies while males may use strategies that are more spatial-based when solving mathematical problems (Wong, 2017). These spatial-based strategies have been shown to increase efficiency when performing mathematical problem solving favoring stronger mathematical performances among males (Wong, 2017). Additionally, mathematical performance may reveal discrepancies between the confidence levels of females and males that may impact their mathematics achievement. According to Bohlmann and Weinstein (2013), learners' perceived ability has the potential to produce notable variations in their future trajectories of mathematics achievement. Research studies (Wong, 2017; Rosselli, Ardila, Matute, & Inozemtseva, 2009; Jackson et al., 2013) have revealed that males performed mental math with greater accuracy, possessed a stronger self-concept on mathematical performance, and demonstrated more success at solving complex mathematical problems. As mathematical calculations increase in complexity in middle school, the performance gap tends to widen (Jackson et al., 2013). Mathematical performance during middle school has been considered a strong predictor for future academic performance in mathematics making middle school a critical segment for female learners (Jackson et al., 2013).

Additionally, there is a gender gap in the use of DGBL with males more likely to engage in the use of digital games than females (Admiraal et al., 2014). While the use of DGBL may be beneficial to males and females for improving mathematical performance, males prefer the instructional design of the digital games more frequently than females. Males tend to be more engaged in games that are action based while girls tend to favor games that offer simulations or puzzles (Admiraal et al., 2014). Even when playing the same digital game, males and females may approach the game differently with males taking a more competitive approach while females engage more in active discovery (Admiraal et al., 2014). Furthermore, males tend to demonstrate more competitive traits to defeat opponents while females focus more on mastery of the content. There is also a higher incidence of males possessing prior knowledge of gaming that provides an advantageous start to DGBL (Admiraal et al., 2014). According to Jackson et al. (2013), visual graphics incorporated in software applications are utilized more commonly by males than females. In the study by Jackson et al. (2013), males scored lower than females on pretests, but there were no significant variations of the scores on the posttests between males and females resulting in males demonstrating higher gains in mathematics achievement when utilizing instructional technology. On the other hand, females demonstrated an elevated disposition to provide assistance to their peers reinforcing their mathematical skills while facilitating improved performance (Jackson et al., 2013).

Student-centered Classroom

The effective integration of instructional technology requires a shift in the classroom environment that reverses the role of the educator and the learner (Lim et al., 2013). In the traditional classroom, educators utilize conventional pedagogical practices that consist of teacher-led demonstration followed by an explanation of mathematical concepts. This teacher-centered approach should be replaced by active discovery where learners generate their own knowledge while using instructional technology (Chan & Leung, 2014). The function of the educator should be transformed from the primary source of instruction to an envoy that focuses students' attention to specific learning objectives (Lim et al., 2013).

The implementation of a student-centered classroom provides benefits beyond increased levels of learner engagement. The level of confidence of the learner increases in proportion to the amount of control the learner feels while completing a task according to Asmundis et al. (2015). By providing learners with autonomy over their instruction through assignment choice, time management, and project development, they may feel empowered fostering confidence and value while participating in the activity (Bohlman & Weinstein, 2013).

A student-centered classroom that integrates problem-based learning provides greater opportunity for self-regulated learning (Huang, Liu, & Chang, 2012). The learners may experience enhanced learning efficiency as they are provided technological tools to problem solve. An example of this student-centered approach is the use of diagnostic tests that provide instant feedback for self-correction. Since the feedback is provided to the learner immediately, the learner has an opportunity to utilize the formative assessment to make corrections during the course of the assignment allowing the learner to reduce the amount of cognitive load and take control of the program (Huang et al., 2012).

Digital Game-Based Learning Programs

Study Island was established in 2000 as a method to enhance performance on state testing through the use of engaging digital games that are individually aligned with specific state standards including the Mississippi state standards (Study Island, 2017). Published by Edmentum, Study Island offers individualized programs that may be accessed from any digital device allowing students to work on the program in other classrooms or at home. Students receive built-in remediation for incorrect responses and rewards for meeting the mastery level set by the teacher. Study Island's mathematics program provides a mini-lesson, content questions, and a game mode that provides DGBL (Study Island, 2017).

Calculation Nation is a collection of digital learning games offered by the National Council of Teachers of Mathematics (NCTM) as part of Illuminations that offers resources for teachers and parents that are aligned with the content standards established by the NCTM. The games provide students the opportunity to work independently or challenge other students in web-based mathematics games. Each game provides the learning objective, instructions, and information about the game (National Council of Teachers of Mathematics, 2017).

Math Playground offers games on a variety of mathematics objectives, and the games are sorted by topic, popularity, and grade level (Math Playground, 2017). The games offer competition against other players or against the computer. Math Playground also offers animated instructional videos that are indexed for easy selection. Created by Colleen King, Math Playground was developed in 2002 as a method to assist her math class when practicing mathematics facts. The games have expanded to included problem solving games, logic games, and real world scenarios (Math Playground, 2017).

Coolmath began as a website in 1997 to make learning mathematics more enjoyable (Coolmath.com, 2017). The site consists of three sections with Coolmath.com, Coolmath4kids.com, and Coolmath-games. Coolmath provides a reference section with a dictionary, math tips, puzzles, and a list of mathematics-related occupations (Coolmath.com, 2017). Coolmath.com offers four areas of mathematics lessons including pre-algebra, algebra, pre-calculus, and practice. Lessons are scaffolded based upon difficulty and provide immediate feedback. Coolmath-games offer a variety of formats with games sorted by strategy, skill, and popularity (Coolmath.com, 2017).

Sheppard Software began producing educational software in 1982 (Sheppard Software, 2017). The goal was to design activities to enhance learning through sounds and graphics that made learning more enjoyable and noteworthy (Sheppard Software, 2017). Additionally, Sheppard Software's purpose is to design games with various levels of difficulty to provide challenges for learners at all academic levels. Sheppard Software offers many math games that may be selected based upon the desired mathematical operation or by age groups (Sheppard Software, 2017).

Digital Game-Based Learning and Motivation

Motivation is a catalyst for learning, and in the absence of motivation, learners may not initiate the construction of knowledge (Katai et al., 2014). Instructional technology programs, such as DGBL, offer active learner involvement and progressive encounters to maintain engagement during the instructional process (Katai et al., 2014). Multiple studies have examined the connection between game-based learning and motivation (Jeng-Chung, 2014; Bilgin, Baek, & Park, 2015; Erickson, 2015). Motivation may be intrinsic where the learner participates in a task due to interest, or motivation may be extrinsic where the learner participates due to external forces related to the potential outcomes (Katai et al., 2014). Intrinsic motivation has been shown to increase the level of engagement learners contribute to the learning process (Katai et al., 2014). Research conducted by Proulx, Romero, and Arnab (2016) determined that DGBL fosters levels of autonomous motivation in learners when several factors are present including when the learner felt in control and when the learner felt competent. In the presence of teacher support that is deemed regulatory and intrusive, learners may perceive lessened autonomy and experience reduced intrinsic motivation (Proulx et al., 2016). Extrinsic motivating factors, including team competition and challenging tasks, also demonstrate success in fostering motivation in learners (Proulx et al., 2016). A balance between the level of intrinsic and extrinsic motivation may achieve the best result in increasing learner motivation and engagement within the appropriate setting (Proulx et al., 2016).

Advantages of DGBL

Technology has proliferated all aspects of research and business requiring that learners gain knowledge in the application of technology to solve real-world problems (Lim, et al., 2013). Understanding key technological concepts is essential to compete in the job market in the 21st century and should be integrated into primary and secondary school instruction (Katai et al., 2014). Frequently, technology provides learning opportunities that surpass traditional instructional methods through flexible instructional time, greater learner control over the instructional content, individualized pacing of instruction based upon the learner's needs, and availability of instruction outside the confines of the classroom (Kalyuga & Liu, 2015). The language utilized by instructional technology requires a precise syntax. Similar to formal language, instructional technology requires that the learners input specific words that may result in the acquisition of new language and improved language skills for the learners (Garrido, 2012).

According to previous research (Huang, Liu, & Chang, 2012), mathematical instruction administered employing instructional technology has resulted in improved learner achievement scores. For example, Jackson et al. (2013) performed a study where the learners in the experimental group utilizing instructional technology demonstrated greater achievement than the learners in the control group utilizing traditional mathematics instruction. During the Jackson et al. (2013) study, significant differences were only experienced in the males of the group with no significant variations in the female members (Jackson et al., 2013). Additionally, instructional technology promotes improved recall of mathematical facts that has been associated with higher success rates when challenged with advanced mathematics skills (Stickney, Sharp, & Kenyon, 2012). Through repetition, automaticity is developed as learners recall their mathematics facts. Automaticity may be achieved by utilizing a variety of software applications that are designed to provide the practice necessary to master mathematics facts and increase computational fluency (Stickney et al., 2012).

Digital games are often adaptive adjusting based upon the skill level of the player. Adaptability provides for ongoing adjustment based upon the continuous evaluation of the abilities of the learner. As a result, information is scaffolded providing activities that challenge the players based upon their proficiencies, and responses are monitored altering the playing level accordingly (Sampayo-Vargas et al., 2013). Subsequently, game adaptability minimizes redundant information and maximizes the instructional content and challenge of the game. For example, a player that is struggling with selecting the correct responses to a game may be an indication that the level of difficulty is too great. The adaptability feature should manage the level of challenge providing the players with greater opportunity to master the content (Sampayo-Vargas et al., 2013).

Other components of DGBL may be advantageous in the classroom through the contribution of engaging activities with little labor on the part of the teacher. In lieu of the teacher establishing learning activities that provide the gifted learner with a real-world simulation, DGBL manages many of these instructional tasks. Additionally, many of the games do not rely on the content knowledge of the teacher (Waddington, 2015). Another significant advantage of DGBL is the acceptance of several solutions to achieve a designated learning goal allowing multiple methods for learners to find the same solution (Chen et al., 2015). Furthermore, DGBL may optimize intrinsic motivation due to the incorporation of active involvement, progressive challenges, and scaffolded learning (Katai et al., 2014). Learners are allowed the opportunity to interact with the learning material building connections between what the learners know and what the learners do not know (Obergriesser & Stoeger, 2015).

DGBL and Assessment

Assessment is a critical component for measuring learner growth in the classroom. In the mathematics classroom, the use of technology as a reliable tool for assessment provides a popular advantage as an objective scoring method that has the capability to provide instant performance feedback (Pasztor et al., 2015). Assessments evaluated utilizing technology minimize scoring errors and provide educators with improved analysis of the achievement data. For example, educators can utilize technology to perform a statistical analysis on assessments to readily identify common misconceptions. Further benefits are that many of the technological programs provide results immediately upon completion of an assessment, and the struggle of reading illegible handwriting is eliminated (Pasztor et al., 2015). In spite of the advantages, there are also disadvantages to assessments that are administered using technology such as the lack of partial credit for multiple step questions that educators would generally provide credit for during manual scoring (Huang et al., 2012). Additionally, there are unfavorable reviews for many online assessments that limit the ability of the learners to think divergently. In either scenario, discrepancies exist between computer-scored assessments and manually scored assessments that should be acknowledged (Huang et al., 2012).

DGBL and Cognitive Load

Cognitive load refers to the ability of the brain to process information within the confines of the working memory (Kalyuga & Liu, 2015). Instructional technology requires that learners process greater amounts of information simultaneously increasing the cognitive load capacity.

According to Katai et al. (2014), a program that can engage more senses will be more effective than a program that may only engage one sense. This multi-sensory approach aligns with the Montessori Method that began in the early 1900s (Katai et al., 2014). The relationship between the stimulation of the senses and the increased ability to learn has revealed that the brain is organized to receive information from the different sensory systems providing the learner with a better concept of what is being taught. The multi-sensory learning approach is supported by information about neurons that are designed to fire when multiple senses are activated (Katai et al., 2014). As a result, utilizing a multi-sensory approach where more parts of the body are engaged is preferred over a traditional approach.

