Learner Perceptions and Cognitive Outcomes of Digital Game-Based Learning in Mathematics

Valdez Lamont Mosley

Dissertation submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the Degree of

Doctor of Philosophy
In
Curriculum and Instruction

John G. Wells, Chair
Jeremy V. Ernst
Ken R. Potter
Thomas O. Williams Jr.

May 11, 2021
Blacksburg, Virginia

Keywords: Digital Game-Based Learning, Perceptions, Mathematics, Mixed methods

Learner Perceptions and Cognitive Outcomes of Digital Game-Based Learning in Mathematics

Valdez Lamont Mosley

Abstract

Despite the recent popularity of digital game-based learning (DGBL), far too little evidence exists concerning its benefits in mathematics. The purpose of this research study was to: (a) determine whether or not DGBL is a viable tool in helping students to improve achievement in middle school mathematics and (b) gauge their perceptions regarding the use of DGBL. This study consisted of a convenience sample of sixth-grade students enrolled at a large suburban middle school in a school division in the Commonwealth of Virginia. This study followed a sequential explanatory mixed-methods approach using a one-group, pretest-posttest research design to collect data from participants before and after DGBL intervention to determine if a relationship existed with improved scores on the Ratios and Proportional Relationships Test. Ratios and Proportional Relationships Test scores were collected from the fall 2020 pre and post-test administrations. *Students' Perceptions of Digital Game-Based Learning Survey* (SPoDGBLS) responses were also collected from participants before (pre) and after (post) the intervention to determine the changes in student perceptions of DGBL. Small group, semi-structured, open-ended interviews were conducted to collect in-depth information regarding student perceptions of a digital game-based approach for learning mathematics. Results of the study found that on average student participants scored higher on the posttest than the pretest, albeit not significantly higher than the posttest cut score. Results also showed that student perceptions of the usefulness of DGBL improved over the course of the 5-week study. The study recommends that school and division leaders consider incorporating DGBL into mathematics instruction.

Learner Perceptions and Cognitive Outcomes of Digital Game-Based Learning in Mathematics

Valdez Lamont Mosley

General Audience Abstract

The purpose of this research study was to: (a) determine whether or not digital game-based learning (DGBL) is a viable tool in helping students to improve achievement in middle school mathematics and (b) gauge their perceptions regarding the use of DGBL. A sequential explanatory mixed-method, one-group, pretest-posttest design was followed to compare 21 sixth-grade participants' Ratios and Proportional Relationships Test scores and Students' Perceptions of Digital Game-Based Learning Survey responses before and after a DGBL intervention. Small group interviews were conducted to collect in-depth information regarding participant perceptions of DGBL in mathematics. Results of the study found that participants scored higher on the posttest than the pretest and their perceptions of the usefulness of DGBL improved over the course of the 5-week study. The study concluded that DGBL is a viable tool that can be successfully integrated into regular math instruction and have a positive impact on middle school students' ability to learn and/or retain new math information.

Dedication

I would like to dedicate this dissertation to my wife (Kori L. Mosley), late mother (Patricia A. Mosley), and late grandmother (Grace T. Mosley) who have encouraged me to always follow my dreams and pursue my passions. I hope to someday inspire others the way that you all have inspired me. I am so thankful for all of your love and support over the years.

Acknowledgements

First and foremost, I would like to give thanks to my Lord and Savior, Jesus Christ. Without you, this would not be possible.

A special thanks to Dr. John Wells, my committee chair and mentor, for your time, guidance, and support throughout the research process. Thank you Dr. Ken Potter, Dr. Jeremy Ernst, and Dr. Thomas Williams Jr. for graciously agreeing to serve on my doctoral committee, providing support and feedback, and pushing me to reach my full potential.

A sincere thanks goes out to my family, friends, and colleagues for being there when I needed you the most and for encouraging me to continue to work hard on completing this dissertation.

Last but not least, I would like to thank the teacher and the participants in the study. I will forever be grateful to all of you for your help in completing this study.

TABLE OF CONTENTS

List of Tables

List of Figures

CHAPTER I: INTRODUCTION

1.1 Overview

"Our educational context has changed, and a new context demands new thinking" (Prensky, 2012, p. 2). Traditional direct instruction in math (traditional mathematics instruction) is based on students passively absorbing mathematical constructs invented by authoritative adults or information recorded in textbooks. Traditional mathematics instruction has been commonly criticized for ignoring the needs of low-achieving students (Clements & Battista, 1990). Traditional direct instruction (TDI) is typically lecture based and involves listening and note taking, and allows teachers to provide examples and present new information to students (Pilli, & Aksu, 2013; Sungur & Tekkaya, 2006). TDI takes place at an abstract level and students have a tendency to retain less when being taught in this manner (Sharma, 1997). The abstractness of mathematics when using this teacher-centered instructional method causes students to find mathematics to be challenging and complicated (Gersten et. al., 2005; Sharma, 1997). Although, TDI allows teachers to transmit information directly to students, it pressures them to construct mental representations which lowers their capacity for learning and ability to acquire new knowledge and skills (Pilli, & Aksu, 2013; Slavin, & Davis, 2006). Additionally, research on TDI indicates that it does not foster mathematical reasoning, promote higher order mathematical thinking, or help students develop problem solving skills (Clements & Battista, 1990; Slavin, & Davis, 2006). According to MacKenzie, 2014; Zheng, & Spires, 2014; Cheng, & Su, 2012; Young et al., 2012; Papastergiou, 2009; and Chaudhary, 2008, TDI has been found to be less appealing to today's students compared to other instructional methods. This may be a result of TDI having to compete with the modern technologies that students have access to and/or are exposed to on a daily basis (Kickmeier-Rust & Albert, 2010; Prensky, 2001).

Recently, education reform in the United States (U.S.) has been focused on the needs of 21st century learners as their learning preferences are very different from the TDI learners (Jukes, McCain, & Crockett, 2010; Prensky, 2001). "Today's students are no longer the people our educational system was designed to teach" (Prensky, 2001, p. 1). Twenty-first century learners appear to be more comfortable with using technology than ever before and simply do not learn in the same fashion as previous generations (Conole et al., 2008). In fact, learning itself has evolved into an acquisition of knowledge that is more accessible through digital devices (El-Hussein & Cronje, 2010). Students learn best when using current 21st century technologies such as computers and digital games (Li, 2012; Sardone & Devlin-Scherer, 2010). When 21st century technologies are readily available and properly integrated into instruction, learning becomes relevant, and more progressive to learners of today. It is imperative that educators must start teaching students the way they learn best through computer use and gaming (Dingli, Seychell, & SpringerLink, 2015). Prensky's research (2011) indicated that the existing educational system is unsuitable for 21st century learners and the skills they need. In order to effectively reach 21st century learners, our instructional philosophies, dispositions, and methodologies should be current, progressive, innovative, and focused on using 21st century technologies such as computers and digital games to help improve student engagement, achievement, and overall academic success (Bennett, Maton, & Kervin, 2008; Prensky, 2011; Palfrey, & Gasser, 2008; Sarkar, Ford, & Manzo, 2017).

Technology plays an integral part in our daily lives. From birth, children are introduced to a variety of technologies including computers, tablets, smartphones, smart watches, calculators, televisions, drones and much more. Students grow up exclusively experiencing the connected digital world that we live in today. They have little patience for lectures and step-by-step instruction and prefer fast paced multi-media, engaging lessons through computers, digital games, and other technological tools (Sarkar, Ford, & Manzo, 2017). Modern technology provides students with an abundance of educational opportunities to practice and deepen their learning, more than in the past (Cheng & Su, 2012; Cheung, & Slavin, 2013; Gee, 2007a; Kickmeier-Rust & Albert, 2010). There is an abundance of information, tools, and assistive technologies such as text to speech, graphic organizers, and word prediction software that are readily accessible to students. The constant infusion of technology has changed the way students think and learn (Sarkar, Ford, & Manzo, 2017). Technology can help educators integrate 21st century skills into their daily instruction and be a vehicle for helping students become strong critical thinkers and problem solvers (Prensky, 2011; Wang, Myers, & Sundaram, 2013). According to the National Council of Teachers of Mathematics (2016), "Technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students' learning" (p. 3). The use of technology in mathematics instruction can support inquiry-based learning and develop mathematical thinking, decision making, reasoning, and problem solving skills (NCTM, 2016).

Researchers (Chaudhary, 2008; Cheng, & Su, 2012; Clements & Battista, 1990; MacKenzie, 2014; Papastergiou, 2009; Sharma, 1997; Young et al., 2012; Zheng, & Spires, 2014) have found TDI to be inadequate for teaching 21st century learners partly because it is abstract, absorbed passively, less appealing, and does not reach all types of learners. According to Prensky (2001) teachers have a better chance of reaching their 21st century learners when using technology. Twenty-first century technologies such as computers and digital games develop 21st century skills, and increase student engagement and achievement (Cheung, & Slavin, 2013; Conole et al., 2008). Since students prefer, are accustomed to, and have had access to technology all of their lives, it is important for educators to incorporate it into their teaching practices to increase student engagement and foster academic success (Kickmeier-Rust & Albert, 2010; Prensky, 2001).

1.2 Nature of the Problem

In the recent past, the digital divide referred to the gap between schools and communities who have or did not have access to computers and the Internet at home and at school (Culp, Honey, & Mandinach, 2005; McConnaughey, Nila, & Sloan, 1995). The new digital divide now separates students who use and do not use technology for learning (Warschauer, 2012; Warschauer, & Matuchniak, 2010). The new digital divide exists between learners who use technology in active and innovative ways such as gaming and those who use it in passive ways such as for note taking. Students passively using technology are doing the same types of activities and tasks as before but are just doing them now with a computer (Valadez, & Durán, 2007; Warschauer, 2012; Warschauer, & Matuchniak, 2010). Students in today's classrooms are in need of developing 21st century skills that are necessary for life after graduation. Although the use of 21st century technologies has increased over the last few decades the problem is that students are still being taught using mostly teacher-centered instructional methods (Ahmad, Shafie, & Latif, 2010).

Mathematics is traditionally taught using mostly teacher-centered instructional methods and has been found to be passively absorbed, ineffective, and tends to ignore the needs of low-achieving students (Clements & Battista, 1990; Stigler & Hiebert, 2004). Foundational math knowledge is necessary for future success in school. Algebra is a gateway math course that has been found to prepare students for high school, college, and postsecondary careers as well as help them develop a solid math foundation that can be applied to everyday life (Bangser, 2008; Kvasz, 2006). Algebra is in itself a branch of mathematics, yet it is also included in almost all other branches of mathematics. Algebraic thinking begins in kindergarten with students being able to use representations to show math in a symbolic way (Van de Walle, Karp, & Bay-Williams, 2010). Handelsman et al. (2004), stated "There is mounting evidence that supplementing or replacing lectures with active learning strategies and engaging students in discovery and scientific process improves learning and knowledge retention" (p. 521). Considering that TDI has been found to be inadequate for teaching 21st century learners (e.g., Chaudhary, 2008; Cheng, & Su, 2012; Clements & Battista, 1990; Kickmeier-Rust & Albert, 2010; MacKenzie, 2014; Papastergiou, 2009; Stigler & Hiebert, 2004; Young et al., 2012; Zheng, & Spires, 2014), it is important for educators to incorporate instructional methods such as digital game-based learning (DGBL) into their teaching practices to engage students in authentic learning tasks that promote meaningful learning.

A significant number of research studies related to DGBL have been conducted in mathematics (Ahmad & Latih, 2010; Hussain et al., 2014; Karafili & Stana, 2012; Katmada, Mavridis, & Tsiatsos, 2014; Ke, 2008; Kebritchi, Hirumi, & Bai, 2010; Lee, 2009; Pareto et al., 2011; Swearingen, 2011; Wilson et al., 2006; Zavaleta et al., 2005). Research indicates that DGBL is an effective approach for engaging students in relevant learning tasks (Prensky, 2003a). Previous studies have found DGBL to be an effective way to enhance students' achievement (Eow & Baki, 2009; Iacovides, Aczel, Scanlon, Taylor, & Woods, 2011), motivation (Lin & Liu, 2009), attitudes (Papastergiou, 2009) and critical thinking skills (Gee, 2007a). DGBL can motivate students and be used as an educational tool to facilitate effective mathematics learning (Betz, 1995; Moreno, 2002). Therefore, considering how digital games can be effectively integrated into teaching and learning remains an important question, worthy of further research (Hwang & Wu, 2012; Liu, 2011).

In contrast to TDI, DGBL is a student-centered learning approach that uses digital games for educational purposes (Papastergiou, 2009; Tan et. al., 2008). Games can be an effective tool to enrich conceptual understanding, problem solving skills, and engage students in mathematics instruction (Andrews, 2016; Lester et al., 2014; Ota & DuPaul, 2002). DGBL can enhance instruction and foster engagement and motivation (MacKenzie, 2014), but little research has been conducted to show the potential benefits for middle school students' mathematical cognitive development. Therefore, DGBL could be an approach used to engage 21st century learners in pertinent student-centered mathematics activities and tasks that develop cognitive skills and abilities (Ota & DuPaul, 2002; Papastergiou, 2009; Prensky, 2003a).