Benefits from the multi-sensory approach may be minimized or eliminated if the level of input becomes overwhelming (Kalyuga & Liu, 2015). Technological applications may tax the cognitive resources of the learner too heavily resulting in a negative impact on the learner's construction of knowledge. Kalyuga and Liu (2015) discussed the two significant areas of the brain that are involved in cognitive architecture, working memory and long-term memory. The working memory processes information while the long-term memory stores the schemas that are used to categorize information (Kalyuga & Liu, 2015). Information processed in the working memory becomes stored as knowledge in the long-term memory. Once stored, knowledge may be retrieved reducing the amount of information that must be processed by the working memory. Cognitive load refers to the information that is being processed in the working memory based upon prior knowledge of the learner (Kalyuga & Liu, 2015). If a task has a high level of interactivity, the learner may experience increased capacity for cognitive load resulting in minimal academic attainment. Cognitive load can be a factor in DGBL if the game becomes too complicated resulting in the learner losing sight of the academic objective of the game (Kalyuga

& Liu, 2015). For example, the learner may spend time deciphering how to manipulate the avatar resulting in the inability to focus on the objective of the game.

The application of digital devices and digital games in the classroom must consider the amount of cognitive load required by the activities. While the multimedia approach may employ multiple senses such as sight, touch, and hearing that provide the brain with a higher possibility of capturing and processing information into a useful capacity (Katai et al., 2014), the multimedia approach may also create navigation difficulties that overwhelm the learner resulting in negligible academic gains and learner frustration (Kalyuga & Liu, 2015). To decrease cognitive load, digital learning games may imbed learning strategies in the games such as concept mapping. Learning strategies have demonstrated a positive effect resulting in increased levels of learner motivation and correspondingly, increased academic attainment (Giannakas, Kambourakis, Papasalouos, & Gritzalis, 2017).

Challenges of DGBL

There are specific challenges that must be addressed to sustain successful results when utilizing instructional technology such as DGBL. Millions of dollars have been dedicated to the purchase of instructional technology in the schools, but many educators are not utilizing the equipment and the programs in the classrooms for their intended purpose (Reid, 2014). Some critics express concern that the incorporation of instructional technology will weaken traditional education, and there has been inadequate research to convince critics to abandon this view opposing the widespread implementation of instructional technology (Reeves & Oh, 2017). One challenging issue is that the adoption of instructional technology has not equated to the integration of instructional technology in the classroom for several potential reasons such as minimal faculty interest, ambiguous instructional goals, and indeterminate strategies (Reid, 2014). As a result, the presence of technology is not sufficient to ensure that student engagement with the subject matter will increase (Hilton, 2016). Educators administering DGBL must possess proficient knowledge of both the programs and the devices to aid in efficient utilization. Substantial training is required to understand the capacity of technological devices and software programs to perform complex operations and promote higher-level thinking skills (Hillman, 2014).

Another significant issue with the implementation of instructional technology in the classroom is the widening gap between the researcher and the classroom teacher (Musti-Rao et al., 2015). Technology designers often develop programs based upon their own pedagogical practices without customization options (Musti-Rao et al., 2015). As a result, educators are deprived of the ability to personalize the programs to fit their instruction. To ensure that the implementation of new digital devices achieves the intended purpose, software developers and school administrators must take responsibility for proper integration in the classroom (Musti-Rao et al., 2015). A key component of successful integration of technology is alignment with curriculum. Developing a consensus regarding the educational aims of specific grade levels requires that software developers collaborate with school personnel to determine the best method for connecting learners with the appropriate digital devices to meet those objectives (Jackson et al., 2013). By working together, software developers and administrators could monitor the implementation of instructional technology to ensure that the digital devices are utilized for their intended purpose (Hillman, 2014). However, efforts to diminish the gap between researchers and educators have been minimal with much of the research and design on instructional technology focusing on primary instruction that occurs in the place of the classroom teacher in lieu of supplementary instruction that supports the classroom teacher (Kinshuk, Huang, Sampson, & Chen, 2013). With the rapid progression of digital programming and devices, maintaining lines of communication between the developers and educators to facilitate the proper administration of instructional technology hinders the optimal application and integration in the classroom (Kinshuk et al., 2013). Furthermore, the latest available research findings may no longer be applicable due to the rapid development of software and the rate of advancements in the production of digital devices (Jackson et al., 2013). Likewise, the potential success of one digital device or software application may not be generalized to other applications or devices that appear similar in function even when produced by the same publisher (Fokides, 2018). As a result, research findings on a specific technological tool may not be inferred as applicable to another form of technology (Jackson et al., 2013). With the lack of appropriate research on classroom implementation, games utilizing multiple modes for presenting non-linear information and sophisticated navigation that requires the learner to process information concurrently may overwhelm the learner resulting in increased levels of frustration (Kalyuga & Liu, 2015).

Several other challenges have been identified during the integration of instructional technology in the classroom. According to a study by Sánchez-Mena, Martí-Parreño, & Aldás-Manzano (2017), teachers perceive ease of use of technology with effectiveness as an educational tool. On the contrary, a common problem is the burden instructional technology may place on the classroom teacher by adding to an already full list of duties. The teacher must often obtain the digital devices through means such as a laptop cart that must be charged prior to use with the digital devices appropriately loaded in the cart for charging purposes. Finally, they often must return the properly loaded cart after instruction (Reid, 2014). Hindering the process further, teachers cannot depend on the availability of the limited number of devices, and there is often paperwork that accompanies the use of the digital devices resulting in teachers debating if the extra work is worth the additional effort (Reid, 2014). Reliability of the devices is also an issue that adds to the workload of the teacher. With advancements in technology frequently surpassing the available training in the use of technological programs and devices, utilizing technology in the classroom is often deemed difficult and unreliable. Surveys of faculty members that utilize technology reported that once an educator makes an unsuccessful attempt to utilize a specific technology, they seldom attempt to use the same technology in the future (Reid, 2014).

Another significant challenge in the utilization of instructional technology in the classroom is that learners enter the classroom with varying levels of technological proficiency requiring that some undergo instruction in operating and manipulating the devices and the programs (Hillman, 2014). Due to limited time spent on one subject area in the classroom, learners may spend their instructional time focused on the digital device in lieu engaging with the mathematical concept (Hilton, 2016). Without appropriate guidance and helpful instruction, the frustration level of the learners may increase diminishing the efficiency of technological devices and programs such as DGBL. Gifted learners in particular may exhibit negative reactions when subjected to unfamiliar concepts that they are unable to govern (Ku et al., 2014). As a result, gifted learners may avoid participating in the task due to loss of self-confidence and the inability to perform the task successfully creating a withdrawal response from the learners (Ku et al., 2014). Gifted learners may become frustrated by differences in the input devices such as keypads or calculators that do not operate similar to familiar devices. Learners may be incapable of manipulating the program in congruence with their expectations creating heightened frustration levels that may have been alleviated by explicit instruction on the appropriate method for navigating the digital device (Ku et al., 2014). Additionally, introducing DGBL and other instructional technology using previously mastered concepts may provide the learners with increased fluency prior to attempting more complex tasks (Musti-Rao et al., 2015). Outcomes of DGBL may also be improved by frequent integration into classroom discussions and instruction because the repetition allows familiarity to enhance the ability of learners to manipulate software applications and digital devices (Jackson et al., 2013).

One of the principal challenges of integrating instructional technology in the classroom is unrealistic academic expectations that often accompany the new programs and devices. Instructional technology is not designed to overcome instructional deficiencies or replace sound instructional practices (Jackson et al., 2013). Administrators may incorporate instructional technology in the classroom to compensate for an incompetent teacher, or classroom teachers may employ instructional technology as a primary method of instruction. In either scenario, replacing the teacher is not the intended design for instructional technology (Jackson et al., 2013). Presenting another challenge, research on technology is generally completed in controlled environments measuring specific outcomes. Once the technology is integrated into an actual classroom, the results may vary depending on the climate of the classroom, the readiness of the learners, and the capability of the teacher (Hillman, 2014). When instructional technology lacks user-friendly capabilities, the likelihood of the technology being implemented incorrectly rises substantially voiding any alignment with the previous research-based results (Hillman, 2014). Another challenge is that some educators limit the capabilities of the instructional technology by failing to exert the required effort to ensure the technology is utilized in the intended method that the technology was designed to perform (Hillman, 2014). Due to the rate of advancement frequently surpassing the ability of educators to keep pace, software applications and digital devices may be implemented in the classroom prior to the establishment of appropriate supports hindering the maximization of achievement (Musti-Rao et al., 2015). To avoid common misconceptions regarding the integration of instructional technology in the classroom, the educator must be trained on the proficient use of specific digital tools to achieve an explicit academic objective (Lim et al., 2013).

Gaps in Literature

The amount of research on the impact of instructional technology on academic achievement has been insufficient to determine the effectiveness of technology when used in lieu of traditional teaching methods (Reeves & Oh, 2017). Furthermore, there are undetermined barriers that exist between technology adoption and integration into classroom instruction (Reid, 2014). Without identification of the obstacles that prevent educators from utilizing instructional technology in the classroom, the development of instructional goals and sound instructional strategies by administrators and researchers is difficult (Reid, 2014). Additional research may provide educators, administrators, and stakeholders improved direction for how technology should be integrated into the classroom.

Educators have expressed concerns regarding the limited research on specialized curricula for gifted learners (Callahan et al., 2015). Additionally, there has been minimal research on instructional tools and practices that may motivate gifted learners in the discipline of mathematics (Asmundis et al., 2015). Educating gifted learners requires specialized practices due to the demands encountered when establishing an educational environment that engages the learners in such a way to encourage optimal growth (Jong & Shang, 2015). Due to an inadequate number of research studies analyzing how the learning environment effects motivation and how DGBL impacts mathematical learning, educators may be unable to bridge the gap between gifted learners and their non-gifted counterparts to realize optimal mathematics achievement relative to learners' abilities (Lüftenegger et al., 2015). This gap is significant because when gifted learners continue to be underserved, enormous losses to society may result due to untapped potential (Gallagher, 2015).

Summary

Due to the pressures associated with high-stakes testing, many schools have shifted their efforts on learning outcomes in lieu of focusing on the most efficient methods for learning. As a result, the acquisition of knowledge at these schools may be limited and void of learner interaction prohibiting the expansion of knowledge beyond the prescribed minimum objectives (Asmundis et al., 2015). Conversely, the constructivist approach dictates that the acquisition of conceptual understanding is established through the active engagement of learners with the instructional content (Gilakjani et al., 2013). In accordance with this theory, learners must participate exhibiting behaviors that are aligned to achieve specific learning objectives (Ya-Hui Hsieh et al., 2015).

Additional research is necessary to provide more information for educational stakeholders on the effects of digital learning games for increasing learner outcomes. By measuring the impact of participation and collaboration during the utilization of DGBL on academic achievement and identifying the features of effective game designs, the results may influence how DGBL is perceived by educators and learners (Chen et al., 2015). Further research could aid in determining the effectiveness of DGBL including a methodical investigation and meta-analysis of DGBL and knowledge acquisition (Chen et al., 2015). The approaches for motivating gifted learners may be demanding because the procedures should offer engaging formats that inspire gifted learners by stimulating their interests to encourage academic growth (Jong & Shang, 2015). Additionally, instruction should utilize instruments that are specifically designed for educational objectives to maximize learning efficiency. The implementation of DGBL may offer educators an instructional tool that is capable of meeting the needs of gifted learners while promoting academic growth in the subject of mathematics (Asmundis et al., 2015).

CHAPTER THREE: METHODS

Overview

This quasi-experimental non-equivalent control group study was seeking to determine if the mathematics achievement of gifted learners utilizing DGBL for supplemental mathematics instruction would increase at a higher rate in comparison to gifted learners who did not utilize DGBL for supplemental mathematics instruction using the SGP from the STAR Math assessment. This methods chapter provides information about the study design, the research question and null hypotheses, the participants and setting, instruments, research procedures, and the data analysis.

Design

This study utilized a quasi-experimental non-equivalent control group design. This design was most appropriate because this study utilized a pretest and a posttest, and the research participants were randomly assigned to the treatment group or the control group (Gall, Gall, & Borg, 2007). The STAR Math assessment (Renaissance Learning, 2016) was the instrument that was utilized in the study to determine how the independent and dependent variables were related (Gall et al., 2007). The STAR Math assessment was given at the beginning and at the conclusion of the study, and the resulting SGP was utilized for the dependent variable. There was a manipulation of the independent variable, the use of DGBL, in this quasi-experimental study supporting the use of the non-equivalent control group design. This design allowed for the formation of research groups that accepts the clear interpretation of data to measure the dependent variable, levels of mathematics achievement (Gall et al., 2007). Support for this research design may also be established by multiple studies that have utilized this specific design (Husamah, 2015; Budiman, Halim, Meerah, & Osman, 2014; Tan & Tan, 2015).

The digital game programs utilized in this study include Study Island, Calculation Nation, Math Playground, Coolmath, and Sheppard Software. All programs are web-based, and Study Island is a subscription service. The Study Island software provides audit logs that report time on task and accuracy. Calculation Nation, Math Playground, Coolmath, and Sheppard Software were monitored by classroom teachers and students using paper charts with a column for tracking their time on task. Prior to the beginning of the study, the participants completed a pretest using the STAR Math assessment. The students assigned to the treatment group worked on DGBL programs for a minimum of 540 minutes over a nine-week period. The students assigned to the control group completed paper-based worksheets on similar mathematics objectives as the treatment group for a minimum of 540 minutes over a nine-week period. At the conclusion of the nine weeks, the treatment group and the control group were evaluated using a posttest on the STAR Math assessment. During the nine-week study, all students in the treatment group and the control group continued to receive standards-based mathematics instruction in the classroom setting.

Research Question

The research question for this study is**:**

RQ1: Is there a statistically significant difference between the mathematics student growth percentile scores of gifted learners who utilize digital game-based learning in comparison to gifted learners who do not utilize digital game-based learning?

Hypotheses

The null hypotheses for this study are:

$H_0$1: There is no significant difference between the mathematics student growth percentile scores of gifted students who utilize digital game-based learning in comparison to gifted students who do not utilize digital game-based learning as shown by the STAR Math assessment.

$H_0$2: There is no significant difference between the mathematics student growth percentile scores of male gifted students who utilize digital game-based learning in comparison to male gifted students who do not utilize digital game-based learning as shown by the STAR Math assessment.

$H_0$3: There is no significant difference between the mathematics student growth percentile scores of female gifted learners who utilize digital game-based learning in comparison to female gifted learners who do not utilize digital game-based learning as shown by the STAR Math assessment.

Participants and Setting

The population for this study consisted of gifted sixth grade students from two middle schools along the Mississippi Gulf Coast. A convenience sample was recruited by selecting study participants from a group of sixth grade middle school students located in southern Mississippi enrolled during the fall semester and the spring semester of the 2017-2018 school year. The two middle schools consist of a lower-to-middle socioeconomic levels with free and reduced lunch rates from 63.7% to 69% of the student population (National Center for Education Statistics, 2018). Enrollment rates in the schools range from 480 to 1060 students. The participants were chosen from students attending classes for the gifted and talented and enrolled in traditional mathematics classes. Participants were recruited by classroom teachers and encouraged using teacher-selected incentives such as school supplies and packaged edible treats. The teachers introduced the research during normal school hours and sent home informational letters up two weeks prior to commencement of study. After seven days of no response, the teachers sent reminder notices home with the students.

The number of participants in this study was 105, which surpassed the mandatory minimum for a medium effect size when conducting an independent-samples *t*-test (Gall et al., 2007). Within the schools, the participants were selected from students maintaining an individualized education plan (IEP) for giftedness while enrolled in mixed-ability classrooms that include gifted and non-gifted students. The gifted students attended gifted and talented classes that teach problem-solving skills and provide enriched instruction at an accelerated pace in a pullout program that removes the gifted students from the regular classroom for one class period daily or for one full school day per week. The gifted pullout program for one class period generally lasts for fifty-three minutes daily while the one-day per week program lasts for six to eight hours per day. In this study, 56 of the gifted students were placed in a treatment group that utilized DGBL for supplemental mathematics instruction, and 49 of the gifted students were placed in a control group that utilized paper-based activities for supplemental mathematics instruction.

The target population for this study consisted of students enrolled in two public middle schools. Central Middle School (pseudonym) and Eagle Middle School (pseudonym) are located within two adjacent coastal counties in the state of Mississippi. The targeted population was placed in groups and yielded 105 sixth grade gifted students ($n = 56$ females, $n = 49$ males). Participants ranged in age from 10 to 12 years with an ethnic composition of 87% European Americans, 9% African Americans, 3%, Asian Americans, and 1% Latinos/Latinas. Gall et al. (2007) state that the study population size must surpass the minimum of 100 participants to attain medium effect size that consists of a statistical power of 0.7 and a 0.05 alpha level.

Instrumentation

The instrument utilized for the pretest and the posttest in this study is the STAR Math assessment developed and revised by Renaissance Learning (2017). The purpose of this instrument is to provide educators with a reliable tool for measuring the mathematics ability of students to facilitate appropriate instructional placement, monitor student growth, and increase awareness of student performance including use as a predictor for student performance on state tests. The researcher received permission to utilize the STAR Math assessment as the instrument in the study (see Appendix D). Originally developed in 1998, the STAR Math assessment was produced as a result of the commercial success of the STAR Accelerated Reader program and was designed to enhance instructional practices by providing educators with the mathematical ability levels of their students (Renaissance Learning, 2011). The STAR Math assessment may be used as a tool for screening students in grades one through twelve to determine placement, for monitoring student progress, or for diagnostic purposes (Renaissance Learning, 2014). The development of the STAR Math assessment enlisted the contributions of professional designers and editors with backgrounds in education and expertise in the specific content areas. The assessment items follow rigid specifications for item development and strict review processes including checks for accuracy, readability, and fairness (Renaissance Learning, 2014).

The STAR Math assessment was administered at the beginning and at the conclusion of this study and is designed for administration in repeated increments with frequency not impacting the results of the assessment. The STAR Math assessment is computer-adaptive dynamically adjusting along a scale based upon the responses of the students preventing the use of Cronbach’s alpha. As students choose a correct response, the next question increases in difficulty. When an incorrect response is given, the subsequent question will be less difficult.

As a result, the Math STAR assessment is able to provide the achievement levels of students with efficiency. Renaissance Learning (2014) provides estimations derived from calculations utilizing a split-half method and generic reliability based upon the norms from a sample size of 29,228 students. The overall sample yielded a reliability rating of 0.94 using the split-half method (Renaissance Learning, 2014). Alternate forms of reliability were conducted utilizing 7,517 students, and the overall sample yielded an estimated alternate forms reliability of 0.91 (Renaissance Learning, 2014). In accordance with Gall et al. (2007), the STAR Math assessment's reliability ratings exceed 0.90 deeming the assessment as highly reliable. Validity of the STAR Math assessment was established based on the information provided from Renaissance Learning (2014). According to Gall et al. (2007), validity is the extent that research controls the extraneous variables preventing those variables from impacting the results. Correlation estimates comparing how students performed on the STAR Math assessment to more than 30 commonly administered standardized tests in various geographic regions were performed including more than 10,000 students. The results of the administrations support the validity of the STAR Math assessment (Renaissance Learning, 2014). The summary reveals that 13 studies have published predictive validity for the STAR Math assessment. These studies included 27,663 students in the sixth grade. The average correlation for these studies was 0.73 for predictive validity for sixth grade STAR Math scale scores (Renaissance Learning, 2014). Concurrent validity for the STAR Math assessment included 27 studies with 4,202 sixth grade students participating in the studies. The average correlation for concurrent validity was 0.66 for sixth grade STAR Math scale scores (Renaissance Learning, 2014). Published data on the reliability and validity of the STAR Math assessment is available through the National Center on Response to Intervention where the assessment has received high ratings.

Renaissance Learning (2015) provides several norm-referenced scores to represent student performance on the STAR Math assessment. The participating teachers administered the STAR Math assessments in the students' classrooms at the introduction and at the conclusion of the study. The STAR Math assessment was administered on classroom computers and required approximately twenty minutes of class time. See Appendix E for administration instructions. The scores are used to provide a snapshot of student achievement at the time of the assessment. The SGP is utilized in this study and quantifies the individual growth of the students as calculated by the Renaissance Learning STAR Math program. Developed by Betebenner, the SGPs are determined using estimates of conditional density from students' present assessment scores with students' previous assessment scores (Betebenner, 2011). Conditional density estimation is accomplished by employing quantile regression. As a result, the SGPs are reflective of the probability of score outcomes based upon previous scores. The SGPs are norm-referenced scores indicating individual growth by comparing scores from assessment dates falling within two separate testing windows. The range of scores for the SGP is from 1 to 99 with higher numbers indicating higher rates of student growth from one test administration to the next test administration. The determination of the level of growth is the result of external factors such as state performance standards (Betebenner, 2011). For this study, participants used the same pseudonym throughout the study providing STAR Math the ability to monitor student growth from the pretest to the posttest and generate individual SGP scores.

Additional scores provided by the STAR Math assessment include a scaled score that provides longitudinal data for the individual student, a percentile rank that provides a national comparison of students, a normal curve equivalent that utilizes comparisons to other achievement tests for gathering research data, and a grade equivalent that compares the performance of students within the same region. The STAR Math assessment also provides a grade placement ranging from 00 to 0.9 representing the months September through June and the math instructional level that provides the current level of instruction that should be provided by the educator for the individual student.

The STAR Math assessment consists of 34 questions in a multiple-choice format with each question having a 90 second time limit. The average time for 75% of students is less than 15 minutes (Renaissance Learning, 2016). The STAR Math assessment has been utilized as an instrument in numerous studies (Shapiro, Dennis, & Fu, 2015; Monpas-Huber, 2015; U.S. Department of Education Center on Intensive Instruction, 2016). The STAR Math assessment is an appropriate instrument for this study and has been deemed both reliable and valid for assessing the achievement levels of gifted learners.

Procedures

Prior to collecting data, the researcher obtained permission from the Institutional Review Board (IRB) at Liberty University and conformed to the ethical guidelines published by the IRB at Liberty University (2015). The permission letter from Liberty University IRB is included in Appendix A. Additionally, permission was obtained from the participating school district administrations followed by permission from the administration at the individual schools. Permission letters from the participating school districts are included in Appendix E and Appendix F. After securing district and school permission, participation was elicited from the teachers at the participating schools by organizing meetings with 6th grade mathematics and gifted teachers. Teachers were provided information regarding the potential benefits of the study including additional achievement data, supplemental instruction that is aligned with state standards, and incentives designed to increase student motivation. Students were recruited by the participating teachers through classroom discussion introducing the purpose and benefits of the study and the potential for earning incentives. Since the participants were minors, written permission was sought from the students through assent forms and from their parents or guardians through parent/guardian consent forms. See Appendix C for the assent form for minors and Appendix B for the parent/guardian permission forms. The assent and consent forms were distributed and collected by the teachers.

Prior to commencement of the study, training of facilitating teachers was conducted followed by a question and answer session. The training and information sessions were held at the individual schools on a teacher workday. During the training, teachers were informed of the purpose of the study, instructions on how to administer the STAR Math assessment, instructions for the administration of digital learning games such as Study Island, Calculation Nation, Math Playground, Coolmath, and Sheppard Software programs, provided student login instructions, and provided the estimated time for the completion of the individual components for the treatment group and the control group. The researcher registered participants into the STAR Math program using pseudonyms. The researcher assigned the pretest and the posttest in the STAR Math program and provided teachers with participant login cards with appropriate passcodes to allow students to sign in and complete the assessments. Participants maintained the same pseudonym and login information for the duration of the study. The STAR Math program electronically scored the pretests and posttests resulting in no scoring requirements for the teachers. Since the participants utilized the same login codes for both the pretest and the posttest, the STAR Math assessment could track the scores of the individual participants and generate the SGP by comparing pretest and posttest scores. Data for participants who did not complete both the pretest and the posttest were omitted. Additionally, progress reports were checked to ensure that any participants who did not complete a minimum of 540 minutes of supplemental mathematics activities between the pretest and the posttest were omitted.