1.3 Rationale for the Study

Many schools have the ability to use technology in ways that can support learning opportunities and improve learning goals for students (Cheung, & Slavin, 2013). Wells and Lewis (2006) reported that nearly 100% of all U.S. public schools had Internet access. Li (2007) reported that almost all U. S.

public schools also had access to computer technology. Gray, Thomas, Lewis, and National Center for Education Statistics (2010) found that teachers used computers in the classroom for instructional purposes 40% of the time; and that 97% of teachers had daily access to one or more computers in their classroom; and 93% of the computers having Internet access (Gray et al., 2010). Technology has the ability to engage students in activities and tasks that support authentic learning experiences (Fried, 2008; Jones, Squires, & Hicks, 2008; Lombardi, 2007) but having access to technology alone does not guarantee equity and accessibility into technology rich learning experiences (Valadez, & Durán, 2007; Warschauer, 2012). Without proper integration of 21st century technologies for innovative problem-based learning experiences, students could leave school unprepared for the technological world that awaits them. Research findings show there is a need for conducting research on the effectiveness of using DGBL for teaching mathematics.

There have been many research studies conducted regarding the benefits of DGBL (e.g., Divjak, & Tomić, 2011; MacKenzie, 2014; Tsai, Yu, & Hsiao, 2012; Van Eck, 2006; Yurov, Beasley, Kwak, & Floyd, 2014), but very little has been conducted to show the benefits DGBL has on middle school students in mathematics. As previously described, Algebra is a branch of mathematics that prepares students for upper level mathematics, postsecondary careers and everyday life **(**Bangser, 2008; Kvasz, 2006 Van de Walle, Karp, & Bay-Williams, 2010). A recent study performed at Stanford University suggested that digital math games can help students improve their math proficiency, ability to reason through and solve open-ended tasks and math problems, and strengthen a deeper understanding of mathematics (Pope, & Mangram, 2015). Digital games are an integral part of digital native's culture and play an essential role in their lives (Fromme & Unger, 2012; Mumtaz, 2001; Prensky, 2001). Digital games are intrinsically motivating and appeal to digital natives by adding elements of curiosity, challenge, and fantasy into tasks found in virtual environments (Malone, 1981). Digital games are teaching tools that have the ability to spark student interest in learning information present in gameplay

(All, Nunez Castellar, & Van Looy, 2014). Digital games are capable of immersing students in a 'flow' state where they are so engaged in an activity or task that they lose track of time (Csikszentmihalyi, 1990; Kaye & Bryce, 2012; Seligman & Csikszentmihalyi, 2000; Van Eck, 2006; Wang & Chen, 2010). Digital games familiarize students with skills needed in the 21st century such as critical thinking and problem solving (Prensky, 2003a; Van Eck, 2006). Despite DGBL's recent popularity, far too little evidence exists concerning its benefits in mathematics. This study explored the potential for DGBL to improve math achievement for students identified as having learning difficulties in mathematics.

1.4 Purpose of the Study

The purpose of this research study was to: (a) determine whether or not DGBL is a viable tool in helping students to improve achievement in middle school mathematics and (b) gauge their perceptions regarding the use of DGBL. A constructivist paradigm was used to assess the effects DGBL had on student mathematics learning outcomes in a math course at a large suburban middle school in Virginia. The effect of DGBL on mathematics learning outcomes was measured using students' math scores on the Ratios and Proportional Relationships Test (Appendix A). The independent variable, DGBL, is defined as a type of learning approach that uses engaging risk-free digital games played on digital devices for educational purposes (Erhel, & Jamet, 2013; Ke, 2008; Papastergiou, 2009). The dependent variables, math achievement outcomes and perceptions, are the outcomes related to test scores on the pre and post Ratios and Proportional Relationships Test (Appendix A) and students' perceptions of their learning experiences with regard to the use of a digital game-based approach for learning mathematics.

1.5 Research Questions

The following research questions guided this study:

RQ1: To what extent are differences evident in students' Ratios and Proportional Relationships pre and post test scores following the implementation of DGBL into regular math instruction?

RQ2: How do the post Ratios and Proportional Relationships Test scores of student participants differ from the Ratios and Proportional Relationships Posttest cut score?

RQ3: What changes in student perceptions of DGBL occur following implementation of the mathematics intervention?

1.6 Delimitations, Limitations, and Assumptions

This sequential explanatory mixed methods study examined whether or not DGBL is a viable tool in helping students to improve achievement in middle school mathematics. In light of this, the delimitations of this study included a convenience sampling of sixth grade students preassigned to a Middle School Math Course 1 and who had daily access to a laptop computer. The results of this study were limited to sixth grade students from low socioeconomic households who attended the same, large suburban middle school. Therefore, an assumption cannot be made that the results would be applicable to student groups of other grade or performance levels, socioeconomic status (SES), or type of school. Another limitation to this study was the ability of the teacher to understand and implement the study as it was designed. Lastly, it is an assumption that when answering survey questions about their experiences using a digital game-based approach for learning mathematics, students did so honestly.

1.7 Definition of Terms

Active learning: A process where students actively engage in learning activities. This includes students experimenting, problem solving, and thinking for themselves or collectively rather than passively listening (Felder & Brent, 2009; Weltman, 2007).

Digital games: An adapted version of traditional games that uses application software to deliver content and provide pathways to mastery in a web browser or on electronic consoles and devices (Gee, 2009; Rapini, 2012; Tang, Hanneghan, & Rhalibi, 2007).

Digital game-based learning (DGBL): A type of instructional approach where digital games are played on digital devices for educational purposes. DGBL uses engaging risk-free digital games for learning, experimentation, and practice. DGBL integrates digital games into practice to teach concepts through gameplay (Erhel, & Jamet, 2013; Ke, 2008; Papastergiou, 2009).

Digital immigrant: An individual born prior to the digital age era (Prensky, 2001).

Digital native: An individual born during or after the advent and widespread acceptance of the digital technology of the digital age (Prensky, 2001).

Educational game: Student-centered games designed to assist individuals acquire new information and skills while they play. These types of games include rules, goals, and challenges and provide the learner with immediate feedback (Shute, Rieber, & Van Eck, 2011).

Engage: The ability to gain and secure an individual's attention in a process, task, or activity (Kapp, 2012).

Feedback: The process of supplying an instant, direct, and clear reaction about information provided by an individual on a task, activity, or product (Kapp, 2012).

Game: Games are structured forms of play used for enjoyment and learning. They are engaging, socially motivating, fun, rewarding, and can enhance awareness, knowledge, enjoyment, and pleasure (Rapini, 2012).

Gamification: The application of game design elements and principles to a task or activity to drive motivation and increase engagement (Johnson et al., 2013; Kapp, 2012).

Learning: The act of reorganizing cognitive experiences to acquire and make sense of new knowledge or skills (Merriam & Caffarella, 1999; Young et al., 2012).

Motivation: The desire that energizes and drives an individual to participate or become interested in something (Kapp, 2012).

Prior knowledge: The starting point for conceptual change whereby learners construct new knowledge (Slavin & Davis, 2006).

Response to intervention (RTI): A systematic approach to academic and behavioral intervention used to identify, support, and provide intensive assistance to students with learning difficulties or special needs who are at risk for underperforming in school. RTI can assist in the development of process models, intervention plans, strategic planning, and strategies to improve the academic performance of "at-risk" students (Prasse, 2010).

Traditional direct instruction (TDI): TDI is an instructional approach where students receive information directly from the classroom teacher. TDI is typically lecture based and involves listening and note taking (Sungur & Tekkaya, 2006).

1.8 Organization of the Study

This dissertation includes five chapters. Chapter 1 includes an overview, the nature of the problem, the rationale for the study, the purpose of the study, the research questions, the study's delimitations, limitations and assumptions, and definition of terms used throughout the study. Chapter 2 presents a comprehensive review of literature of previous studies and information from the field of study. Chapter 3 includes a description of the methodology used to complete the study. Topics include the research questions, the appropriateness of the research design, participants, setting, measures, instruments, and procedures used to collect and analyze data. Chapter 4 summarizes the data collected during the study. Chapter 5 discusses the findings from the study, implications, and makes recommendations for future research studies.

CHAPTER II: LITERATURE REVIEW

In preparation for this study, a comprehensive literature review was conducted regarding efficacy of digital game-based learning (DGBL) for middle school mathematics students. This chapter reviews supporting literature, and cites the major conclusions and findings related to math and DGBL. Extensive research was conducted to identify relevant empirical studies and information from the field of study, present a broad overview of the topic, and shed light on current research and literature regarding DGBL. After reviewing the existing research, it is noted that additional research is needed due to a lack of sufficient empirical evidence documenting the benefits DGBL has on helping middle school students improve their math abilities.

The organizational framework divides this chapter into nine sections. First, a synopsis of the U.S. educational system over the past 20 years is shared, followed by a brief history of Public Law 107-110, Educate to Innovate Campaign, and Every Student Succeeds Act. The second section provides a framework of the educational learning theories that this paper is built upon. The third and fourth sections identify traditional direct instruction (TDI) methods and design models that can be applied in DGBL and mathematics. The fifth section discusses culture as it pertains to digital natives. The sixth section identifies the affordances and constraints of digital learning tools such as handheld devices, laptops, 3D virtual environments, and educational games. The seventh section defines digital games, describes their functions, and discusses what they are designed to accomplish. Lastly, the eighth section presents a brief synopsis of DGBL and mathematics achievement along with the perceptions, benefits, and impact of DGBL. It also presents previous empirical studies and discusses the selection of the research design.

2.1 Background

The educational system in the U.S. has changed dramatically in the past 20 years (Birman et al., 2013). It has experienced an explosion of technological advances that have led to variations in the way that educators approach teaching and learning (Cheng & Su, 2012; Prensky, 2001; Tsai, Yu, & Hsiao, 2012; Wu et al., 2012). Curriculum content has changed, students are accustomed to having the Internet and technology at their fingertips, and there is an increased pressure for students to do well on state-mandated tests. In a recent study, it was identified that most classroom teachers in the U.S. had daily access to technology (Gray et al., 2010). Ninety-six percent of teachers surveyed in a quantitative research study recognized the need to build technology applications into their learning environments and 95% of the teachers supported investing additional spending in technology by schools, states, and the federal government (Hart Research Associates, 2012). Educators use technology to plan lessons and improve student learning; students use technology to seek information, conduct research, and to communicate (Darling-Hammond, Zielezinski, & Goldman, 2014; McKnight et al., 2016; van Broekhuizen, 2016).

While President of the U.S., Lyndon Johnson proposed that "we set full educational opportunity as our first national goal" (Johnson, 1966, p. 33). In 2001, thirty-six years later, Public Law 107-110 was proposed and signed into law by President George W. Bush. This legislation reauthorized the Elementary and Secondary Education Act of 1974 and renamed it the No Child Left Behind Act (NCLBA). The NCLBA was used to measure academic outcomes of all students by including a system of accountability for determining school success (National Education Association, 2008; Harris, 2003). Title I provisions and technology integration into instruction were part of these inclusions (Bush, 2001). The NCLBA also expanded and reframed public education by creating a standards-based education reform that monitored schools' annual progress to ensure that all students were properly educated and prepared for life, college, and the workplace (Linn, Baker, & Betebenner, 2002).

In 2009, President Barrack Obama launched the Educate to Innovate Campaign for Excellence in Science, Technology, Engineering & Math (STEM) education. The campaign was established to further the efforts of the NCLBA of 2001. It focused on improving education, expanding opportunities for all Americans, transforming the economy, unlocking discoveries, and producing individuals who can solve scientific problems (Obama, 2009). The Educate to Innovate campaign was designed to keep the U.S. competitive in an increasingly global economic environment by fortifying the caliber of the U.S. workforce and driving economic growth (National Science Foundation, 2008). STEM education is an essential component to the U.S. remaining the world's technology leader and being competitive in a rapidly changing global economy (Morrissey, 2010).

In 2015, President Barack Obama signed the Every Student Succeeds Act (ESSA) to replace the NCLBA of 2001, shifting authority and decision-making power from the federal government back to state and local governments (Bush, 2001; Darrow, 2016; Moussaoui, 2017). ESSA places an emphasis on the success of disadvantaged, minority, and low-income students. President Obama stated at the ESSA signing ceremony,

> "this bill upholds the core value that animated the original Elementary and Secondary Education Act signed by President Lyndon Johnson -- the value that says education, the key to economic opportunity, is a civil right. With this bill, we reaffirm that fundamental American ideal – that every child, regardless of race, income, background, the zip code where they live, deserves the chance to make of their lives what they will" (Remarks by the President at Every Student Succeeds Act signing ceremony, 2015).

With the ESSA, the nation will continue to make strides toward satisfying the commitment it made over 15 years ago to students and families with the NCLBA. The act gives each state government the authority to set its own academic standards for what each student needs to know and should be able to do at each grade level and allows them to create accountability systems that help ensure a quality education for all students no matter their race, language, zip code, disability, or background (Darrow, 2016; Kane, 2017; Moussaoui, 2017).

2.2 Theoretical Framework

Merriam & Caffarella (1999) stated, "Learning involves the [cognitive] reorganization of experiences in order to make sense of stimuli from the environment" (p. 254). According to Vygotsky (1978) learning occurs at the intersection of an individual being able to move from performing tasks with guidance to doing them independently. Learning is at the very core of the educational process and is one of the most important activities that children engage in early in their lives (Servilio, 2009). This dissertation's theoretical framework (Figure 1) is based on the philosophical beliefs of realism and built upon constructivist learning theories. It provides a theoretical foundation from which DGBL emerges.