The SGP scores were accessed through the STAR Math program and manually recorded in an Excel spreadsheet by the researcher. The researcher confirmed that all data were transferred accurately by comparing the data in the Excel spreadsheet with the original data from the STAR Math Growth Report. Data in the Excel spreadsheet were checked to confirm that pseudonyms were placed correctly in the designated control group or treatment group. Additionally, the data was checked for duplicate pseudonyms and blank fields.

All students were assigned a pseudonym, and the demographic information included the sex of the student. The data from the pretest and the posttest generated the SGP that was analyzed using SPSS statistical software. The results of the analysis are stored electronically using the Excel spreadsheet program, and spreadsheet access is password protected.

Data were collected from two middle schools in two different school districts beginning in the sixth week of the third academic term. The data were collected from a pretest utilizing the STAR Math assessment that was administered at the beginning of the study and from a posttest utilizing the STAR Math assessment that was administered at the conclusion of the study during the sixth week of the fourth academic term. Both the treatment group and the control group received traditional mathematics instruction throughout the course of the study. Students were assigned randomly to the treatment group or the control group using a lottery system. Participating teachers assigned pseudonyms by drawing cards with each card containing a letter and a number. The letter represents the school and the number represents the individual student. For example, the teacher may have drawn a card with E14 written on one side. The E represents all students at the specific middle school, and the 14 represents the specific student. The teachers recorded the identifying letters and numbers on a chart next to the students' names. The teachers secured the identifying participant charts in locked filing cabinets in their rooms. Students with early numbers on their card were assigned to the treatment group. Students with later numbers on their card were assigned to the control group. Of the 105 gifted participants who completed the study, 56 were assigned to the treatment group, and 49 were assigned to the control group. All participants logged into the STAR Math assessment by utilizing their identifying letter and number as their login and were provided a common password by the facilitating teachers. The participants completed the pretest using the STAR Math assessment. The treatment group spent a minimum of 540 minutes over the course of nine weeks completing DGBL programs such as Study Island, Calculation Nation, Math Playground, Coolmath, and Sheppard Software. The control group spent a minimum of 540 minutes over nine weeks completing mathematics activities from supplemental mathematics worksheets. Participants recorded their selected activities and the time spent on the activities on weekly progress reports that included their letter and number for identification purposes. At the completion of the study, the participants logged in and completed the STAR Math assessment utilizing their identifying letter and number and a common password provided by the facilitating teacher. The STAR Math assessment calculated the SGP by comparing the rate of change from the pretest and posttest scores of the participants into percentile scores to evaluate individual growth. For example, a participant assigned E15 would input E15 to log in for the pretest and for the subsequent posttest. As a result, the STAR Math assessment could compare the pretest and posttest score for each participant to determine the SGP.

Data Analysis

Independent-samples *t*-tests were performed to determine if a statistical difference existed between the students' mathematics growth in the treatment group and the control group as measured by the SGP of the STAR Math posttest assessment. The SGP of the STAR Math assessment ranges from 1 to 99 with higher scores indicating greater student growth (Renaissance Learning, 2016). The independent-samples *t*-test is appropriate since the study was seeking to determine whether the variations of the mean scores of the SGP between separate groups for mathematics growth were statistically significant (Gall et al., 2007). Furthermore, the participants were drawn randomly for placement in the treatment group or in the control group supporting the use of the independent-samples *t*-test (Gall, et al., 2007). The independent-samples *t*-test was employed to determine if there are any differences in means for the outcome variable, student growth in mathematics (Warner, 2013). Three separate analyses were performed. The first analysis was performed utilizing the independent-samples *t*-test to test H_01 to determine if any statistical significance exists in mathematical growth between gifted learners who utilize DGBL and gifted learners who do not utilize DGBL as measured by the SGP of the STAR Math assessment. A second analysis was performed using the independent-samples *t*-test to test H_02 to determine if any statistical significance exists in mathematical growth between gifted male learners who utilize DGBL and gifted male learners who do not utilize DGBL as measured by the SGP of the STAR Math assessment. A third analysis was performed utilizing the independent-samples *t*-test to test H_03 to determine if any statistical significance exists in mathematical growth between gifted female learners who utilize DGBL and gifted female learners who do not utilize DGBL as measured by the SGP of the STAR Math assessment. The

STAR Math assessment data were generated electronically by the STAR Math assessment. The researcher transcribed the information into SPSS.

The target population for this study consisted of students enrolled in two public middle schools located within two adjacent coastal counties in the state of Mississippi. Participants consisted of males and females ranging in age from 10 to 12 years with an ethnic composition of 87% European Americans, 9% African Americans, 3%, Asian Americans, and 1% Latinos/Latinas. The participants have an IEP in place for giftedness on file with their school districts. Gifted student participants were randomly assigned to the treatment group (n = 56) or the control group (n = 49). In accordance with Gall et al. (2007), a minimum of 105 participants were utilized in this study to conduct an independent-samples *t*-test with a medium effect size that consists of a statistical power of 0.7 and a 0.05 alpha level. Additionally, the data were examined to ensure that the outcomes had a range between a minimum score of one and a maximum score of 99.

For each of the groups, the data were screened for inconsistencies using a box and whisker plot to detect the presence of outliers and analyze the data distribution. The dependent variable, SGP scores, was measured on equal intervals. The observations between the variables were independent. Random sampling was used to ensure that the participants are reflective of the population and have equal opportunity to participate in either the control group or the treatment group. The sample size is greater than 50 allowing for normality to be assessed through the utilization of the Kolmogorov-Smirnov test to determine if the *p*-value is greater than 0.05 indicating a normal distribution and the likelihood of the results generalizing to the remaining population of sixth grade gifted learners (Warner, 2013). A Levene's Test for Equality of Variance was conducted to determine the homogeneity of variance. If the Levene's

Test for Equality of Variance is statistically significant, a violation of the variance assumption will result in rejection of the null hypothesis. If the Levene's Test is not statistically significant, there will be no rejection of the null hypothesis and the assumption of equal variance will be considered tenable (Warner, 2013).

The independent-samples *t*-test is appropriate for this study since the dependent variable, SGP scores, is measured using an equal interval scale, and the independent variable, use of DGBL programs, is categorical with participants belonging to the treatment group or the control group and coded as male or female (Warner, 2013). First, the independent-samples *t*-test was conducted to determine if there is a statistically significant difference between the mathematics growth of gifted learners who utilized DGBL to the mathematics growth of gifted learners who did not use DGBL as measured by the SGP of the STAR Math assessment. Second, an independent-samples *t*-test was conducted to determine if there is a significant difference between the mathematics growth of male gifted learners who utilized DGBL in comparison to male gifted learners who did not utilize DGBL as measured by the SGP of the STAR Math assessment. Third, an independent-samples *t*-test was conducted to determine if there is a significant difference between the mathematics growth of female gifted learners who utilized DGBL in comparison to female gifted learners who did not utilize DGBL as measured by the SGP of the STAR Math assessment. To determine effect sizes, Eta squared was used, and Cohen's *d* was used for differences between means (Warner, 2013).

Descriptive statistics were calculated and reported including the mean (*M*) and the standard deviation (*SD*) for each of the data sets. The test values for the three null hypotheses include the number (*N*), number per cell (*n*), degrees of freedom (*df*), t value (*t*), and the significance level (*p*) including the effect size.

CHAPTER FOUR: FINDINGS

Overview

This study was conducted to determine whether there is a statistically significant difference in the SGP of gifted learners when utilizing DGBL for supplemental mathematics instruction in comparison to the SGP of gifted learners when not utilizing DGBL for supplemental mathematics instruction. The independent variable is the utilization of DGBL programs including Calculation Nation, Illuminations, Math Playground, Coolmath, and Sheppard Software in the treatment group. The dependent variable is the mathematics SGP cores achieved on the STAR Math assessment by the participants at the conclusion of the study. This chapter provides the results of the data analysis as relating to the research question followed by the null hypotheses.

Research Question

RQ1: Is there a statistically significant difference between the mathematics student growth percentile scores of gifted learners who utilize digital game-based learning in comparison to gifted learners who do not utilize digital game-based learning?

Hypotheses

$H_0$1: There is no significant difference between the mathematics student growth percentile scores of gifted students who utilize digital game-based learning in comparison to gifted students who do not utilize digital game-based learning as shown by the STAR Math assessment.

$H_0$2: There is no significant difference between the mathematics student growth percentile scores of male gifted students who utilize digital game-based learning in comparison to male gifted students who do not utilize digital game-based learning as shown by the STAR Math assessment.

$H_0$3: There is no significant difference between the mathematics student growth percentile scores of female gifted learners who utilize digital game-based learning in comparison to female gifted learners who do not utilize digital game-based learning as shown by the STAR Math assessment.

Descriptive Statistics

For the purposes of this study, data were collected from 105 gifted students. All of the students were enrolled in sixth grade in public middle schools in Southeast Mississippi and had IEPs in place with their school districts for giftedness. Of the 105 students completing the study, 56 were enrolled in the treatment group utilizing DGBL, and 49 were enrolled in the control group who did not utilize DGBL. The participants in the treatment group and the control group completed a pretest, spent 540 minutes on supplemental mathematics activities over a nine-week period, and completed a posttest. The significance of the pretest and posttest was to measure the learners' SGP in mathematics over the nine-week period. The Renaissance Learning STAR Math assessment generated the SGP by measuring differences between pretest scores and posttest scores based upon the individual performances by the participants. Participants utilized their individually assigned pseudonyms to log in to the STAR Math assessment for both the pretest and the posttest allowing the STAR Math assessment to track participants and generate individual SGPs. For this study, the participants were drawn from two middle schools and are assumed to represent the remaining gifted population. The participants' responses were independent of one another with completion of one student's work not impacting another student's work. The SGP scores of the participants in the DGBL treatment group were assumed to be independent of the SGP scores of the participants in the non-DGBL group.

The treatment group utilizing DGBL had a mean SGP score of 56.16 while the control group that did not utilize DGBL had a mean SGP score of 61.22. The standard deviation in the SGP for the treatment group was 30.124, and the standard deviation for the SGP for the control group was 29.059. See Table 1 for descriptive statistics. The overall score of the SGP for the participants in the control group was higher (5.06) than overall score of the SGP for the participants in the treatment group. The males utilizing DGBL had a mean SGP score of 57.00 while the males who did not utilize DGBL had a mean SGP score of 70.71. The standard deviation in the SGP for the males in the treatment group was 25.137, and the standard deviation for the SGP for males in the control group was 21.282. The overall score of the SGP for the male participants in the control group was higher (13.71) than the overall score of the SGP for the male participants in the treatment group. The females utilizing DGBL had a mean SGP score of 55.32 while the females who did not utilize DGBL had a mean SGP score of 54.11. The standard deviation in the SGP for the females in the treatment group was 34.860, and the standard deviation for the SGP for the females in the control group was 32.298. The overall score of the SGP for the female participants in the control group was higher (5.06) than overall score of the SGP for the female participants in the treatment group.

Table 1

Descriptive Statistics for the DGBL Groups and Non-DGBL Groups

Group		*N*	Mean	Std. Deviation	Std. Error Mean
DGBL		56	56.16	30.124	4.025
	MALE	28	57.00	25.137	4.750
	FEMALE	28	55.32	34.860	6.588
NON-DGBL		49	61.22	29.059	4.151
	MALE	21	70.71	21.282	4.644
	FEMALE	28	54.11	32.298	6.104

Results

Assumptions Tests

For all three null hypotheses, assumption tests of normality were performed to determine if the data were normally distributed for the treatment group and the control group. The Kolmogorov-Smirnov test was used for each hypothesis, and results are indicated in Table 2. For all three hypotheses, the DGBL group findings were not significant ($p > .05$), but the non-DGBL groups had significant results violating the assumption of normality. The researcher continued to assess normality using Q-Q plots that provided a visual description of the results.

Table 2

Kolmogorov-Smirnov Test for Normality for DGBL and Non-DGBL

	Kolmogorov-Smirnov		
	Statistic	df	Sig.
DGBL	.111	56	.083
MALE	.112	28	.200
FEMALE	.159	28	.068
NON-DGBL	.141	49	.017
MALE	.194	21	.037
FEMALE	.165	28	.046

Null Hypothesis One

$H_0$1: There is no significant difference between the mathematics student growth percentile scores of gifted students who utilize digital game-based learning in comparison to gifted students who do not utilize digital game-based learning as shown by the STAR Math assessment.

To compare the distribution of the data for the 105 gifted students participating in the study, Q-Q plots were used. Based upon a visual assessment of the Q-Q plots, the SGP scores were approximately normally distributed satisfying the condition of normality to perform the independent-samples *t*-test. See Figure 1 shows the Q-Q plot for the DGBL treatment group and Figure 2 shows the Q-Q plot for the non-DGBL control group. Data screening revealed no errors or inconsistencies for the dependent variable, SGP, for the DGBL group or the non-DGBL group. Inspection of box and whiskers plots revealed no outliers in the data for the dependent variable, SGP scores. See Figure 3 for box and whisker plots.

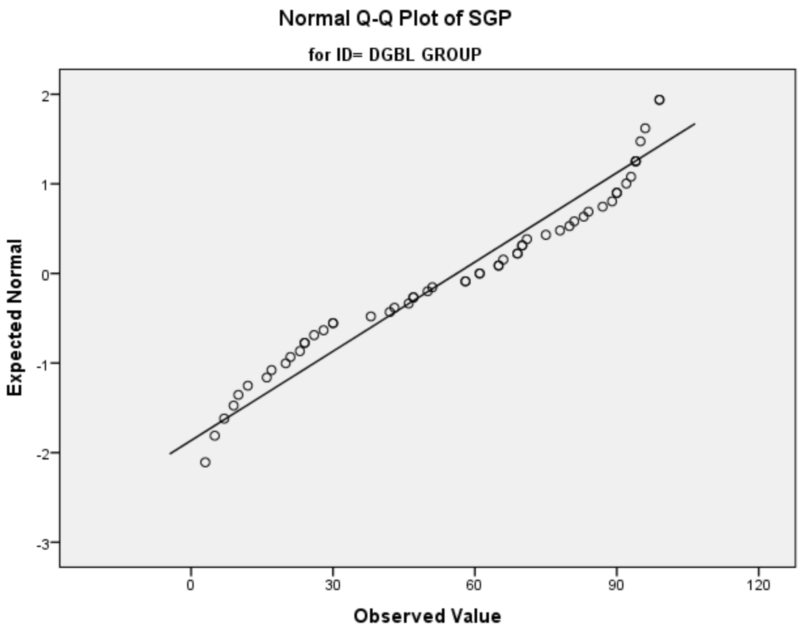

Figure 1. DGBL group Q-Q plot.

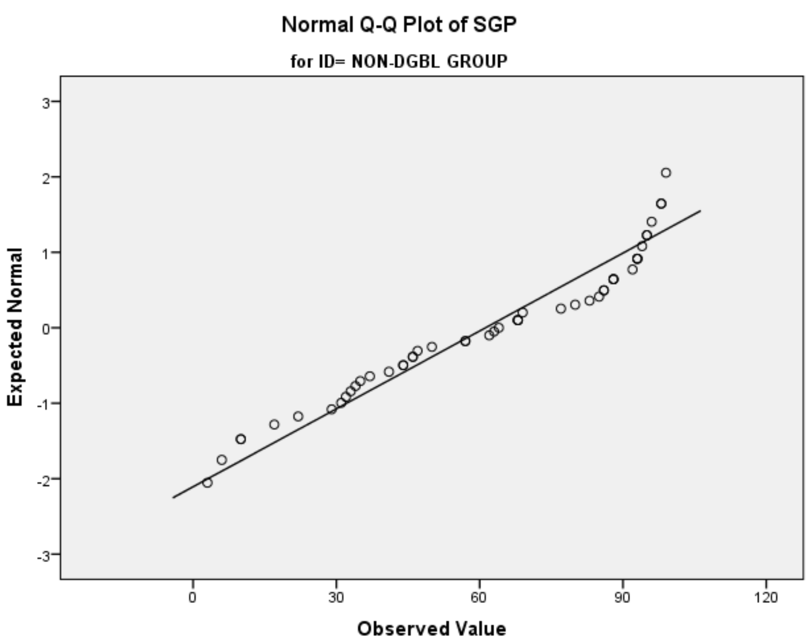

Figure 2. Non-DGBL group Q-Q plot.

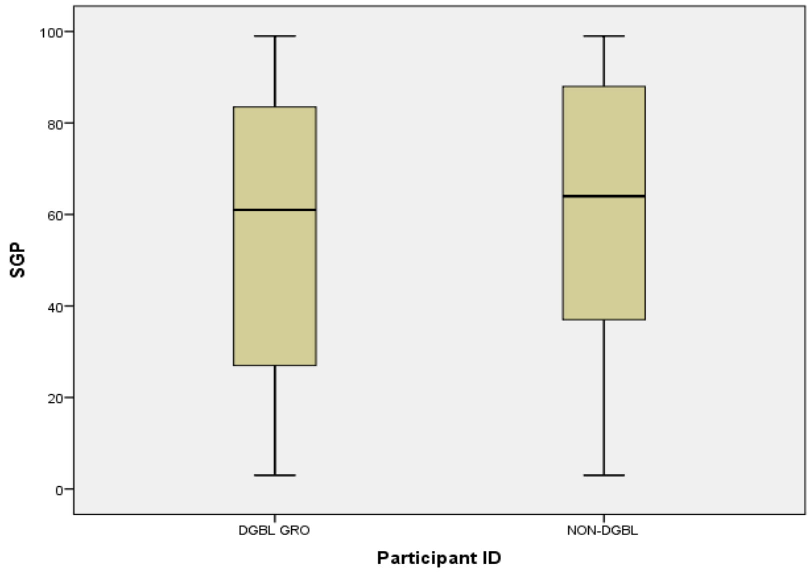

Figure 3. Box and whisker plots.

A Levene's test of equality was performed to evaluate the assumption of equality of variance between the DGBL treatment group and the non-DGBL control group. The Levene's test for the first null hypothesis indicated equal variances, $F = 0.159$, $p = .691$. Since the Levene's Test is not statistically significant, there is no rejection of the null hypothesis and the assumption of equal variance is considered tenable (Warner, 2013). The results of the Levene's test for the first null hypothesis are shown in Table 4.

An independent-samples *t*-test was performed to determine if there is a statistically significant difference between the means of the SGP scores for the DGBL treatment group and the non-DGBL control group. The results of the independent-samples *t*-test are indicated in Table 4. Examination of the means of the SGP scores for the DGBL group ($M = 56.16$, $SD = 30.124$) and the non-DGBL group ($M = 61.22$, SD = 29.059) revealed no significant differences ($p = .384$). Since there was no significant difference in the means of the SGP scores between the DGBL group and the non-DGBL group, the researcher failed to reject first null hypothesis.

Further, the Cohen's effect size (*d* = 0.171) indicated a small effect size. See Table 3 for descriptive statistics for the DGBL group and the non-DGBL group.

Table 3

Descriptive Statistics for the DGBL Group and Non-DGBL Group

Group	*N*	Mean	Std. Deviation	Std. Error Mean
DGBL	56	56.16	30.124	4.025
NON-DGBL	49	61.22	29.059	4.151

Table 4

Independent-Samples Test DGBL Group and Non-DGBL Group

	Levene's Test		*t*-test for Equality of Means						
								95% Confidence Interval of the Difference	
Equal Variances Assumed?	*F*	Sig.	*t*	*df*	Sig. (2-tailed)	Mean Difference	Std, Error Difference	Lower	Upper
Yes	.159	.691	-.874	103	.384	-5.064	5.797	-16.560	6.432
No			-.876	102.001	.383	-5.064	5.783	-16.533	6.406

Null Hypothesis Two

$H_0$2: There is no significant difference between the mathematics student growth percentile scores of male gifted students who utilize digital game-based learning in comparison to male gifted students who do not utilize digital game-based learning as shown by the STAR Math assessment.

Q-Q plots were used to compare the distribution of data for the 49 male gifted students participating in the study. Based upon a visual assessment of the Q-Q plots, the SGP scores were approximately normally distributed satisfying the condition of normality to perform the independent-samples *t*-test. See Figure 4 for the Q-Q plot for males in the DGBL treatment group and Figure 5 for the Q-Q plot for males in the non-DGBL control group. Data screening revealed no errors or inconsistencies for the dependent variable, SGP, for the males in the DGBL group or the males in the non-DGBL group. Inspection of box and whiskers plots revealed no outliers in the data for the dependent variable, SGP scores. See Figure 6 for box and whisker plots.

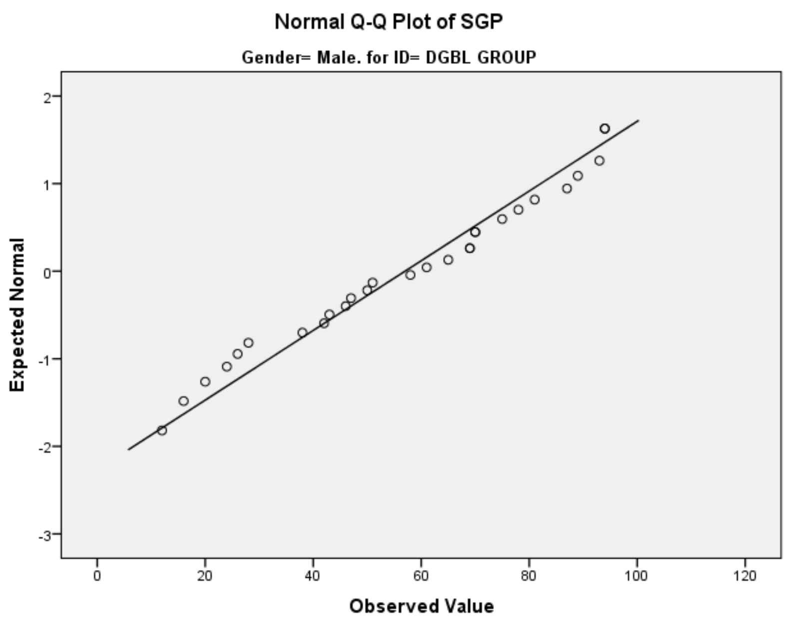

Figure 4. Male DGBL Q-Q plot.

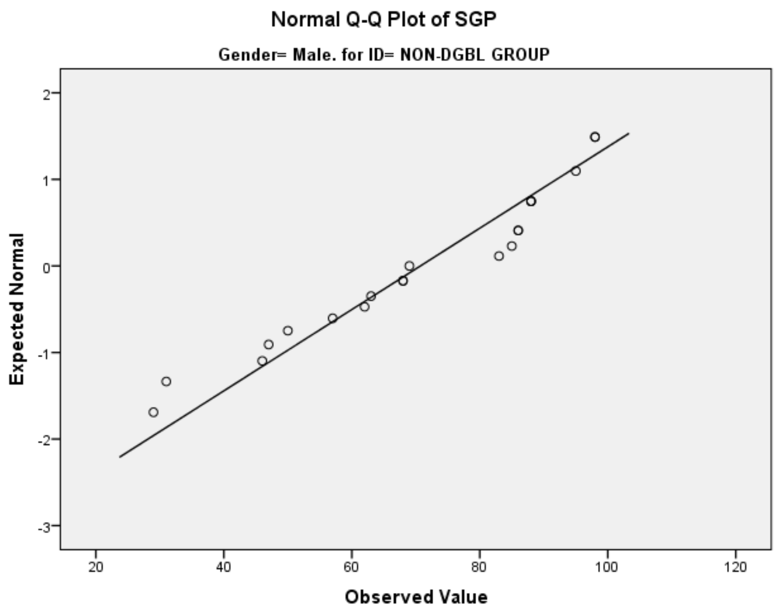

Figure 5. Male non-DGBL Q-Q plot.