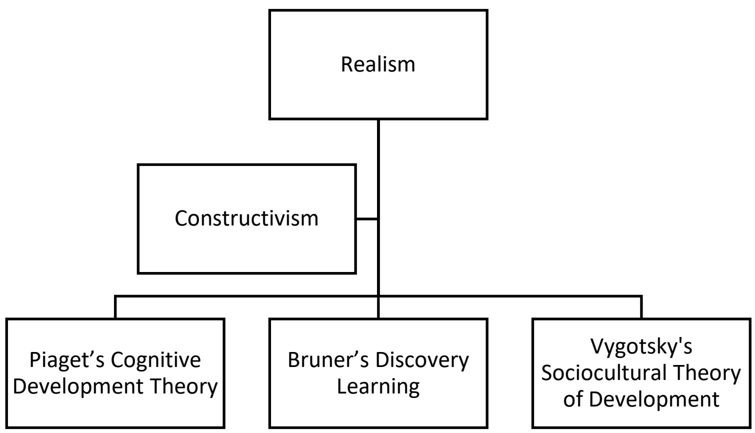


Figure 1. Theoretical Framework of the study.

According to Ornstein, Levine, & Gutek (2011) realism is an educational philosophy developed by Aristotle in the third century A.D. Aristotle believed that knowledge was gained through the human sense organs and that the purpose of education was to equip humans with the ability to reason, make decisions, and govern society. Realists place an emphasis on multi-sensory learning, assert that reality exists outside of the mind, and believe that knowing involves sensation, abstraction, observation, and experimentation. Realism emphasizes subject matter like science and mathematics and teaching methods that focus on helping students reach mastery levels of understanding (as cited in Ornstein et al., 2011).

Constructivism

Constructivism posits that learning is an active and continuous process where knowledge is constructed by tapping into and linking prior learning, perceptions, and experiences to new information (Connolly et al., 2007; Felder & Brent, 2009; Fosnot, 2013; Resnick, 1987; Slavin, & Davis, 2006; Steffe & Gale, 1995; von Glasersfeld, 1995; Weltman, 2007; Wu et al., 2012). The new knowledge created by the learner in this process is made relevant and may later lead to deeper conceptual understanding (von Glasersfeld, 1995). "Cooperative learning, hands-on activities, discovery learning, differentiated instruction, technology, distributed practice, critical thinking, and manipulatives are elements that embrace the constructivist educational philosophy" (White-Clark et al., 2008, p. 41). Social constructivism is based on Lev Vygotsky's philosophy that knowledge and cognitive development are constructed through social interaction, collaboration, and meaningful learning experiences with others in sociocultural contexts (Berger & Luckmann, 1966; Slavin & Davis, 2006; Vygotsky, 1978). Cognitive constructivism focuses on the mental processes that affect learning and maintains that knowledge is constructed and modified by learners at different stages of intellectual development (Slavin & Davis, 2006). According to Grippin & Peters (1984) cognitive constructivism recognizes that "the human mind is not simply a passive exchange-terminal system where stimuli arrive and the appropriate responses leave. Rather, the thinking person interprets sensations and gives meaning to the events that impinge upon his [or her] consciousness" (p.70). From the cognitive constructivist position, learning is the result of actively internalizing, interpreting, and reconstructing information (Slavin & Davis, 2006). Multiple studies have endorsed a constructivist approach in teaching mathematics (Carpenter et al., 1989; Hmelo-Silver, Duncan, & Chinn, 2007; Simon, 1995). Constructivism encourages the creation of student-centered teaching approaches like DGBL that effectively communicate learning goals and objectives, and allow students to investigate, explore, and become self-regulated learners (Simon, 1995). Table 1 presents the constructivist learning theories and how they are connected to the contemporary classroom.

Table 1.

Constructivist Learning Theories

Theorist	Learning Theory	Definition	Connections to the contemporary classroom
Jean Piaget	Cognitive Development Theory	Piaget's Cognitive Development Theory describes the developmental stages children progress through to acquire knowledge and how they develop biologically and intellectually (Huitt & Hummel, 2003).	• When teachers understand the developmental stages that children progress through they are better suited to align instruction to their students' cognitive levels. • Developmentally appropriate DGBL can promote learning and the development of cognitive skills.
Jerome Bruner	Discovery Learning	Bruner's Discovery Learning Theory is an inquiry-based learning theory that encourages learners to actively participate in the learning process and use prior knowledge to construct new knowledge (Mayer, 2004).	• When students figure things out for themselves by exploring and experimenting with ideas and concepts, they construct their own understanding and knowledge. • DGBL can provide opportunities for students to explore, experiment, and learn through play in a risk-free learning environment.
Lev Vygotsky	Sociocultural Theory of Development	Lev Vygotsky's Sociocultural Theory of Development describes the zone of proximal development as the intersection of an individual's ability to perform guided tasks and their ability to perform tasks independently (Vygotsky, 1978).	• When a student is in the zone of proximal development on an educational task, the teacher can provide the student with the appropriate assistance needed to achieve the task, tapering off the assistance as it becomes unnecessary. • DGBL can provide students with guided practice at the beginning of a task and decrease the amount of guidance once students are more capable of performing tasks independently.

Piaget's Cognitive Development Theory

Piaget's Cognitive Development Theory describes the developmental stages children progress through to acquire knowledge and how they develop biologically and intellectually (Huitt & Hummel, 2003). In Piaget's theory, play is a vehicle for children to develop their cognitive skills (Piaget, 1999). Piaget believed that knowledge is developed at different stages and constructed through age-appropriate learning opportunities and experiences (Huitt & Hummel, 2003; Ornstein et al., 2011; Piaget, 1999). There are four stages (sensorimotor, preoperational, concrete-operational, and formal-operational) and two adaptation processes (assimilation and accommodation) in Piaget's theory that identify a particular phase in a child's life, regardless of intelligence (Slavin, & Davis, 2006). Piaget's stages describe when children typically develop certain cognitive abilities like classifying objects, thinking abstractly and logically, solving complex problems, and using deductive reasoning skills (Cankaya, Uysal, & Kuzu, 2010; Slavin, & Davis, 2006). Piaget recognized that not all children pass through the four stages at specific ages and that some kids may display characteristics of multiple stages at a time. For example, Piaget's concrete-operational stage (7 to 11 years old) describes the capabilities of older elementary or beginning middle school students. At this stage of development, children engage in problem solving without physically experiencing things in the real world. Children in this stage, "begin thinking in a mathematical and logical way" (Ornstein et al., 2011, p. 119). DGBL can provide students with opportunities to develop mathematical thinking, logical thinking, and problem solving skills.

Cognitive development is driven by a child's ability to balance pre-existing and new knowledge (Huitt, & Hummel, 2003). Piaget described two processes (assimilation and accommodation) children use throughout life to adapt to their environment. Piaget (1999) defined play as assimilation. Children's play "occurs when assimilation is dissociated from accommodation but is not yet reintegrated in the forms of permanent equilibrium in which, at the level of opera-tional and rational thought, the two will be complementary" (p. 162). Assimilation occurs when new information is incorporated into a child's existing ideas. Accommodation is when the child reorganizes their existing knowledge to make room for the new information (Huitt, & Hummel, 2003; Van Eck, 2006). A schema is the mental structure that helps the child organize and interpret information. Equilibrium occurs when a child's schema can accept new information and disequilibrium when it is unable to fit new information into an existing schema (Huitt, & Hummel, 2003). DGBL can provide students with educational play and age-appropriate learning opportunities to activate prior knowledge, organize new knowledge, and use their newly acquired knowledge to solve problems (Tsai, Yu, & Hsiao, 2012; Turuk, 2008).

Bruner's Discovery Learning

Discovery learning is an inquiry-based learning theory introduced by Jerome Bruner in the 1960's that encourages learners to actively participate in the learning process and use prior knowledge to construct new knowledge. Discovery learning seeks to develop critical thinking and problem-solving skills and promote creativity, deeper thinking, and understanding (Mayer, 2004). "Practice in discovering for oneself teaches one to acquire information in a way that makes that information more readily viable in problem solving" (Bruner, 1961, p. 26). Bruner believed that children discovered new knowledge through play. Bruner (1972) stated:

> Play appears to serve several centrally important functions. First, it is a means of minimizing the consequences of one's actions and of learning, therefore, in a less risky situation. Second, play provides an excellent opportunity to try combinations of behavior that would, under functional pressure, never be tried (p. 693).

Discovery learning encourages autonomy and independence and assumes that learning occurs when students actively interact with their environment to solve problems and construct new knowledge (Mayer, 2004). DGBL can provide opportunities for students to explore, experiment, and learn through play in risk-free learning environments. DGBL can also engage students in inquiry-based learning and encourage them to use past knowledge and experiences to construct new knowledge (Cheng & Su, 2012; Gee, 2007b, Slavin, & Davis, 2006; Prensky, 2003b).

Vygotsky's Sociocultural Theory of Development

Lev Vygotsky's Sociocultural Theory of Development suggests that culture, social interaction, and comprehension play fundamental roles in the development of cognition and higher-order learning (McLeod, 2018; Vygotsky, 1978). Vygotsky believed that humans use written and verbal language to develop cultural competence and mediate their social environments. Vygotsky states, "Every function in the child's cultural development appears twice: first, on the social level, and later, on the individual level; first, between people (interpsychological) and then inside the child (intrapsychological)" (Vygotsky, 1978, p. 57). Vygotsky claimed that there are four elementary mental functions (attention, sensation, perception, and memory) that through social interactions are sophisticated and transformed from core functions to higher mental functions (McLeod, 2018).

Vygotsky described the zone of proximal development as the intersection of an individual's ability to perform guided tasks and their ability to perform tasks independently (Vygotsky, 1978). Vygotsky viewed play as the source of development that creates the zone of proximal development. Vygotsky (2016) stated:

> In play a child is always above his average age, above his daily behavior; in play it is as though he were a head taller than himself. As in the focus of a magnifying glass, play contains all developmental tendencies in a condensed form; in play it is as though the child were trying to jump above the level of his normal behavior (p. 18).

Vygotsky believed that providing the appropriate assistance to a child in the zone of proximal development will help them to transition prior knowledge to a more expanded and developed form of knowledge that requires higher brain functions (Turuk, 2008). According to Slavin and Davis (2006), constructivist views of learning draw heavily from Vygotsky's learning theories. Vygotsky's

Sociocultural Theory of Development acknowledges the importance of direct instruction but it also emphasizes the importance of interaction and independent learning. DGBL can be used to help students acquire new knowledge and skills, develop cognition through social interaction, and become independent thinkers and learners (Shute, Rieber, & Van Eck, 2011).

Myriad learning theories were explored to establish a specific foundation for the study of DGBL. Many were dismissed from this framework because they viewed learning from a motivational perspective. Instead, the constructivist theories explained above placed a primary focus on learning as an active process of constructing new knowledge. Furthermore, they suggest that play promotes cognitive development in children.

2.3 Instructional Methods

Instructional methods are approaches used to present information to students with the goal of effectively turning the acquired knowledge into learning. These methods can be categorized into two main types: teacher-centered and student-centered. No one approach to instruction is better than the other but certain approaches are better suited for certain goals (Shuell, 1996). Several instructional methods, inspired by Socrates' "Socratic method" and John Dewey's "Learning by doing" principle, can be leveraged in DGBL (Dewey, 1938; Felder & Brent, 2009; Handelsman et al., 2004; Palmer et al., 2001; Ryan, 1995; Weltman, 2007).

Distributed practice was first discussed in Hermann Ebbinghaus' book *Memory: A Contribution to Experimental Psychology* in 1964. Distributed practice spaces out instructional content and practice over multiple learning sessions to promote retention, allow the recollection of information, and store new information in working memory (Ausubel & Youssef, 1965; Kapp, 2012). DGBL can space out instruction, provide practice on newly learned information, and provide students with multiple opportunities to grasp, retain, and recall information (Ausubel & Youssef, 1965; Holmes, 2015; Kapp, 2012; Slavin, & Davis, 2006). Instructional scaffolding was introduced by Jerome Bruner in the 1960's.

It was designed to chunk information into small manageable parts to promote a deeper level of learning, build students' confidence, maintain learners' interest, extend their abilities to accomplish tasks, and provide them with support and guidance in their learning processes (Gredler, 1997; Vygotsky, 1978; Wood, Bruner, & Ross, 1976). DGBL can provide students with guided practice at the beginning of a task and decrease the amount of guidance over time once students are capable of performing tasks more independently (Melero, Hernández-Leo, & Blat, 2011; Slavin, & Davis, 2006). Differentiated instruction encourages teachers to modify instruction when needed by providing alternate avenues for learning by planning activities that target students' interests, readiness levels, learning styles, and learning profiles (Servilio, 2009; Tomlinson, 2001; VanSciver, 2005). Confucius, in the fifth century B.C., and Marcus Quintilianus later in the first century A.D., may perhaps have been the first educators to use different methods, practices, and avenues to modify instruction (Chin, 2007; Ornstein et al., 2011; Palmer et al., 2001). DGBL can provide a personalized learning environment that is engaging and responsive to a variety of different types of learners (Gros, 2007; Servilio, 2009; White-Clark et al., 2008). Similar to DGBL, the "learning by doing" approaches that are essential in project and case-based learning also encourage active learning, reflective thinking, and develop problem-solving and higher order thinking skills (Gordon, 2014; Lester et al., 2014; McGinty, 2000; Moursund, 1999; Ornstein, Levine, Gutek, & Vocke, 2015; Powell 2000; Ryan, 1995).