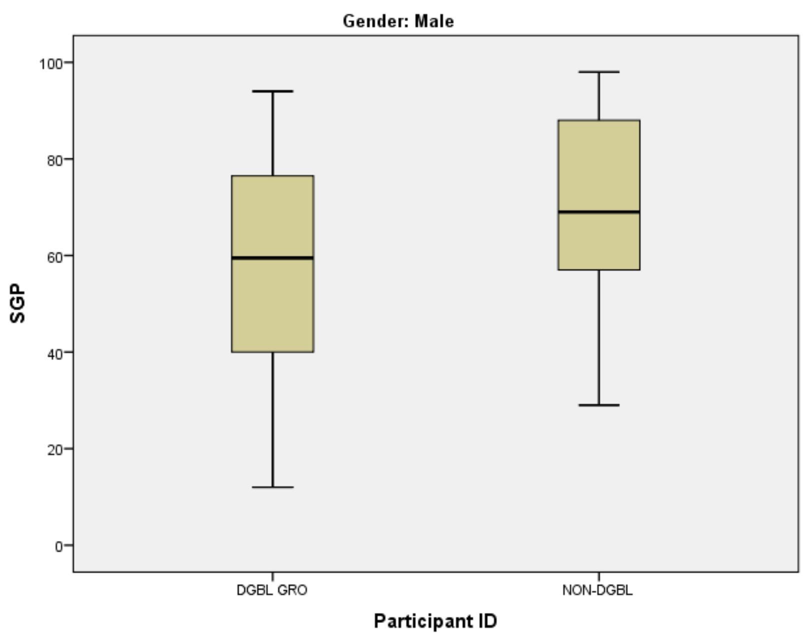

Figure 6. Box and whisker plots.

A Levene's test of equality was performed to evaluate the assumption of equality of variance between the males in the DGBL treatment group and the males in the non-DGBL control group. The Levene's test for the second null hypothesis indicated equal variances, *F* =

0.969, p = .330. Since the Levene's Test is not statistically significant, there is no rejection of the null hypothesis and the assumption of equal variance is considered tenable (Warner, 2013). The results of the Levene's test for the second null hypothesis are shown in Table 6.

An independent-samples *t*-test was performed to determine if there is a statistically significant difference between the means of the SGP scores for males in the DGBL treatment group and the males in the non-DGBL control group. The results of the independent-samples *t*-test for males are indicated in Table 6. The analysis did not demonstrate a significant difference (p = .05) in the SGP scores for the males in the DGBL group (M = 57.00, SD = 25.137) and the males in the non-DGBL group (M = 70.71, SD = 21.282). Since there was no significant difference in the means of the SGP scores between the males in the DGBL group and the males in the non-DGBL group, the researcher failed to reject second null hypothesis. Further, the Cohen's effect size (d = 0.589) indicated a small effect size. See Table 5 for descriptive statistics for the male DGBL group and the male non-DGBL group.

Table 5

Descriptive Statistics for the Male DGBL Group and Male Non-DGBL Group

Group	*N*	Mean	Std. Deviation	Std. Error Mean
MALE DGBL	28	57.00	25.137	4.750
MALE NON-DGBL	21	70.71	21.282	4.644

Table 6

Independent-Samples Test Male DGBL Group and Male Non-DGBL Group

	Levene's Test		*t*-test for Equality of Means						
								95% Confidence Interval of the Difference	
Equal Variances Assumed?	*F*	Sig.	*t*	*df*	Sig. (2-tailed)	Mean Difference	Std, Error Difference	Lower	Upper
Yes	.969	.330	-.874	47	.050	-13.714	6.805	-27.404	-.024
No			-.876	46.246	.045	-13.714	6.643	-27.085	-.344

Null Hypothesis Three

$H_0$3: There is no significant difference between the mathematics student growth percentile scores of female gifted learners who utilize digital game-based learning in comparison to female gifted learners who do not utilize digital game-based learning as shown by the STAR Math assessment.

Q-Q plots were used to compare the distribution of the data for the 56 female gifted students participating in the study. Based upon a visual assessment of the Q-Q plots, the SGP scores were approximately normally distributed satisfying the condition of normality to perform the independent-samples *t*-test. See Figure 7 for the Q-Q plot for the females in the DGBL treatment group and Figure 8 for the Q-Q plot for the females in the non-DGBL control group. Data screening revealed no errors or inconsistencies on the dependent variable, SGP, for the females in the DGBL group or the females in the non-DGBL group. Inspection of box and whiskers plots revealed no outliers in the data for the dependent variable, SGP scores. See Figure 9 for box and whisker plots.

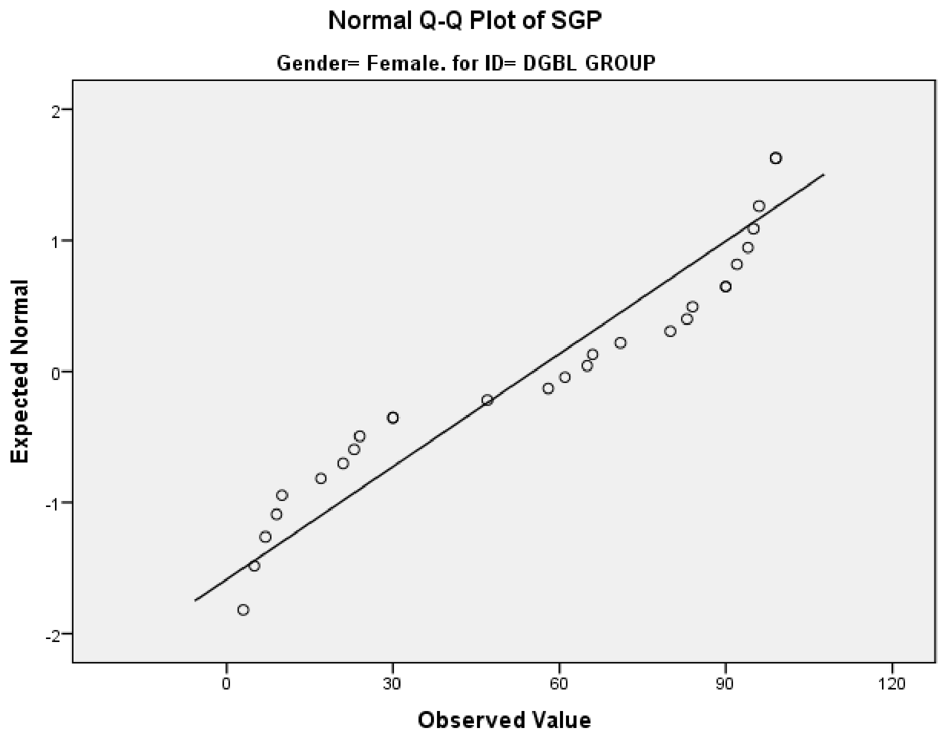

Figure 7. Female DGBL Q-Q plot.

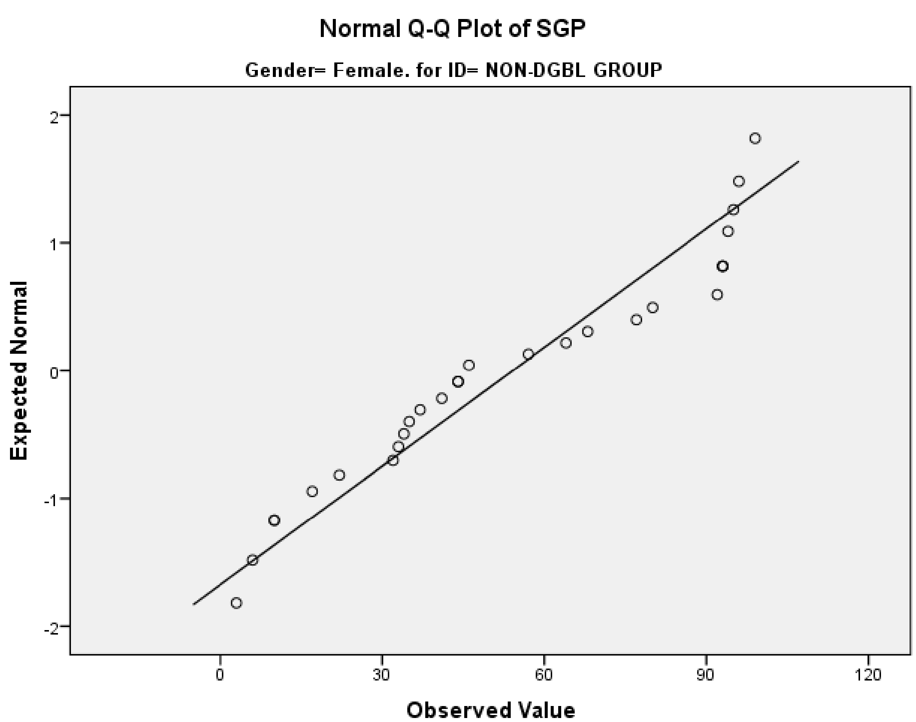

Figure 8. Female Non-DGBL Q-Q plot.

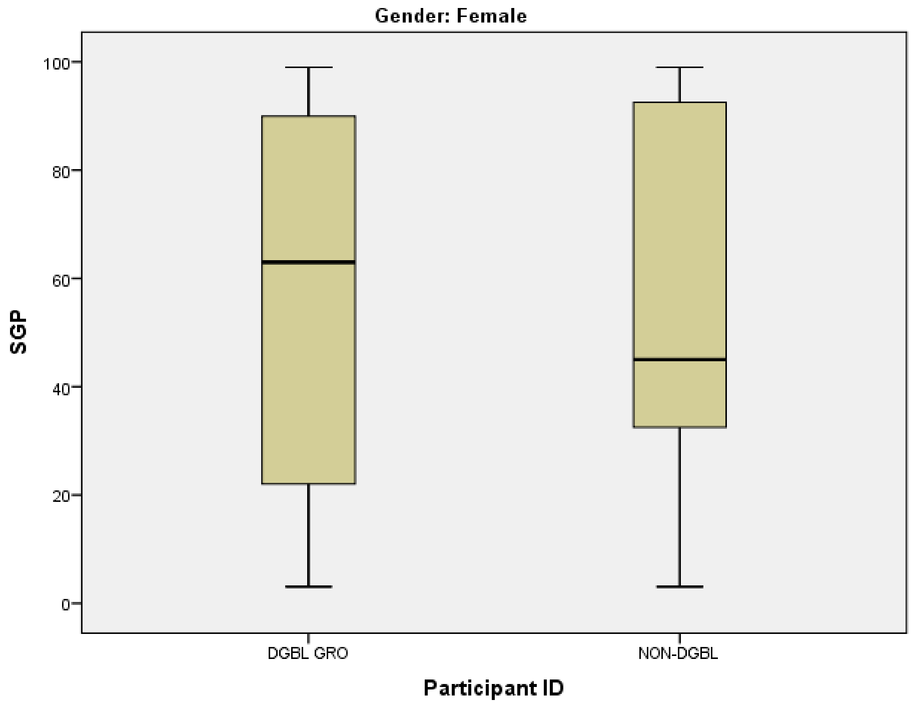

Figure 9. Box and whisker plots.

A Levene's test of equality was performed to evaluate the assumption of equality of variance between the females in the DGBL treatment group and the females in the non-DGBL control group. The Levene's test for third null hypothesis indicated equal variances, $F = 0.568$, $p = .454$. Since the Levene's Test is not statistically significant, there is no rejection of the null hypothesis and the assumption of equal variance is considered tenable (Warner, 2013). The results of the Levene's test for the third null hypothesis are shown in Table 8.