2.4 Culture and Digital Natives

Culture has been defined in many ways. Neito (1992) defined culture as "the ever-changing values, traditions, social and political relationships, and worldview shared by a group of people bound together by a combination of factors that can include a common history, geographic location, language, social class, and/or religion" (p. 306). According to Tylor (1958) culture is "that complex whole which includes knowledge, belief, art, morals, law, customs, and any other capabilities and habits acquired by man as a member of society" (p. 23). "Culture allows people to know who they are, where they are, and where they are going. Culture is not easily eroded; yet, when it is people can become lost, marginalized, fragmented, and befuddled" (Watkins, 2008, p.1001). The U.S. is a hodgepodge of cultures (often referred to as a melting pot) that is becoming an increasingly culturally homogenized society (Erickson, 1997). As a result, the educational system is multicultural, each student bringing aspects of their own culture into the classroom. Culture greatly affects teaching and learning because it "includes institutions, language, values, religion, ideals, habits of thinking, artistic expressions, and patterns of social and interpersonal relationships" (Lum, 1996, p. 46). Many features of culture contribute to how individuals gain an understanding of themselves and the world around them (Norton, 2013).

Cultural trends in the U.S. have shifted over time. One example is the cultural shift to an age where the world gained Internet access and computer-based technologies and digital tools (Oblinger, & Oblinger, 2005; Sandars, & Morrison, 2007). Students who identify with digital culture adopt certain habits and share common traits such as digital language (Banks, 1993; Erickson, 1997; Gay, 2010; Slavin & Davis, 2006). Prensky (2001) stated, "Our students today are all native speakers of the digital language of computers, video games and the Internet" (p. 1). In fact, 21st century learners share a common cultural background; they have all grown up using technology. Because 21st century learners have known only digital culture, optimistically, teachers can embrace technology to activate students' background knowledge to increase student achievement (Gay, 2010; Prensky, 2001). Implementing technology into the classroom can connect school learning to the 21st century skills students will need in the real-world (Clark, & Ernst, 2009a; Sardone & Devlin-Scherer, 2010). Conole et al. (2008) found that students were sophisticated users of technology and used technology for personal needs and to support their learning. Thus, when teachers utilize technology, the curriculum is more likely to become culturally relevant to 21st century learners.

Prensky (2001) coined the terms "digital natives" and "digital immigrants." Digital natives are 21st century learners who have been surrounded by and have grown up with the arrival and dissemination of the digital technology of the digital age. Digital immigrants are individuals that were born prior to the digital age who have had to adapt to the new era (Prensky, 2001). Prensky (2001) states, "our Digital Immigrant instructors, who speak an outdated language (that of the pre-digital age), are struggling to teach a population that speaks an entirely new language" (p. 1). Digital natives are not the same learners our educational system was designed for. "It is now clear that as a result of this ubiquitous environment and the sheer volume of their interaction with it, today's students think and process information fundamentally differently from their predecessors" (Prensky, 2001, p. 1). Digital natives' brains have changed and they think differently simply because they've experienced things differently from those born in the pre-digital age (Prensky, 2001). Based on these different cultures, digital immigrants need to move out of their comfort zones to accommodate their digital native students who are innately with their technological world.

In addition to educators having different backgrounds, there are other significant differences between teachers that are digital natives and digital immigrants. Digital immigrant teachers are serious minded, speak an outdated language, prefer to teach and learn things separately, and show or explain each stage in a process (Prensky, 2001). Digital immigrant teachers assume that what worked for them in their formal education should work for the current generation. By shifting from primarily using TDI to using learning technologies that students are familiar with, digital immigrant teachers have a better chance of reaching their 21st century learners (Prensky, 2001). In contrast, teachers that are digital natives like to network, are accustomed to getting information quickly, would rather perform multiple operations or tasks simultaneously, prefer computer games, and desire visual representations over text. Digital natives resist old methods and find sitting and listening to lectures boring and painful to pay attention to for long periods of time. Even though digital immigrants' views of education differ from digital natives, it is important for digital immigrants to use technology in the teaching and learning process to meet the needs of technology native students (Prensky, 2001).

Students born into the digital age have significant characteristics in common. They process information differently, have had extensive exposure to technology, and are familiar with different types of multimedia (Prensky, 2001). These characteristics impact the ways that we have to teach digital natives. Digital native's learning styles and methods used to process information are different from earlier generations that learned using print (Prensky, 2001). Nowadays, digital natives are exposed to technology early in life and gain new knowledge best through digital pathways. Natives spend a lot of time watching television, working on computers, playing video games, or surfing on the Internet. They spend more time using digital media and devices than playing outside or reading books (Prensky, 2001). Even younger kids and babies are wired up and tuned in with learning tablets like Leapfrog, MobiGo, and InnoTab. The digital games on these tablets can be used for enhancing and strengthening literacy skills, and teaching children to read (Dörner et al., 2016; Ronimus et al., 2014). According to Prensky (2001) it is important for 21st century educators to also embrace using these types of technologies because they can enhance "parallel processing, graphics awareness, and random access" skills and "have profound implications" for learning (p.11). Because digital natives are already proficient using technology, digital immigrant teachers can incorporate DGBL into instruction to promote student engagement through active learning opportunities.

2.5 Digital Learning Tools

Digital learning tools can be incorporated into instruction to facilitate student learning. The affordances of digital learning tools are limitless when they are made accessible to students. Handheld devices, laptop computers (laptops), 3D virtual environments, and educational games are just a few digital learning tools that afford learners to complete tasks more effectively and efficiently (Freidhoff, 2008).

Affordances

Handheld Devices. According to researchers, (e.g., Churchill & Churchill, 2008; Klopfer, Squire, & Jenkins, 2002; Patten, Sánchez, & Tangney, 2006) there are several educational affordances of handheld devices. Churchill and Churchill (2008) described five educational affordances: (1) multimedia-access tool, as handheld devices can deliver courseware, multimedia resources, and other subject matter; (2) connectivity tool, as handheld devices allow students to connect with others, engage in discussions, ask questions, get instant feedback, exchange ideas, and share information; (3) capture tool, as handhelds enable students to take photos and document their learning experiences; (4) representational tool, as handhelds allow students to create representations and share their knowledge visually; (5) analytical tool, as handhelds allow students to input, display, represent and analyze data in graphs, concept maps, diagrams, and spreadsheets (Churchill & Churchill, 2008). Klopfer et al. (2002) also described five affordances: (1) portability, as handhelds can be transported wherever the user goes; (2) social interactivity, as handhelds allow users to collaborate with others; (3) context sensitivity, as handhelds are capable of gathering and exchanging real and simulated data; (4) connectivity, as handhelds have the ability to provide immediate feedback and connect users to a common wireless network; and (5) individuality, as handhelds can be used to scaffold information specific to individual learner needs. Patten, Sánchez, and Tangney (2006) described seven affordances of applications for handheld devices: (1) administration applications (e.g., calendars and grade books) allow users to store, retrieve, view and share information, as well as schedule events, meetings, and appointments; (2) referential applications (e.g., digital books, digital libraries, Google Dictionary, Google Translate, and Evernote) allow users to access educational content in the classroom or alternate learning environment; (3) interactive applications (e.g., Quizlet) allows users to study, practice, and retain information being learned; (4) micro-world applications (e.g., GeoGebra*)* are virtual manipulatives that allow learners to gain new knowledge through experimentation; (5) data collection applications (e.g., Numbers or

Microsoft Excel) have the ability to perform calculations, manage lists, and record, store, organize, and access data and information; (6) location awareness applications (e.g., Foursquare and museum guides) present users with content based on their geographical location; and (7) collaboration applications (e.g., Google Docs) afford users to share calendars, organize schedules, work with peers, and share knowledge to achieve learning goals and objectives (Patten et al., 2006). Handheld devices can be used in DGBL to assist learners to boost their productivity in the learning process. Most handheld devices have the same features and capabilities of standard laptops just on a smaller scale (Churchill & Churchill, 2008).

Laptops. Laptops are mobile computers that offer students access to educational resources and personalized learning experiences. They extend learning beyond the walls of the school classroom and help students with organization, collaboration, and academic tasks such as conducting research (Cengiz. Gulek, & Demirtas, 2005; Kay & Lauricella, 2011; Lindorth & Bergquist, 2010). Laptops afford students to connect, communicate, and collaborate with others, share information and learning resources, receive instant feedback, and learn subject specific and cross-curricular content (Aguilar-Roca, Williams, & O'Dowd, 2012; Barak, Lipson, & Lerman, 2006; Nicol & MacLeod, 2005; Russell, Bebell, & Higgins, 2004). Student-centered instructional approaches like DGBL that engage students and promote active learning can be integrated into instruction using laptops (Finn & Inman, 2004; Fried, 2008; Kay & Lauricella, 2011; Lindorth & Bergquist, 2010; Suhr, Hernandez, & Warschauer, 2010).

3D Virtual Environments. Dalgarno and Lee (2010) proposed that 3D virtual environments can be used to facilitate learning tasks that: (1) develop spatial sense and geometric reasoning; (2) would be impossible to attempt in the real world; (3) increase intrinsic motivation and engagement; (4) improve the transfer of knowledge and skills to real life situations; and (5) enable collaborative learning that is not possible with 2D environments. Students can take virtual field trips, investigate future careers, and explore, construct, and manipulate objects in 3D virtual environments (Barkand & Kush, 2009; Chaudhary, 2008; Lim, Nonis, & Hedberg, 2006; Wang, 2012). 3D virtual environments provide opportunities for students to strengthen collaboration skills, acquire new knowledge, and develop a better understanding of instructional content (Boniolo & Spadaro, 2010; Bouta, Retalis, & Paraskeva, 2012; Dillenbourg, 1999; Jones, Squires, & Hicks, 2008). Students can also immerse themselves in 3D virtual environments to interact with peers, practice real world skills, solve real-world problems, and participate in inquiry and discovery-based learning (Chaudhary, 2008; Edirisingha, Nie, Pluciennik, & Young, 2009). DGBL can enable students to interact in 3D virtual environments to facilitate learning.

Educational Games. Educational games are used in child care, preschools, elementary schools, secondary schools, and university classrooms (Dörner, Göbel, Effelsberg, Wiemeyer, 2016; Neville, Shelton, & McInnis, 2009; Shute, Rieber, & Van Eck, 2011). These types of digital learning tools can be fun, engaging, interactive, and customized to meet the needs and interests of diverse students (Schrader, Lawless, & Deniz, 2010; Young et al., 2012; Yurov, Beasley, Kwak, & Floyd, 2014). Educational games can provide learners with opportunities to interact, collaborate, role play, and solve authentic problems (Erhel & Jamet, 2013; Vrasidas & Solomou, 2013). Educational games can develop students' conceptual understanding and basic processing skills (Annetta, Minogue, Holmes, & Cheng, 2009; Barab et al., 2007; Clark et al., 2011; Neulight, Kafai, Kao, Foley, & Galas, 2007). Educational games encourage critical and higher order thinking, and teach students to transfer learning to real world situations (Barab et a., 2009; Busch et al., 2013; Ott & Pozzi, 2012; Li, 2012; Sardone & Devlin-Scherer, 2010; Yang, 2010). Papastergiou (2009) found that educational games enhanced students' knowledge of embedded course content and subject matter, and encouraged positive student motivation, knowledge sharing, and engagement with content. Educational games encompass methods of teaching that shift the responsibility of learning from the teacher to the student (Shute, Rieber, & Van Eck, 2011). Teacher perceptions of the value of educational games can influence whether they are integrated into the learning environment (Sardone & Devlin-Scherer, 2010). DGBL incorporates educational games into instruction with the goal of engaging, supporting, and educating students.

Constraints

Digital learning tools offer a lot of affordances to students but they also have constraints that can make completing tasks less effective and efficient. For example, spell-checker applications can identify misspelled words in text but they do not help students improve proofreading and editing skills (Freidhoff, 2008). Additionally, digital learning tools may hinder productivity and frustrate students when they lag, freeze, or glitch (deNoyelles & Seo, 2012; Papastergiou, 2009; Merchant et al., 2012; Yang, 2012). These technical problems can cause students to lose assignments and other materials and possibly prevent teachers from integrating digital learning tools into instruction because they disrupt the learning process (Cheng, Lou, Kuo, & Shih, 2013; Omale, Hung, Luetkehans & Cooke-Plagwitz, 2009; Lim et al., 2006). Other constraints of digital learning tools include incorrect content, and misaligned learning objectives and assessments (Baek, 2008; Cheng et al., 2013; De Grove, Bourgonjon, & Van Looy, 2012; Tsai, Yu, & Hsiao, 2012).

2.6 Digital Games

According to Gee (2009), “Digital games are, at their heart, problem-solving spaces that use continual learning and provide pathways to mastery through entertainment and pleasure” (p. 67). Digital games engage learners, encourage active student participation, and support learning through "cognitive workouts" that stimulate the mind, develop hand-eye coordination, and teach critical thinking, problem-solving, and decision-making skills (Levine, 2006, p.13). “Even when the context of the game is not directly relevant to the subject area, the transferable skills associated with problem-solving, such as lateral thinking, information gathering and analysis, and developing and testing solutions, can be valuable nonetheless” (Whitton, 2010, p. 51). Further, when presented in the form of a digital game, children have the freedom to play, pretend, practice, reflect, strategize, formulate hypotheses, think intuitively, and learn by doing (Gee, 2007a; Klopfer, Osterweil, & Salen, 2009).

Several research studies found that student's attitudes, perceptions, motivation, and achievement improved after using digital games in instruction (Cheng, & Su, 2012; Divjak, & Tomić, 2011; Kebritchi, Hirumi, & Bai, 2010). Ke (2008) revealed that fourth and fifth-grade students' attitude towards math improved after a five-week summer math program that used digital games in instruction (Ke, 2008). Wilson et al. (2006) used an adaptive digital game to remediate nine elementary students with math difficulties and noted an increase in their math performance and attitudes towards math. Digital games can accommodate different learning styles, promote self-directed learning, build flexible thinking skills, and encourage practice, socialization, and experimentation (Dini, 2012; Gee, 2007b; Prensky, 2003b; Rapini, 2012). Wang & Sun (2011) proposed that reward systems (e.g., scoring, item granting, achievement, entertainment, feedback, and unlocking mechanism) are essential in digital games that are used for learning. Reward systems can inspire intrinsic motivation in a learner while offering extrinsic rewards (Blizzard, 2004; Fitz-Walter, & Tjondronegoro, 2011; Hallford & Hallford, 2002; Hamari & Eranti, 2011; Malone, 1981; Jakobsson, 2011; Wang & Sun, 2011). DGBL uses engaging risk-free digital games to teach concepts through gameplay.

2.7 Digital Game-Based Learning

DGBL is a student-centered approach to teaching and learning that involves the efficient use of virtual learning environments, 21st century learning technologies, and digital games to reach specific learning objectives and anticipated learner outcomes (Dziorny, 2005; Gee, 2007a; Hamari, & Nousiainen, 2015; Teed, 2013).

> "Digital game-based learning is a competitive activity in which students are set educational goals intended to promote knowledge acquisition. The games may either be designed to promote learning or the development of cognitive skills, or else take the form of simulations allowing learners to practice their skills in a virtual environment" (Erhel, & Jamet, 2013, p. 156).

DGBL facilitates knowledge acquisition, boosts memorization skills, provides students with immediate and constructive feedback, promotes active learning, and develops reasoning, decision-making, and problem-solving skills (Chaudhary, 2008; Ding, Guan, & Yu, 2017; McFarlane, Sparrowhawk & Heald, 2002; Oblinger & Oblinger, 2005; Pareto et al., 2011; Sardone & Devlin-Scherer, 2010; Shute, Rieber, & Van Eck, 2011; Tsai, Yu, & Hsiao, 2012). This type of learning approach can support and assess student learning and performance, encourage critical thinking, and increase student engagement (Barab et al., 2009; Chaudhary, 2008; Cicchino, 2015; Gee, 2007a; Hall, Meyer, & Rose, 2015; Levine, 2006; Prensky, 2003a; Van Eck, 2006). DGBL can enhance instruction, teach transferable skills, and motivate struggling students (All, Nunez Castellar, & Van Looy, 2014; Clark, & Ernst, 2009b; Ke, 2008; Papastergiou, 2009; Van Eck, 2006). It has the ability to promote intrinsic motivation, challenge learners' existing knowledge base, and provide them with authentic learning activities and experiences that spark their interest and curiosities (Erhel & Jamet, 2013; Lepper, 1988; Malone, 1981; Ryan, Rigby, & Przybylski, 2006; Sardone & Devlin-Scherer, 2010; Uysal & Yildirim, 2016; Yang, 2010). Researchers have found that DGBL can produce extended neuro-cognitive demands on working and episodic memory and provide players with memorable events that involve visual and auditory images (Baniqued et al., 2013; Granic, Lobel, & Engels, 2014; Gredler, 1997; Salthouse, 2010; Tulving, 1972; Wheeler, Stuss, & Tulving, 1997). DGBL has been shown to enrich teaching and learning, promote student lesson engagement, and provide student-centered instruction that meets children's individual needs (All, Nunez Castellar, & Van Looy, 2014; Chaudhary, 2008; Cheng & Su, 2012; Erhel, & Jamet, 2013; Lester et al., 2014; Prensky, 2003a; Rapini, 2012; Schaaf, 2012).

The term, "Gamification" is often confused with "DGBL" because it incorporates game-based mechanics and elements (eg., rewards, tasks, incentives, point systems, badges, experience points, levels, and leaderboards) to a task or activity to boost performance, measure progress toward goals and objectives, and promote intrinsic motivation (Blizzard, 2004; Dörner, Göbel, Effelsberg, Wiemeyer, 2016; Hallford & Hallford, 2002; Hoffmann, Huff, Patterson, & Nietfeld, 2009; Johnson et al., 2013; Kapp, 2012; Lee & Hammer, 2011; Sicart, 2008; Wang & Sun, 2011). "Gamification is using game-based mechanics, aesthetics and game thinking to engage people, motivate action, promote learning, and solve problems" (Kapp, 2012, p. 10). The overall goal of gamification is to "gamify" the user's experience by creating a system that motivates players to engage in an activity or tasks and reach a goal or objective (Johnson et al., 2013; Kapp, 2012). Unlike gamification, however, DGBL uses game elements to teach subject matter in ways that are more meaningful, relevant, and appealing to 21st century students (Cheng, & Su, 2012; Hamari, & Nousiainen, 2015; Shute, Rieber, & Van Eck, 2011; Teed, 2013).

Hwang and Wu (2012) analyzed 137 articles based on the emerging trends of DGBL between 2001 and 2010. The authors discovered that in the first five years the research agenda was dominated by studies on motivation, attitudes, and perceptions. Their study also showed that DGBL research contributions quadrupled from 2006 to 2010, implying that DGBL became more of a research priority (Hwang, & Wu, 2012). Bragg (2003) conducted a 14-week study examining the effect DGBL had on 210 fifth and sixth grade students' attitudes toward mathematics and game playing. The study concluded that DGBL may assist students in developing positive attitudes toward math and game playing (Bragg, 2003). Scholars have also found DGBL to be more effective than TDI at improving learning and motivation (Chaudhary, 2008; Cheng, & Su, 2012; MacKenzie, 2014; Zheng, & Spires, 2014; Young et al., 2012). Several studies (e.g., Ahmad & Latih, 2010; Katmada, Mavridis, & Tsiatsos, 2014; Lee, 2009; Pareto et al., 2011; Zavaleta et al., 2005) found that DGBL improved students' conceptual understanding, knowledge acquisition, and mathematical reasoning. Bourgonjon et al. (2013) examined teachers' beliefs, perceptions, and acceptance of DGBL and found that very few teachers felt comfortable using the approach in their teaching practice. Their research study provided valuable insight into the importance of exposing pre-service teachers to 21st century approaches to learning (Bourgonjon et al., 2013). Based on the analysis of these studies, DGBL is an emerging teaching approach that has been found effective at influencing students' retention, motivation, learning, and formation of positive attitudes toward mathematics (Divjak & Tomić, 2011; Erhel & Jamet, 2013; Iacovides et al., 2011; Kebritchi, Hirumi, & Bai, 2010; Lin & Liu, 2009; MacKenzie, 2014; Papastergiou, 2009; Pilli & Aksu, 2013; Woo, 2014). However, an area of DGBL not yet thoroughly explored is its use with at-risk students to support their learning of mathematics.

Dream Box Learning Platform

Dream Box Learning (DreamBox) is an online program (k-8), which uses adaptive, game-based technology to support learning in mathematics (Dream Box Learning, 2018). Developmentally appropriate interactive games activate students' interest, recall prior knowledge, and support the acquisition of new knowledge. Text to speech technology can even assist students with poor reading and/or comprehension skills. After an initial lesson, DreamBox places students at an appropriate starting point in its curriculum. As students work through each lesson, DreamBox tracks and evaluates their problem solving strategies and adjusts the difficulty level to strengthen conceptual understanding in each subsequent lesson. This differentiated instruction, with flexible pacing and on-demand support when needed, gives students control over their own learning.

The DreamBox platform is aligned with the 2016 Mathematics Standards of Learning (SOL) for Virginia Public Schools. Teachers have access to informative and detailed reports about student usage, time on task, progress through the curriculum, and up to date achievement levels. With these reports teachers are able to make appropriate instructional decisions on how to support students in the classroom (Dream Box Learning, 2018). As such, DreamBox is an ideal platform for exploring the use of DGBL to promote improved learning of mathematics, specifically for at-risk students.

To determine the most appropriate research design for using DreamBox in this study, a body of prior empirical research on DGBL achievement in mathematics and student perceptions were reviewed.

A summary of the key research designs are as follows: Pope and Mangram (2015) used a pre-posttest to measure the number sense of two groups (comparison and intervention group) of third grade students; Hussain, Tan, and Idris (2014) used a pre-posttest to assess a digital game that was designed to teach whole numbers to remedial math students; Swearingen (2011) used a standardized pre-posttest to determine whether playing an interdisciplinary massively multiplayer online game (MMOG) supported mathematics achievement; Lee (2009) used a pre-post quiz to assess the effectiveness of a fractions game with 8th grade students; Wilson et al. (2006) used a pre-posttest to assess an adaptive digital game designed to remediate nine elementary students with math difficulties; Karafili and Stana (2012) used a Likert type questionnaire to gather data about the inclusion of DGBL into the teaching process; Kebritchi, Hirumi, and Bai (2010) used pre-post surveys for assessing both student motivation and overall mathematics achievement; Ke (2008) used a pre-posttest, pre-post attitude survey, and pre-post self-report questionnaire to examine fourth and fifth graders' cognitive math achievement via the use of educational computer games in a summer math program; Bourgonjon (2015) used a five point Likert scale (1= strongly disagree; 5= strongly agree) survey to measure students' perceptions about the use of video games in the classroom.

The single, one-group pretest-posttest research design of these studies (Hussain, Tan, & Idris, 2014; Ke, 2008; Lee, 2009; Swearingen, 2011; Wilson et al., 2006) support the methods of this study. The proposed research had a similar goal, to assess a single group of participants by giving a pretest, implementing a DGBL intervention, and then giving a posttest, which was the same as the pretest (McMillian, 2012). The effect of the intervention was determined by comparing participants' pretest scores to their posttest scores, suggesting that the change between pre-post scores was due to the DGBL intervention. Additionally, the Likert scale surveys used in Bourgonjon, 2015; Karafili & Stana, 2012; Ke, 2008; Kebritchi, Hirumi, & Bai, 2010, were useful for measuring students' perceptions about DGBL. A Likert scale survey was appropriate for this study because measuring participants' perceptions before and after a DGBL intervention could suggest that any change in participants' perceptions occurred as a result of the DGBL intervention. The method selected for this study will be discussed in Chapter 3.

CHAPTER III: METHOD

This chapter explains the method used to complete the sequential explanatory mixed methods research study, including the research questions and the appropriateness of the research design. It describes the participants, setting, instruments, and procedures used for data generation, collection and analysis. This description is presented in ten sections (3.1-3.10). The first, second, and third sections include the research questions, research design, and participants. The fourth, fifth, and sixth sections discuss the setting, instrumentation, and implementation fidelity. The seventh, eighth, and ninth sections include, implementation procedures, data collection, and the procedures used to analyze data. Lastly, the tenth section summarized the chapter.

3.1 Research Questions

The following research questions guided this study:

RQ1: To what extent are differences evident in students' Ratios and Proportional Relationships pre and post test scores following the implementation of digital game-based learning (DGBL) into regular math instruction?

RQ2: How do the post Ratios and Proportional Relationships Test scores of student participants differ from the Ratios and Proportional Relationships Posttest cut score?

RQ3: What changes in student perceptions of DGBL occur following implementation of the mathematics intervention?

Table 2 presents the alignment between the research questions, data sources, and the procedures used in analyzing the data.

Table 2.