An independent-samples *t*-test was performed to determine if there is a statistically significant difference between the means of the SGP scores for the females in the DGBL treatment group and the females in the non-DGBL control group. The results of the independent-samples *t*-test for females are indicated in Table 8. The analysis did not demonstrate a significant difference ($p = .893$) in the means of the SGP scores for the females in the DGBL group ($M = 55.32$, $SD = 34.860$) and the females in the non-DGBL group ($M = 54.11$, *SD* = 32.298). Since there was no significant difference in the means of the SGP scores between the females in the DGBL group and the females in the non-DGBL group, the researcher failed to reject third null hypothesis. Further, the Cohen's effect size (*d* = 0.036) indicated a small effect size. See Table 7 for descriptive statistics for the female DGBL group and the female non-DGBL group.

Table 7

Descriptive Statistics for the Female DGBL and Female Non-DGBL Group

Group	*N*	Mean	Std. Deviation	Std. Error Mean
FEMALE DGBL	28	55.32	34.860	6.588
FEMALE NON-DGBL	28	54.11	32.298	6.104

Table 8

Independent-Samples Test Female DGBL Group and Female Non-DGBL Group

	Levene's Test		*t*-test for Equality of Means						
								95% Confidence Interval of the Difference	
Equal Variances Assumed?	*F*	Sig.	*t*	*df*	Sig. (2-tailed)	Mean Difference	Std, Error Difference	Lower	Upper
Yes	.568	.454	.135	54	.893	1.214	.893	8.981	19.220
No			.135	53.688	.893	1.214	.893	8.981	19.222

Summary

Based upon the data collected from this research study utilizing independent-samples *t*-tests, gifted learners utilizing DGBL for supplementary mathematics instruction did not demonstrate any greater academic gains in mathematics over their gifted peers who did not utilize DGBL for supplementary mathematics instruction as demonstrated by the SGP of the

STAR Math test. There was no statistically significant difference in the SGP scores of gifted learners utilizing DGBL and gifted learners not utilizing DGBL. Additionally, there was no statistically significant difference in male gifted learners utilizing DGBL and male gifted learners not utilizing DGBL. Finally, there was no statistical difference in female gifted learners utilizing DGBL and female gifted learners not utilizing DGBL.

CHAPTER FIVE: CONCLUSIONS

Overview

This chapter commences with a discussion of the statistical analysis of the SGP of the STAR Math assessment. The results of this study are reviewed and conclusions are drawn and interpreted in relation to the research question and three null hypotheses. The implications of this study on the mathematics achievement of gifted learners are considered, and the limitations for this study and recommendations for future research are provided.

Discussion

The purpose of this quasi-experimental non-equivalent control group study was to determine the presence of a statistically significant difference in mathematics achievement when utilizing DGBL between gifted learners in the treatment group and gifted learners in the control group. The STAR Math test, developed by Renaissance Learning (2017), measured the SGP based upon a pretest taken at the beginning of the study and a posttest taken at the conclusion of the nine-week study. The population sample was composed of 105 sixth grade gifted learners from two public middle schools.

The research question was as follows:

RQ1: Is there a statistically significant difference between the mathematics student growth percentile scores of gifted learners who utilize digital game-based learning in comparison to gifted learners who do not utilize digital game-based learning?

$H_0$1: There is no significant difference between the mathematics student growth percentile scores of gifted students who utilize digital game-based learning in comparison to gifted students who do not utilize digital game-based learning as shown by the STAR Math assessment.

An independent-samples *t*-test was used to evaluate the data, and the findings of this study indicated no significant difference between gifted learners who utilized DGBL and gifted learners who did not utilize DGBL. Upon examination of the SGP scores, the mean of the DGBL treatment group ($M = 56.16$) was lower but not significantly different than the mean of the non-DGBL control group ($M = 61.22$). According to these findings, the use of DGBL may produce results slightly lower than those found when using paper-based activities for the supplemental mathematics instruction of gifted learners.

In response to these findings, educators considering the integration of DGBL to provide differentiation for supplemental mathematics instruction of gifted learners should exercise discretion when selecting digital learning games. Since these results contrast with several research study findings (Gerber et al., 2014; Ku et al., 2014; Proulx et al., 2016; Sung and Hwang, 2018), educators should not be daunted when considering the inclusion of digital games into their curriculum since the results of the current study were inconclusive. However, educators should rely on digital games that are research based and aligned with the instructional objectives to improve the academic growth of the gifted learners. This study focused on time-on-task with the use of a variety of digital games in lieu of specific mathematics games focused on targeted objectives. The participants of this study selected their digital learning games from a suggested list, random internet searches, or previously played games. However, they often played games that focused on one objective more than other objectives according to their weekly progress reports. For example, some learners played games that concentrated primarily on geometry because of the enticing game format and did not spend any time interacting with digital games that focused on number sense or algebra skills. As a result, these learners may have shown growth in geometry but may have demonstrated little or no growth in algebra on the posttest. Aligning the digital learning games with a particular instructional goal supports the constructivist theory that requires learners participate in activities and behaviors designed to achieve targeted learning objectives (Ya-Hui Hsieh et al., 2015). When an educator assigns specific games that support the curricular content, the learners utilizing DGBL may demonstrate more favorable results on the specific objective.

$H_0$2: There is no significant difference between the mathematics student growth percentile scores of male gifted students who utilize digital game-based learning in comparison to male gifted students who do not utilize digital game-based learning as shown by the STAR Math assessment.

An independent-samples *t*-test was used to evaluate the data, and the findings were inconclusive requiring further study. Upon investigation of the SGP scores, the mean for the males in the DGBL treatment group ($M = 57.00$) was lower than the mean for the males in the non-DGBL control group ($M = 70.71$) demonstrating that the males in the non-DGBL group outperformed the males in the DGBL group. While the researcher failed to reject the second null hypothesis, further research is needed to determine the relationship between DGBL and the mathematics achievement for male gifted learners.

The findings of this study imply that DGBL may impede the academic growth of gifted males utilizing DGBL for supplementary mathematics instruction in comparison to gifted males not utilizing DGBL. The results of this study conflict with the findings of a study conducted by Jackson et al. (2013) where the male participants demonstrated significant growth between the pretest and posttest when utilizing DGBL. Additionally, findings by Admiraal et al. (2014) demonstrated that males are more likely to have extensive gaming knowledge increasing their capacity to transfer those skills into digital learning games (Admiraal et al., 2014). Often, males find the visual graphics embedded in software applications appealing which increases their engagement with digital games (Musti-Rao et al., 2015). This increased level of engagement supports John Dewey's theory on Experiential Education where learning is promoted through an engaging, interactive environment (Waddington, 2015). Conversely, software applications employ multiple senses simultaneously and may distract the learner by producing navigational difficulties creating negligible academic growth (Kalyuga & Liu, 2015).

$H_0$3: There is no significant difference between the mathematics student growth percentile scores of female gifted learners who utilize digital game-based learning in comparison to female gifted learners who do not utilize digital game-based learning as shown by the STAR Math assessment.

An independent-samples *t*-test was used to evaluate the data, and the findings indicated no significant difference between female gifted learners who utilized DGBL and female gifted learners who did not utilize DGBL. The mean of the SGP scores for the females in the DGBL group ($M = 55.32$) was slightly higher than the females in the non-DGBL group ($M = 54.11$) resulting in the researcher failing to reject the third null hypothesis.

This study not demonstrating a significant difference in the means of the SGP scores between females in the DGBL group and females in the non-DGBL group is unexpected based upon the findings of other research studies (Bohlmann and Weinstein, 2013; Nollenberger, Rodriguez-Planas, & Sevilla, 2016; Wong, 2017). According to research conducted by Wong (2017), females often use language-based strategies when solving mathematics problems in lieu of strategies that are spatially based. Consequently, females may experience limited success at digital games that commonly require use of spatial skills. Females may also be less likely to participate in digital games minimizing their gaming knowledge and potentially decreasing the positive impact of DGBL (Admiraal et al., 2014). Beneficially, females have demonstrated an increased incidence of seeking opportunities to assist their peers during mathematics activities resulting in the reinforcement of their own mathematics' skills (Jackson et al., 2013). This social behavior aligns with Vygotsky's Activity Theory that postulates learning occurs while working cooperatively, and increasing mathematical discourse may facilitate the progression of problem solving skills (Asmundis et al., 2015).

Implications

The findings of this study have practical implications for educators looking for ways to integrate technology into their classrooms as a method for motivating gifted learners while providing differentiated instruction to meet the gifted learners' specific needs. Prior to this study, there was little evidence regarding the use of DGBL for the mathematical instruction of gifted learners. As a result, the findings of this study, which indicate that DGBL is at least as good as other learning activities but could be detrimental to males, add to the existing body of knowledge by providing information on the integration of DGBL for supplemental mathematics instruction for gifted learners.

Since this study showed no statistically significant difference in the SGP of the STAR Math test by the learners in the DGBL group, teachers interested in integrating DGBL to supplement their mathematics instruction and provide differentiation for gifted students should consider utilizing research-based digital learning games that have been proven as effective instructional tools capable of promoting growth in the mathematic achievement of learners. These digital games should promote higher-level thinking and experiential learning while avoiding drill and practice of previously mastered concepts (Fokides, 2018). Selected digital games should be carefully designed and contain built-in learning supports to maximize the potential that digital games are capable of producing. When games do not include learning strategies that create supports for the learner, the positive impact that digital games offer may be negated by the lack of enjoyment by the learners (Giannakas et al., 2017).

This study showed inconclusive findings in the SGP of the STAR Math assessment for male gifted learners in the DGBL group and found no significant differences in the SGP of the STAR Math assessment for female gifted learners in the DGBL group. As a result of these findings, educators must evaluate the types of games utilized for supplemental mathematics instruction. The incorporation of games into the mathematics curriculum provides an opportunity to remove the repetitiveness of teacher-led instruction and the redundant worksheets for games that can potentially enhance learning through activities that are productive and dynamic (Heshmati, Kersting, & Sutton, 2018). However, the simple introduction of technology for mathematics instruction does not imply enhanced engagement with mathematics. Game designers should focus on creating quality games based upon the special needs of their targeted audiences with consideration for the age of the player, learning styles, cultural and socioeconomic backgrounds, and level of educational attainment (Giannakas et al, 2017). When utilizing DGBL in the classroom, teachers should not rely on DGBL as the only source of differentiation. Differentiation should contain a wide variety of tools that address academic levels of learners and match as many learning styles as possible. Learners should be provided choices that may facilitate their acquisition of knowledge through increased motivation and engagement. From the information provided in this study, educators and digital game designers should examine current DGBL games to determine if they are aligned with the desired instructional objectives and meet the educational needs of the targeted audience (Giannakas et al., 2017).

Limitations

This study is limited geographically to one region in southern Mississippi and limited numerically due to the use of a convenience sample that includes two public middle schools from two school districts. As a result, the determination of how the results of this study will generalize to the remaining population of gifted students is unknown. Additionally, variations in the determination of giftedness from one school district to another school district may result in participants eligible for this study being ineligible to participate in gifted studies in other school districts.

The data contained in this study indicated no significant difference when utilizing DGBL in comparison to not utilizing DGBL for supplemental mathematics instruction for gifted learners in any of the subcategories. However, the results of this study for males utilizing DGBL in comparison to males not utilizing DGBL were inconclusive and call for further study based upon the almost statistically significant results ($p = .05$). The results of this study cannot determine if DGBL is the singular cause for variances in the SGP on the mathematics posttest. Differences in SGPs could be the result of inconsistencies in the quality of mathematics instruction, variations in the quality of the selected digital learning games, or other justifications. Furthermore, limitations may include the lack of quality engagement from participants on the pretest, weekly assignments, or on the posttest in either the treatment group or the control group since the participants were aware that the scores resulting from the activities and assessments would not be computed into their mathematics course averages minimizing their motivation for providing their best effort.