Alignment of RQs, Data Sources, and Analyses Procedures

Research Questions	Data Sources	Data Analyses
RQ1: To what extent are differences evident in students' Ratios and Proportional Relationships Test scores following the implementation of DGBL into regular math instruction?	Quantitative • Ratios and Proportional Relationships Pretest • Ratios and Proportional Relationships Posttest	• Descriptive statistics • Two-tailed, paired *t*-test
RQ2: How do the post Ratios and Proportional Relationships Test scores of student participants differ from the Ratios and Proportional Relationships Posttest cut score?	Quantitative • Ratios and Proportional Relationships Posttest • Ratios and Proportional Relationships Posttest cut score	• Descriptive statistics • Two tailed, one sample *t*-test
RQ3: What changes in student perceptions of DGBL occur following implementation of the mathematics intervention?	Quantitative • SPoDGBLS (Pre) • SPoDGBLS (Post) Qualitative • Small Group Interview	• Descriptive statistics • Two-tailed, paired *t*-test • Content Analysis

3.2 Research Design

According to McMillan (2012), "research design refers to the plan for carrying out a study" (p.13). This study followed a sequential explanatory mixed methods approach using a one-group, pretest-posttest research design (Figure 2) to collect data from a group of sixth grade students before and after DGBL intervention to determine if a relation existed with improved scores on the Ratios and Proportional Relationships Posttest (Appendix A) scores. Ratios and Proportional Relationships Test (Appendix A) scores were collected from the pre and posttest administrations. *Students' Perceptions of Digital Game-Based Learning Survey* (SPoDGBLS) (Appendix B) responses were also collected from participants before (pre) and after (post) the intervention to determine the changes in student perceptions of DGBL following implementation of the mathematics intervention. Descriptive statistics (e.g., mean, and standard deviation) were used to describe participants' pre and post data and inferential statistics to determine whether differences were statistically significant (Howell, 2011). This design allowed the degree of change to be measured from pretest to posttest that occurred as a result of the intervention (McMillian, 2012). Therefore, the use of a single one-group pretest-posttest research design was deemed most appropriate for this study (McMillian, 2012; Thiese, 2014).

Group		Pretest		Intervention		Posttest
A	⟶	O_1 O_2	⟶	X_1	⟶	O_1 O_2

Figure 2: Research Design

3.3 Participants

This sequential explanatory mixed methods research study was conducted in three phases. All three phases included a convenience sample of 21 sixth grade students enrolled at a large suburban middle school in Virginia. Participants were sixth grade students preassigned to a Middle School Math Course 1 class by the administrative team of the middle school and grouped together according to similar performance in mathematics. Convenience sampling was appropriate because the primary data source was a specific group of sixth graders that were readily available and suitable for the study (Hays, & Singh, 2012). Participants constituted approximately 5.8 % of the sixth grade students at the middle school. Participant demographics are shown below in Table 3.

Table 3.

Participant Demographics

Characteristics		Number of Participants (n=21)	Percentage
Gender			
	Female	17	80.95%
	Male	4	19.05 %
Age in years			
	11	18	85.71%
	12	3	14.29%
Race			
	African American	9	42.86%
	Hispanic	6	28.57%
	Caucasian	4	19.05%
	Asian	1	4.76%
	Asian Pacific Islander/Native American	1	4.76%
Socioeconomic status			
	Low	21	100 %
	Middle	0	0 %
	High	0	0 %

Participants were from low socioeconomic status (SES) households and ranged between the ages of 11 and 12. A majority of the participants were female (80.95%), 11 years old (85.71%), and African American (42.86%). Participants were similar in grade, SES, and achievement levels on the Ratios and Proportional Relationships Pretest (Appendix A) administered at the beginning of middle school. Any sixth grade student that did not take the Ratios and Proportional Relationships Pretest (Appendix A) in sixth grade was not included as a participant. They received the same intervention but no data were collected from them.

3.4 Setting

The intervention was implemented in a sixth grade math classroom during the 2020–2021 school year at a large suburban middle school in Virginia. The middle school had 1100 students and a 15:1 student-teacher ratio and followed a 90-minute alternate day block schedule.

Approximately 28.3% of the student population received Response to Intervention (RTI) support services. The school's racial and ethnic makeup was approximately 36.3% Asian, 28.7% Caucasian, 18.6% African American, 10.9% Hispanic, 4.9% Multi-Ethnic, and .6% Asian Pacific Islander/Native American. In an effort to provide students with a level of instruction appropriate for their individual needs and learning styles, students enrolled at the targeted middle school were grouped by ability level with approximately 26 students in each class.

3.5 Instrumentation

The key variables targeted in this study were measured by two instruments: The Ratios and Proportional Relationships Test (Appendix A) and the SPoDGBLS (Appendix B). The Ratios and Proportional Relationships Test (Appendix A) is a performance assessment administered annually to sixth grade students that measures academic achievement and calculates their academic growth. Test results provide an estimate of a student's math achievement status relative to other students who take the same assessment. The Ratios and Proportional Relationships Test (Appendix A) reveals the skills and concepts participants have acquired and predicts what they are ready to learn. The SPoDGBLS (Appendix B) was developed based on the five constructs by Bourgonjon (2015) for understanding and predicting students' acceptance of video games in the classroom. The model is an extension of the Technology Acceptance Model (TAM) developed by Davis (1989). Permission was obtained (Appendix E) from Dr. Bourgonjon via email (personal communique, June 12, 2018) to adapt his constructs to gather information about students' perceptions of their learning experiences with regard to the use of a digital game-based approach for learning mathematics. Survey development, along with procedures used to establish reliability, validity (construct/content), and readability are described in the following sections.

Survey Instrument Development, Reliability, Validity, and Readability

The process of developing and establishing the reliability, validity, and readability of the SPoDGBLS (Appendix B) is described in this subsection.

Instrument Development. The items (questions) used to develop the SPoDGBLS (Appendix B) were derived from Bourgonjon's (2015) Items by Construct (Appendix F) list. Modifications to the constructs listed was necessary in order to update select language to better support the current study (i.e., "video games" was replaced by "digital games"). The following procedures were used to develop the instrument.

- Bourgonjon's (2015) Items by Construct (Appendix F) was copied verbatim into a Microsoft Word (MS Word) document.
- The order of the constructs was changed to have shorter items (questions) before longer items (questions). This was done to have items (questions) that were easier to read and understand presented to participants before those that were more difficult.
- Each construct was reviewed by the researcher for alignment with the current study.
- Any terms deemed as outdated or otherwise inappropriate for the study by the researcher were deleted and replaced with terms that would provide a better understanding of the items (questions).
- All replacement terms were highlighted.
- Each item (question) was numbered, placed in sequential order, and saved in MS Word.
- All 22 items were copied and pasted into the table on the Content and Construct Inter-rater Validation Form (CaCIVF) (Appendix G).

After development the instrument was then ready for determining reliability, validity, and readability.

Instrument Reliability. The Items by Construct by Bourgonjon (2015) (Appendix F) was consulted to develop the items (questions) used in the SPoDGBLS (Appendix B). The internal reliability of the items addressing the different constructs in the model was established through Bourgonjon's research (2015) using Cronbach's alpha and found to exceed the common threshold of .70 (Heo, Kim, & Faith, 2015; Tavakol & Dennick, 2011). The original constructs: Experience with games (α=.895), Ease of use (α=.871), Learning opportunities (α=.875), Usefulness (α=.926), and Preference for video games (α=.925) all exhibited acceptable internal reliability (Bourgonjon, 2015). The SPoDGBLS (Appendix B) instrument consisted of 22 items (questions) measuring participant perceptions using a 5-point Likert scale (1= strongly disagree; 5= strongly agree) of the following factors: 1) Experience with digital games, 2) Ease of use, 3) Learning opportunities, 4) Usefulness, and 5) Preference for digital games. Given that just a couple of terms from Bourgonjon's (2015) original constructs were modified and the original constructs exhibited high levels of internal reliability the researcher accepted the previous reliability. To establish instrument validity, the researcher selected a panel of experts who had expertise in integrating educational technologies into instruction.

Instrument Validity. The SPoDGBLS (Appendix B) instrument was derived from the Items by Construct by Bourgonjon (2015) (Appendix F) and although the five constructs that measured students' perceptions were believed to be transferable, validation by the expert panel was required. The panel of experts evaluated the SPoDGBLS (Appendix B) items (questions) for content and construct validity following the procedures described below.

Expert Panel Selection. Fraenkel and Wallen (2009) characterizes an expert for validating content and construct as an individual with extensive knowledge about what is being measured who can competently judge the adequacy of an instrument. Based on suggestions from

Lynn (1986) at least three experts are needed for instrument validation. Guided by this approach, the researcher identified and selected three seasoned experts with experience evaluating instruments and expertise in integrating educational technologies into instruction to serve on the content and construct validity evaluation panel. A general agreement amongst the panel of experts was the goal of the instrument evaluation, which was achieved by establishing a satisfactory level of inter-rater reliability.

Inter-rater Reliability. Inter-rater reliability is the degree of agreement amongst a pair of or a collective group of raters. Fleiss' kappa, was used to assess the consistency amongst the three raters after they completed the CaCIVF (Appendix G) (Fleiss, 1971). The consistency of the answers was measured using the kappa formula below:

$$\mathrm{K} = \frac{\bar{P} - \bar{\mathrm{P}}_e}{1 - \bar{\mathrm{P}}_e}$$

Kappa ranges from 0 to 1 where: κ = 1 indicates a complete agreement and κ = 0 indicates no agreement other than what would be expected by chance alone (Fleiss, 1971). This process was followed for establishing inter-rater reliability and applied in the instrument review process to determine both content and construct validity.

Instrument Review Process. Establishing content and construct validity required a review by a panel of experts who had expertise in integrating educational technologies into instruction. Panelists received an electronic copy of the CaCIVF (Appendix G) via email. The CaCIVF (Appendix G) contained highlighted terms within items (questions) deemed inappropriate for the SPoDGBLS (Appendix B) instrument and instructions on how the experts were to assess the items (questions) for content and construct validity. The instructions followed for the instrument review process were: (a) read the purpose of the SPoDGBLS (Appendix B) instrument and then follow the directions for establishing content and construct validity for each item (b) assess the instrument for content validity by evaluating the highlighted term within each question and decide whether or not it is content valid, (c) assess the instrument for construct validity by evaluating the highlighted term within each question and decide whether or not it is construct valid, (d) provide alternate terms, if the highlighted term is not content or construct valid, in the designated area on the table, and (e) return the completed form via email within the two-week timeframe provided. After the panel of experts read the instructions on how to assess the items (questions) on the CaCIVF (Appendix G) the instrument was then ready to be validated.

Content and Construct Analysis. Panelists were emailed the CaCIVF (Appendix G) shortly after being selected to the evaluation panel. The purpose of the SPoDGBLS (Appendix B) was provided before the instructions on how to perform content and construct analysis. The procedures for validating both content and construct were conducted concurrently. The goal of the analysis was for all evaluation panelists to reach an agreement regarding the construct and content validity of each item on the SPoDGBLS (Appendix B) instrument.

Procedures for Establishing Content and Construct Validity. To establish content and construct validity, all members of the evaluation panel were provided with the 22 items (questions) on the CaCIVF (Appendix G). Panelists were instructed to evaluate the highlighted term in each question and determine whether or not the item (question) was content valid and then decide whether or not it was construct valid. After each question panelists were presented with a column to circle yes if the item was content valid and no if it was not. Panelists were then presented with a second column to circle yes if the item was construct valid and no if it was not. If panelists found an item to be invalid for content or construct they were asked to provide an alternate term that would make the invalid item (question) valid. Only items that were deemed invalid by panelists were added to a new CaCIVF (Appendix G) with the recommended alternate term inserted and emailed back to the panelists for revaluation. This process continued until all survey items (questions) adequately represented the domain of content and construct to be measured. Results were then analyzed to determine the level of agreement for each question among panelists. A content validity index (CVI) was used to gauge the agreement among panelists regarding how essential each question was for the construct being measured. The content validity index is the mean of the content validity ratios for each item on the survey. To obtain the CVI Lawshe's (1975) Content Validity Ratio (CVR) formula was used: CVR = $(n_e - n/2)/(n/2)$. CVR values range from -1.0 to + 1.0; positive values indicate that at least half the panel members rated a question as valid. Lawshe's (1986) criteria for using 5 or less experts requires a minimum CVI score of .99 meaning that all of the experts should agree that a question is valid. If the CVI was .99 or greater the degree of agreement among panelists is deemed sufficient to determine the item is valid. Survey items (questions) with a CVI of less than .99 were deemed invalid and were sent back to the panel for further review. Content validity was established once the group reached a CVI of .99 for all items (questions). The process used to analyze key terms within items (questions) established an instrument that was both content and construct valid. After establishing validity, the readability level of the instrument was determined.

Instrument Readability. Readability tests are used to analyze text and predict what can be understood by a particular audience. To ensure the SPoDGBLS (Appendix B) could be read and understood by the targeted middle school population, two Flesch-Kincaid tests (Reading Ease and Grade Level) were conducted to determine the readability of the instrument (Flesch, 1948; Kincaid et al., 1975). Although both tests count the amount of words, characters, paragraphs, and sentences and calculate the average sentences per paragraph, words per sentence, and characters per word, they have different weighting factors. The Flesch Reading Ease formula is 206.835 – (1.015 x average sentence length) – (84.6 x average number of syllables per word). The Flesch-Kincaid Grade Level formula is (0.39 x average sentence length) + (11.8 x average number of syllables per word) – 15.59. The researcher used the formulae to determine the readability level of the SPoDGBLS instrument, which is reported in the results section.

After determining that the language in the SPoDGBLS (Appendix B) was at an appropriate reading level for sixth grade students, the instrument was prepared to be administered through "SurveyMonkey" to collect pre and post intervention data regarding participants' perceptions about their use of a digital game-based approach for learning mathematics. The SPoDGBLS (Appendix B) is similar in format to school climate surveys that students take at the end of a year to share their experiences about the school that they attend. Students select a response for each question presented to them on their computer screen and then scroll up to answer any questions that were not visible on the computer screen. According to Presser et al. (2004), "The visual presentation of information to the interviewer, as well as the design of auxiliary functions used by the interviewer in computer-assisted interviewing, are critical to creating effective instruments" (p.121). Therefore, careful attention was given to creating the instrument visually appealing and readable to sixth grade students.

3.6 Implementation Fidelity

Implementation fidelity refers to the extent an intervention was delivered as intended and implemented as proposed (Baer et al., 2007; Carroll, Nich, & Rounsaville, 1998; McMillan, 2012; Proctor et al., 2011). There are five specific dimensions in systematically implementing and determining the effectiveness of interventions (Barber, Sharpless, Klostermann, & McCarthy, 2007; Bellg et al., 2004; Dusenbury et al., 2003; Glasgow, Lichenstein, & Marcus, 2003; Martino, Ball, Nich, Frankforter, & Carroll, 2009; Powell & Diamond, 2013; Stein, et al., 2007). The first dimension, adherence, is conceptualized as the magnitude that the procedures and protocols were followed in an intervention (Breitenstein et al., 2010; Mellard, 2010; Barber, Liese, & Abrams, 2003; Waltz, Addis, Koerner, & Jacobson, 1993). Adhering to program protocols can help ensure that intervention objectives and goals are met and that shortcuts have been avoided (American Psychological Association, 2016; Barber et al., 2007; Barber, Sharpless, Klostermann, & McCarthy, 2007; Breitenstein et al., 2010; Epstein & Hundert, 2002; Stein, Sargent, & Rafaels, 2007). The second dimension refers to the amount of exposure (i.e., dosage) participants received of an intervention (Allen, Philliber, and Hoggson, 1990; Dusenbury, Brannigan, Falco, & Hansen, 2003). The third dimension, quality of delivery, "is defined as ratings of provider effectiveness which assess the extent to which a provider approaches a theoretical ideal in terms of delivering program content" (Dusenbury et al., 2003, p. 244). Quality of delivery is the standard a program was implemented and the degree in which instruction and course material was delivered (Dusenbury et al., 2003; Hansen, Graham, Wolkenstein, & Rohrbach, 1991; Hawkins, Abbott, Catalano, & Gillmore, 1991; Mellard, 2010; Tobler and Stratton, 1997). The fourth dimension, participant responsiveness, is the extent to which participants were engaged by or responded to intervention components (Dusenbury et al., 2003; Hawkins et al., 1991; Hansen, 1996; O'Donnell, 2008). The fifth dimension, program differentiation, identifies the features that make a program unique and distinguishes it from another (Dusenbury et al., 2003; Harachi et al., 1999; Mellard, 2010). Three of the five dimensions of fidelity (i.e., adherence, exposure, and participant responsiveness) were evaluated in this study using an Implementation Fidelity Log (Appendix H) to ensure that instructional practices and protocols were followed as precisely and consistently as planned (Breitenstein et al., 2010; Dusenbury et al., 2003; Mellard, 2010; Veenman, Denessen, van den Akker, & Van der Rijt, 2005).

Ensuring Fidelity

Fidelity is important because a poorly implemented intervention may yield inconsistent outcomes and lead to unreliable conclusions about the intervention (Bellg et al., 2004; Carroll et al., 2007; Glasgow, Lichenstein, & Marcus, 2003; Martino et al., 2009). To ensure that DreamBox was implemented with fidelity, the teacher filled out an Implementation Fidelity Log (Appendix H) designed to evaluate whether: (1) the intervention was delivered when it was intended; (2) participants were exposed to the full intervention; and (3) participants were actively participating in the intervention. To further ensure fidelity, direct access was granted to the researcher to the classroom teacher's DreamBox insight dashboard to track participants' usage, progress, and proficiency data. Student reports were checked weekly and an intervention log (Appendix I) was kept for 5 weeks to assure that participants were spending a minimum of 60 minutes per week using the intervention. If these requirements were not being met, the classroom teacher was notified and asked to encourage participants to spend more time using the DGBL intervention.

3.7 Implementation Procedures

Institutional Review Board

Prior to collecting and recording any data research approval letters were obtained from the school division (Appendix P) participating in the study and the Virginia Tech Institutional Review Board (IRB) (Appendix J). Digital packets were prepared that contained informed consent documents (parent consent, student assent, and data release consent form) providing details (e.g. purpose, rationale, procedures, duration) about the research and were securely emailed to students through the school learning management system to be shared with their parents. Only students who returned appropriately signed informed consent documents could participate in the study (Appendices K, L, & M).

Intervention Implementation

Implementation of intervention began the seventh week of the first marking period fall 2020 and ended the third week of the second marking period fall 2020. The study was conducted in three phases: (1) Student Introduction to Research Study; (2) 5 Week DGBL Intervention; and (3) Post Intervention, and the procedures followed in each are outlined below.

- **Phase I: Student Introduction to Research Study**
    - On the first day DGBL was to be implemented in class, the teacher provided study participants a unique access link to a 22 question survey in "Survey Monkey" on the board.
    - Study participants used school issued computers to insert the link into a web browser to access and complete the SPoDGBLS (Appendix B).
    - Survey responses were recorded, kept confidential, and saved directly into the graduate researcher's password protected SurveyMonkey account.
- **Phase II: 5 Week DGBL Intervention**
    - The intervention was implemented by the classroom teacher for 5 weeks as part of the regular math instruction. The teacher presented DGBL five days per week during the last 15 minutes of each class.

    - Each day following regular math instruction, the classroom teacher prompted participants to use their school issued computers to log in to DreamBox to complete targeted, individualized lessons that were automatically generated for them based on their grade level, mathematical ability, and what they are ready to learn.
    - Participants worked on DreamBox lessons for a minimum of 60 minutes per week of the 5-week study.
    - A fully completed DreamBox lesson is indicated when participants have filled in the three stars in the lesson completion meter at the bottom of the computer screen.
- **Phase III: Post Intervention**
    - At the conclusion of the study the third week of the second marking period, the teacher provided participants with another unique access link and asked them to complete the post-intervention SPoDGBLS (Appendix C).
    - Survey responses were recorded, kept confidential, and saved directly into the graduate researcher's password protected SurveyMonkey account.
    - During the week immediately following the conclusion of the study the researcher conducted three, small group, semi-structured, open-ended interviews. Each group was comprised of two students. All three groups were purposefully selected to include students who gave low, middle, and high ratings on the post-intervention SPoDGBLS (Appendix C).

3.8 Data Collection

The sources of data collection utilized in this study included the Ratios and Proportional Relationships Test (Appendix A), the SPoDGBLS (Appendix B), and small group, semi-structured, open-ended interviews. Pre and post intervention data were collected and recorded in two stages as outlined below. All identifying information or data collected from participants was kept confidential and protected from unauthorized disclosure. To ensure the confidentiality of participant data, each participant was assigned a pseudonym (for instance, John Doe = Student 1).

Pre Intervention Data Collection:

- Ratios and Proportional Relationships Pretest (Appendix A). Participants' Ratios and Proportional Relationships Pretest (Appendix A) data from middle school and associated demographics (e.g., gender, age, and race) were recorded in a password protected Excel file by the division-level research administrator and saved on a password protected computer. The test data were used to estimate participants' math achievement levels and record select demographic data. The research administrator provided the password protected Excel file and password, which was saved on the researcher's password protected computer.
- Student's Perceptions of DGBL (Pre). Administered through SurveyMonkey, the survey was used to collect baseline data regarding participants' perceptions about their use of a digital game-based approach for learning mathematics. Student survey responses were recorded when the intervention began the seventh week of the first marking period during math class and saved directly into the researcher's password protected SurveyMonkey account.

Post Intervention Data Collection:

- Ratios and Proportional Relationships Posttest (Appendix A). Following administration of the Ratios and Proportional Relationships Posttest (Appendix A) scores were recorded in a password protected Excel file by the division-level research administrator and saved on a password protected computer. The research administrator provided the password protected Excel file and password, which was saved on the researcher's password protected computer.
- Ratios and Proportional Relationships Posttest (Appendix A) Cut Score. The division-level research administrator provided the researcher with the cut score for comparison with participant Ratios and Proportional Relationships Posttest (Appendix A) scores.
- Student's Perceptions of DGBL (Post). Administered through SurveyMonkey, the survey was used to collect post intervention data regarding participants' perceptions about their use of a digital game-based approach for learning mathematics. Student survey responses were recorded the third week of the second marking period during math class and saved directly into the researcher's password protected SurveyMonkey account.
- Small Group, Semi-structured, Open-ended Interviews. During the week immediately following the conclusion of the study, small group interviews were conducted using an interview protocol (Appendix S) to collect in-depth information regarding student perceptions of a digital game-based approach for learning mathematics. The small group interview protocol (Appendix S) was designed to cross-check the data obtained from the SPoDGBLS (Appendix B). An interview script was developed to guide the interview process. The 22 items (questions) from the SPoDGBLS (Appendix B) were referenced to create five open-ended interview questions. Interview questions were exploratory in

nature and were developed to address the following five constructs of the SPoDGBLS (Appendix B): 1) Experience with digital games, 2) Ease of use, 3) Learning opportunities, 4) Usefulness, and 5) Preference for digital games. Each interview question was reviewed for alignment with the corresponding construct addressed by specific survey questions on the SPoDGBLS (Appendix B). Interview probes were written to encourage interviewees to elaborate further about their responses. In order to select interviewees, study participants were ranked in low, middle, and high groups according to SPoDGBLS (Appendix B) ratings. One male and one female were randomly selected from each group to be interviewed together. The 30-minute, small group interviews were conducted over three days during an extended lunch block, between 10:30 a.m. and 12:30 p.m. Each of the three interviews took place via a video meeting. Audio responses were recorded during the video meeting, transcribed by the researcher into three interview transcripts for use in data analysis, and saved on the researcher's password protected computer.

3.9 Data Analysis

Ratios and Proportional Relationships Test

Statistical analyses were performed using JMP data analysis software. Descriptive statistics (e.g., mean, and standard deviation) were used to describe the study data and inferential statistics to draw conclusions about the data (Howell, 2011). A two-tailed, paired *t*-test was conducted to compare the pre and post scores from each individual and a pre and post comparison of group means. Data were then analyzed using a two tailed, one sample *t*-test to compare participants to the Ratios and Proportional Relationships Posttest (Appendix A) cut score. Statistical significance was determined by a significance level of $\alpha = .05$ and a confidence level of 95% (Gall, Gall, & Borg, 2007; McMillian, 2012).

Student's Perceptions of DGBL

A two-tailed, paired *t*-test was conducted to compare the pre and post SPoDGBLS scores from each individual participant. Statistical significance was determined by a significance level of $\alpha = .05$ and a confidence level of 95% (Gall, Gall, & Borg, 2007; McMillian, 2012).

Small Group, Semi-structured, Open-ended Interviews

The researcher (Coder 1) and an expert (Coder 2) co-coded and analyzed the interview data using content analysis. The procedures commonly used in conducting a content analysis are: 1) Determine the specific objectives to be achieved, 2) Read and analyze the transcripts as a whole to formulate the main points, 3) Make notes about the first impressions of the text, 4) Re-read the transcripts thoroughly line by line, 5) Identify relevant text (i.e., words, phrases, sentences, sections, concepts, explicit statements, and repeated information) in the transcripts and code it, 6) Determine which codes are essential, create new codes if necessary, or combine two or more together to create categories (i.e., themes), 7) Label the categories, determine which are essential, and describe how they are connected, and 8) Determine the hierarchical order of the categories (Creswell, 2014; Frankel & Wallen, 2009).

The content of the three interview transcripts were analyzed using the following steps: 1) The low group interview transcript was read in its entirety, 2) While reading the transcript notes were made of the initial perceptions of the text, 3) Notes were then examined to create a list of prominent ideas, 4) The interview transcript was then re-read line by line, 5) Relevant words, phrases, and sentences that alluded to the constructs were coded, 6) Initial codes were then reviewed by both coders to determine which aligned with a particular construct and which would be used in the coding process, 7) Coder 1 then created a co-coding spreadsheet (Figure 3) in Microsoft Excel (excel) that included six labelled columns and two agreement columns,

A	B	C	D	E	F	G	H
NUMBER	SUBJECT	UTTERANCE	PI	Co-I	Arbitrated CODE		
1	A	easy	Ez	Ez	Ez	1	1
		and sometimes a little bit hard.	0	0	0	1	1
2		Not often.	Ex	Ex	Ex	1	1
3		Mostly, like, Math.	Ex	Ex	Ex	1	1
4		So I, um, am not a fan of digital games but	0	0	0	1	1
		sometimes I do play	Ex	P	Ex	1	0
		because sometimes they are fun.	P	P	P	1	1
5		Like if I do it I'll do like one hour	Ex	Ex	Ex	1	1
6	B	Prodigy and DreamBox and that's it.	Ex	Ex	Ex	1	1
7		I do play DreamBox when I'm told to	Ex	Ex	Ex	1	1
8		but I normally play Prodigy	Ex	Ex	Ex	1	1
		because it is kind of like Mine Craft	P	Ex	Ex	0	1
		and I like that.	P	P	P	1	1
9		It's Math and you got to answer the questions to level up.	W	W	W	1	1
10		I play Prodigy a lot	Ex	Ex	Ex	1	1
		and I play other games but they are not digital.	0	0	0	1	1

Codes
Ex = Experience
Ez = Easy
W = Ways to Learn
B = Benefits
P = Preference

Figure 3: Co-coding Spreadsheet

8) Coder 1 "pulled apart" each sentence into "utterances" in column "C" and coded them in column "E", 9) Coder 2 reviewed the utterances that Coder 1 entered and how they were coded and then independently entered his own codes in column "D". When Coder 2 either did not agree with a code, or saw something different within an utterance, he added additional utterance pieces and codes for them, 10) Coder 1 and 2 met to compare and discuss their codes and to agree on a "arbitrated code" for each utterance. When Coder 2's code agreed with the arbitrated code in column "F" a "1" for agreeance was displayed in column "G" and when Coder 1's code agreed the "1" was displayed in column "H". When both columns (G and H) displayed a "1" there was a complete agreeance on the arbitrated code. If there was a "0" in either the "G" or "H" column, there was not an agreeance reached between the two coders, and 11) Frequency counts were noted for the number of times participants addressed a particular construct during

the interviews. This process was then repeated for the middle and high group interview transcripts.