Recommendations for Future Research

While the findings of this study present information regarding the utilization of DGBL with gifted learners, the researcher recommends the following considerations when conducting future research:

1. Data collection should include participants in various grade levels both above and below the sixth grade.
2. Data collection should include various geographic regions outside of the Mississippi Coastal Counties to determine if findings are consistent with gifted learners in other regions.
3. Replication of the study should include participants from a wider range of ethnicities and socioeconomic levels.
4. Data collection should extend over a time period allowing for more longitudinal results.
5. The researcher should employ specific digital learning games since variations in the academic quality of digital learning games can vary widely from one publisher to the next.
6. Data collection should include a larger number of students to determine if the results generalize to gifted students outside of this study.
7. Data collection should employ mathematics subcategories such as geometry or measurement to determine if the results vary depending upon the mathematical standard.
8. Data collection should compare male gifted learners utilizing DGBL to female gifted learners utilizing DGBL to determine if there is a significant difference between their mathematics growth.

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APPENDIX A: IRB APPROVAL

LIBERTY UNIVERSITY.
INSTITUTIONAL REVIEW BOARD

February 12, 2018

Lynette Cooper
IRB Exemption 3126.021218: Digital Game-Based Learning and the Mathematics Achievement of Gifted Learners

Dear Lynette Cooper,

The Liberty University Institutional Review Board has reviewed your application in accordance with the Office for Human Research Protections (OHRP) and Food and Drug Administration (FDA) regulations and finds your study to be exempt from further IRB review. This means you may begin your research with the data safeguarding methods mentioned in your approved application, and no further IRB oversight is required.

Your study falls under exemption category 46.101(b)(1), which identifies specific situations in which human participants research is exempt from the policy set forth in 45 CFR 46:101(b):

> (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices, such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

Please note that this exemption only applies to your current research application, and any changes to your protocol must be reported to the Liberty IRB for verification of continued exemption status. You may report these changes by submitting a change in protocol form or a new application to the IRB and referencing the above IRB Exemption number.

If you have any questions about this exemption or need assistance in determining whether possible changes to your protocol would change your exemption status, please email us at irb@liberty.edu.

Sincerely,

[redacted]

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

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APPENDIX B: PARENT/GUARDIAN CONSENT FORM

The Liberty University Institutional
Review Board has approved
this document for use from
2/12/2018 to --
Protocol # 3126.021218

PARENT/GUARDIAN CONSENT FORM

Digital Game-Based Learning and the Mathematics Achievement of Gifted Learners
Lynette Cooper
Liberty University
School of Education/Liberty University

Your child, ____________________________, is invited to be in a research study on the impact of digital game-based learning on mathematics achievement in comparison to traditional mathematics assignments. He or she was selected as a possible participant because he or she is between the ages of 10 to 12, is enrolled as a student in the 6th grade, and has an individualized education plan for giftedness. Please read this form and ask any questions you may have before agreeing to allow him or her to be in the study.

Lynette Cooper, a doctoral candidate in the School of Education at Liberty University, is conducting this study.

Background Information: The purpose of this study is to determine if there is a statistically significant difference between the mathematics achievement of students who utilize digital game-based learning in comparison to students who do not utilize digital game-based learning. With the difficulties teachers experience as they attempt to provide instruction that is challenging for gifted students, digital game-based learning may provide an opportunity to use technology in an engaging format while allowing an extension beyond the current grade-level curriculum.

Procedures: If you agree to allow your child to be in this study, I would ask him or her to do the following things:

1. Take a mathematics pretest that will take approximately 20 minutes.
2. Take a mathematics posttest that will take approximately 20 minutes.

Note: Students will complete supplemental mathematics activities for 9 weeks by using digital media or paper-based mathematics practice, based on their classroom procedure. The supplemental mathematics activities are part of the regular classroom activities, independent of this study.

Risks and Benefits of being in the Study: The risks involved in this study are minimal, which means they are equal to the risks you would encounter in everyday life.

Benefits to society include the purposeful integration of instructional technology into the classroom allowing for the development of improved teaching practices that may increase mathematics literacy among students.

Compensation: Your child will not be compensated monetarily for participating in this study but will receive incentive tokens such as stickers, pencils, and edible treats. The students will receive token incentives at the completion of each session and a larger token, such as an ice cream sundae, at the completion of the study.

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Protocol # 3126.021218

Confidentiality: The records of this study will be kept private. In any sort of report I might publish, I will not include any information that will make it possible to identify a subject. Research records will be stored securely and only the researcher will have access to the records. All data collected will be anonymous to protect the privacy of the participants. Data will be stored in a locked filing cabinet or on a password-protected computer. The data will be deleted or shredded after three years.

Voluntary Nature of the Study: Participation in this study is voluntary. Your decision whether or not to allow your child to participate will not affect his or her current or future relations with Liberty University or [Pass Christian School District or Hancock County School District]. If you decide to allow your child to participate, he or she is free to not answer any question or withdraw at any time without affecting those relationships.

How to Withdraw from the Study: If your child chooses to withdraw from the study, please contact the researcher at the email address/phone number included in the next paragraph. Should your child choose to withdraw, any data collected will be destroyed immediately and will not be included in this study.

Contacts and Questions: The researcher conducting this study is Lynette Cooper. You may ask any questions you have now. If you have questions later, **you are encouraged** to contact her at (228) 860-5481/lrcooper@liberty.edu. You may also contact the researcher's faculty advisor, Nathan Putney, Ed.D., at nputney@liberty.edu.

If you have any questions or concerns regarding this study and would like to talk to someone other than the researcher, **you are encouraged** to contact the Institutional Review Board, 1971 University Blvd, Green Hall 1887, Lynchburg, VA 24515 or email at irb@liberty.edu.

Please notify the researcher if you would like a copy of this information for your records.

Statement of Consent: I have read and understood the above information. I have asked questions and have received answers. I consent to allow my child to participate in the study.

____ ________________

Signature of Parent Date

____ ________________

Signature of Investigator Date

APPENDIX C: ASSENT FORM
ASSENT OF CHILD TO PARTICIPATE IN A RESEARCH STUDY

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ASSENT OF CHILD TO PARTICIPATE IN A RESEARCH STUDY

What is the name of the study and who is doing the study?
My name is Lynette Cooper, and I am conducting this study to see if there is a difference in math test scores when using computer games instead of math worksheets.

Why are we doing this study?
We are interested in studying to find out if computer games are a good way to learn math.

Why are we asking you to be in this study?
You are being asked to be in this research study because you are enrolled in sixth grade gifted classes.

If you agree, what will happen?
If you are in this study, you will take a pretest and complete some math assignments. You will be assigned to the computer group or the non-computer group. You will complete the assignments for 60 minutes each week for 9 weeks. At the end of the 9 weeks, you will take a posttest.

Do you have to be in this study?
No, you do not have to be in this study. If you want to be in this study, then tell the researcher. If you don't want to, it's OK to say no. The researcher will not be angry. You can say yes now and change your mind later. It's up to you. If you choose not to participate in the study, you will continue working on the activities assigned by your classroom teacher.

Do you have any questions?
You can ask questions any time. You can ask now. You can ask later. You can talk to the researcher. If you do not understand something, please ask the researcher to explain it to you again.

Signing your name below means that you want to be in the study.

____ ____________________
Signature of Child Date

Researcher	Advisor
Lynette Cooper	Nathan Putney, Ph.D.
(228) 860-5481	(434) 582-2559
lrcooper@liberty.edu	nputney@liberty.edu

Liberty University Institutional Review Board,
1971 University Blvd, Green Hall 1887, Lynchburg, VA 24515
or email at irb@liberty.edu

APPENDIX D: RENAISSANCE LEARNING PERMISSION FORM

RENAISSANCE®

July 14, 2017

Dear Lynette Cooper:

The purpose of this letter is to grant you permission to use Renaissance's materials, including Renaissance Star Math, in your research project.

If you have any questions about the research base for any of our products, please do not hesitate to contact the Research Department, email research@renaissance.com.

Best regards,

[redacted]

Eric Stickney
Director of Educational Research
Renaissance Learning, Inc.
901 Deming Way, Suite 301
Madison, WI 53717-1979
eric.stickney@renaissance.com
(608) 664-3880, ext. 2009
Fax: (608) 664-3882

APPENDIX E: SCHOOL DISTRICT #1 APPROVAL LETTER

[redacted]UBLIC SCHOOL DISTRICT
[redacted]ce
[redacted]tendent

December 4, 2017

Lynette Cooper
21178 Pineville Road
Long Beach, Mississippi 39560

Dear Lynette Cooper:

After careful review of your research proposal entitled Digital Game-Based Learning and the Mathematics Achievement of Gifted Students, I have decided to grant you permission to conduct your study [redacted] Middle School under the following conditions:

- Please make sure you receive permission from the students' parents.
- Provide more information regarding the use of iReady verses STAR math diagnostic exam.

Check the following circles, as applicable:

☑ Data will be provided to the researchers stripped of any identifying information.

☑ We are requesting a copy of the results upon study completion and/or publication.

Sincerely,

[redacted] Ph.D.

64[redacted]

APPENDIX F: SCHOOL DISTRICT #2 APPROVAL LETTER

H[redacted] School District
[redacted]ntendent of Education

1[redacted]

December 1, 2017

Lynette Cooper
21178 Pineville Road
Long Beach, Mississippi 39560

Dear Lynette Cooper:

After careful review of your research proposal entitled Digital Game-Based Learning and the Mathematics Achievement of Gifted Students, we have decided to grant you permission to conduct your study at the [redacted] School District.

Check the following boxes, as applicable:

☒ Data will be provided to the researcher stripped of any identifying information.

☒ We are requesting a copy of the results upon study completion and/or publication.

Sincerely,

[redacted]

A[redacted]erintendent
H[redacted]hool District

[redacted]

[redacted]st. Superintendent
[redacted]ool District

AD
12-1-17

Learning today; Leading tomorrow

[redacted]

APPENDIX G: RENAISSANCE STAR MATH ASSESSMENT ADMINISTRATION INSTRUCTIONS

Administration of the STAR Math assessment should adhere to the following guidelines:

- The researcher will create two classes for the individual schools and assign the STAR Math assessment.
- The researcher will enroll the students into the STAR Math assessment using pseudonyms (G1, M1, R1, etc.)
- The researcher will provide login instructions for the classroom teachers and generate login cards for student participants.
- The participating teachers will follow the procedures below:
  - Check to ensure the STAR Math test will open on the classroom computers using provided login instructions.
  - Assign class time for students to complete the STAR Math assessment.
  - Distribute login instructions and guide students through login procedures.
  - Once students are logged in to the STAR Math assessment, STAR Math may ask the students to choose a specific class. Assist students selecting the _____ class and direct them to click the Next button.
  - Assist students experiencing difficulty logging into the test should ask for assistance immediately because students entering an incorrect password three times will be locked out of the test.
  - Students that have not tested in the 180 days prior to the test administration will be asked several practice questions to ensure understanding of the test format.
  - Read the following instructions to the class:
    - Today, we are taking the STAR Math assessment to measure your current achievement level in mathematics.
    - The questions consist of two to four responses utilizing A, B, C, or D in the answer choices.
    - You may click the appropriate letter using the mouse followed by pressing Enter or by clicking the appropriate letter on the keyboard and clicking Next.
    - Once an answer has been selected and you have clicked Next, the answer may not be changed.
    - If you are using audio during the test, you may click the audio button on the screen allowing the student to pause, play, or replay the audio.
    - You will have 90-seconds to answer sample questions. Once three of the sample questions are answered correctly, you may begin the test. If the sample questions are not answered correctly, you will be provided three additional sample questions. You must answer two of the second set of sample questions correctly. In the event you do not answer at least two sample questions correctly, you will not be allowed to begin the test, and an alert will tell you to seek help from the teacher.
    - You will have 3-minutes to answer test questions. The format for the test questions is the same as the format of the sample questions. However, if

the time expires on a question prior to pressing enter, the test will record a chosen answer if one was selected. If the answer was not chosen when the time expired, the answer is scored as incorrect.
    - When you have 15-seconds left to answer a question, a clock appears on the screen.
    - You may select the Start button and begin the test.

- At the conclusion of the test, the student will press the OK tab, and the students will be automatically logged out of the STAR Math assessment (Renaissance Learning, 2016).