The categories compiled from the three interview groups were then examined to find common themes around each of the constructs. These common themes helped to explain any differences in perceptions found between the low, middle, and high groups. The resulting frequency counts provided a better understanding as to why certain participants provided positive, negative, or neutral responses to a construct associated with a specific item on the SPoDGBLS (Appendix B). Triangulation (Figure 4) was achieved by comparing the results from the SPoDGBLS with the content analysis of the interviews. The SPoDGBLS data indicated the changes in student perceptions of DGBL following implementation of the mathematics intervention and the content analysis of the interviews provided a mechanism for interpreting quantitative survey responses.

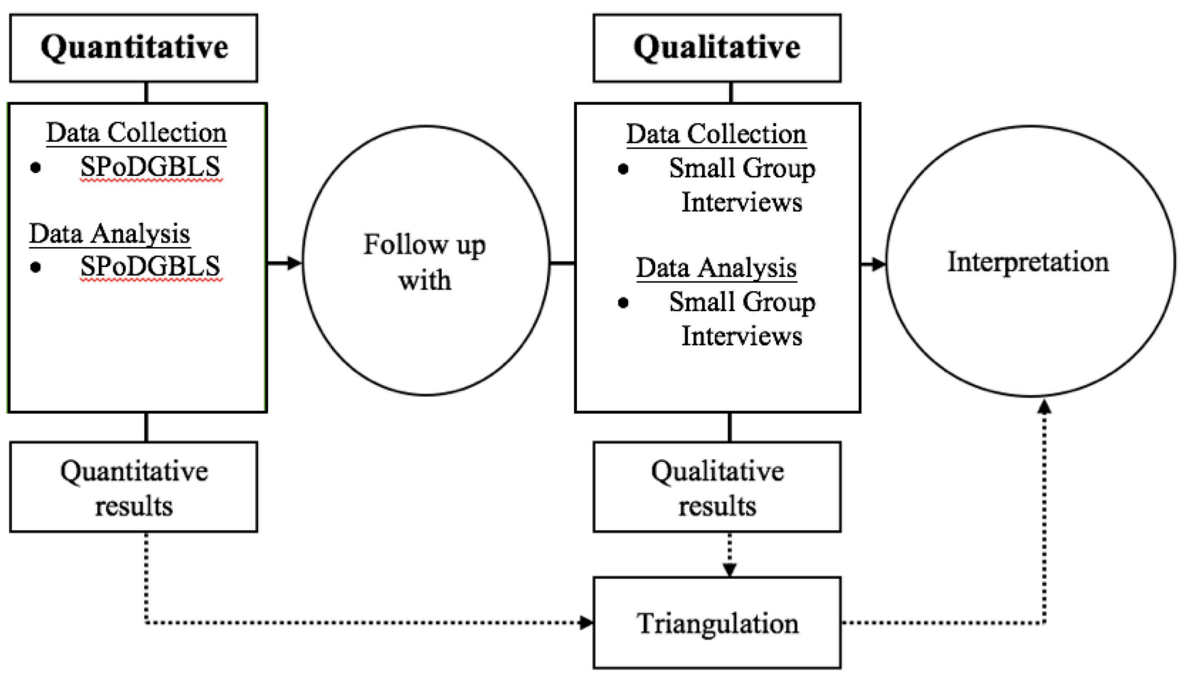


Figure 4: Explanatory Sequential Mixed Methods Design with Triangulation. Adapted from *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches* (p. 270), by J.W. Creswell, 2014, Thousand Oaks, CA: SAGE. Copyright 2014 by SAGE Publications, Inc.

3.10 Summary

This Method chapter presented the research questions that guided this study and presented the overall strategy used to conduct it in a coherent way. The sample for this study was conveniently derived from a virtual sixth grade math classroom at a large suburban middle school in Virginia. Participants were grade six students enrolled in Middle School Math Course 1 and the teacher selected to participate had over 15 years of experience teaching middle school mathematics. The study employed a mixed research method and a one-group pretest-posttest research design to collect data before and after an intervention and measure the degree of change that occurred as a result of the intervention (McMillian, 2012). Chapter 4 presents research findings derived from data analysis, along with discussion of those analyses.

CHAPTER IV: FINDINGS

The purpose of this research study was to: (a) determine whether or not digital game-based learning (DGBL) is a viable tool in helping students to improve achievement in middle school mathematics and (b) gauge their perceptions regarding the use of DGBL. This chapter describes the participants, analysis of data used to establish instrument reliability, validity and readability, data assessment, data analysis, and summary of findings. This description is presented in the following six sections (4.1-4.6).

4.1 Participants in the Study

The sample for this study was 21 sixth grade students enrolled at a large suburban middle school in Virginia who were preassigned to a Middle School Math Course 1 class. These preassigned student participants were grouped together according to similarities of performance levels in mathematics. Information about the participants was collected to describe them collectively as a whole. Table 4 summarizes the demographic characteristics of the participants.

Table 4.

Participants' Demographic Characteristics

Sex	n	%	Age	n	%	Race	n	%	SES	n	%
F	17	(80.95)	11	18	(85.71)	AA	9	(42.86)	L	21	(100)
M	4	(19.05)	12	3	(14.29)	H	6	(28.57)	Mid.	0	(0.0)
						C	4	(19.05)	H	0	(0.0)
						A	1	(4.76)			
						API/NA	1	(4.76)			

Notes: Female = F, Male = M, Low = L, Middle = Mid., High = H, African-American = AA, Hispanic = H, Caucasian = C, Asian = A, Asian Pacific Islander/Native American = API/NA

A majority of the participants were female (80.95%), 11 years old (85.71%), African-American (42.86%), and from low socioeconomic status (SES) (100%) households. The school that the participants attended was a middle school (i.e., grades 6-8) of approximately 1100 students with a 15:1

student-teacher ratio. Table 5 summarizes the racial and ethnic composition of the school.

Table 5.

School Racial and Ethnic Composition

Race/Ethnicity	n	%
Asian	399	(36.3)
Caucasian	316	(28.7)
African American	205	(18.6)
Hispanic	120	(10.9)
Multi-Ethnic	54	(4.9)
Asian Pacific Islander/Native American	7	(0.6)

4.2 Instrumentation

The items (questions) from an instrument that was previously determined to be reliable and valid was modified to develop the *Student's Perceptions of Digital Game-Base Learning Survey* (SPoDGBLS) (Appendix B). The SPoDGBLS was developed based on the five constructs by Bourgonjon (2015) (Appendix F) for understanding and predicting students' acceptance of video games in the classroom. The researcher established the reliability and validity of the SPoDGBLS to gather information about students' perceptions of their learning experiences with regard to the use of a digital game-based approach for learning mathematics.

Instrument Reliability

Internal consistency indicates the degree to which individuals' answers to items (questions) measuring the same trait are consistent (McMillan, 2012). The internal consistency reliability of the items (questions) used in the SPoDGBLS was established through Bourgonjon's research (2015) using Cronbach's alpha. Cronbach's alpha is a measure of internal consistency of how closely related a set of items are as a group (McMillan, 2012). Table 6 explains how a Cronbach's alpha score is interpreted.

Table 6.

Cronbach's Alpha Interpretation

Cronbach's alpha	Internal consistency
$\alpha \geq 0.9$	Excellent
$0.8 \leq \alpha < 0.9$	Good
$0.7 \leq \alpha < 0.8$	Acceptable
$0.6 \leq \alpha < 0.7$	Questionable
$0.5 \leq \alpha < 0.6$	Poor
$\alpha < 0.5$	Unacceptable

The reliability estimates, Cronbach's alpha, for the SPoDGBLS constructs are shown in Table 7.

Table 7.

Internal Consistency Reliability (Cronbach's Alpha)

Construct	Number of Items	Cronbach's Alpha
Experience with Digital Games	5	.895
Ease of Use	3	.871
Learning Opportunities	7	.875
Usefulness	4	.926
Preference for Digital Games	3	.925

Reliability estimates for the Experience with Digital Games, Ease of Use, and Learning Opportunities constructs fell in the good range ($0.8 \leq \alpha < 0.9$) of internal consistency. The Usefulness and Preference for Digital Games constructs generated Cronbach's alpha scores of greater than 0.9 which indicated excellent internal consistencies. Given the exploratory nature of the analysis, items addressing the different constructs in the model were considered acceptable and reliable (McMillan, 2012).

Inter-rater Reliability

To determine the inter-rater reliability for the 22 items (questions) on the SPoDGBLS (Appendix B), the Fleiss' kappa (Fleiss, 1971) was used to assess the consistency amongst the three raters after they completed the Content and Construct Inter-rater Validation Form (CaCIVF) (Appendix G). When the raters assigned the same numerical ratings to the items (questions) a consensus was reached and an inter-rater reliability was established. Table 8 presents the results of the statistical measure and displays the degree of agreement amongst the three inter-raters.

Table 8.

Inter-rater Reliability Established Among Raters

		Raters			
Item	1	2	3	κ	Percent Agreement
1	1	1	1	1	100%
2	1	1	1	1	100%
3	1	1	1	1	100%
4	1	1	1	1	100%
5	1	1	1	1	100%
6	1	1	1	1	100%
7	1	1	1	1	100%
8	1	1	1	1	100%
9	1	1	1	1	100%
10	1	1	1	1	100%
11	1	1	1	1	100%
12	1	1	1	1	100%
13	1	1	1	1	100%
14	1	1	1	1	100%
15	1	1	1	1	100%
16	1	1	1	1	100%
17	1	1	1	1	100%
18	1	1	1	1	100%
19	1	1	1	1	100%
20	1	1	1	1	100%
21	1	1	1	1	100%
22	1	1	1	1	100%

Note: 1 indicates that the item was accepted, 0 indicates that it was rejected.

Viera and Garrett (2005) suggest that kappa values between 0.81-0.99 represent an almost perfect agreement and a kappa value of 1.0 as a perfect agreement. Fleiss (1971) also suggests that a kappa value of 1.0 means a complete agreement. The overall value of kappa was 1.0 as shown in Table 9.

Table 9.

Inter-rater Reliability Kappa

Items	Acceptance	Rejection	Agreement P_i
1	3	0	1.0
2	3	0	1.0
3	3	0	1.0
4	3	0	1.0
5	3	0	1.0
6	3	0	1.0
7	3	0	1.0
8	3	0	1.0
9	3	0	1.0
10	3	0	1.0
11	3	0	1.0
12	3	0	1.0
13	3	0	1.0
14	3	0	1.0
15	3	0	1.0
16	3	0	1.0
17	3	0	1.0
18	3	0	1.0
19	3	0	1.0
20	3	0	1.0
21	3	0	1.0
22	3	0	1.0
Total	66	0	1.0
P_i	1	0	22.0

Notes: Minimum score = 0 (Reject), Maximum score = 1 (Accept)

The consistency of the answers was measured using the kappa formula below:

$$K = \frac{\bar{P} - \bar{P}_e}{1 - \bar{P}_e}$$

The calculations were:

$$P_i = \frac{3+3+3+3+3+3+3+3+3+3+3+3+3+3+3+3+3+3+3+3+3+3}{66} = 1$$

$\bar{P} = \frac{1}{(22)}\ (22) = 1$

$\bar{P_e}$=$1^2+1^2+1^2+1^2+1^2+1^2+1^2+1^2+1^2+1^2+1^2+1^2+1^2+1^2+1^2+1^2+1^2+1^2+1^2+1^2+1^2+1^2$=22

Raters were in complete agreement when $\kappa = 1$.

Content Validity

Three inter-raters with an expertise in evaluating instruments and integrating educational technologies into instruction evaluated each item on the SPoDGBLS (Appendix B) instrument for content validity. Using a form developed by the researcher, panelists were presented with a column to circle yes if the item was content valid and no if it was not (Appendix G). The mean was calculated for each item on the SPoDGBLS instrument to determine the percent agreement among the three inter-raters (Table 10). Results indicated that there was an 100% agreement among panelists for all items and each item was determined to be content valid. Inter-rater responses for content validation and content validity index (CVI) for each item (question) are found in (Appendix T).

Table 10.

Inter-rater Evaluation for Content Validity

		Raters			
Item	1	2	3	Number in agreement	Percent Agreement
1	1	1	1	3	100%
2	1	1	1	3	100%
3	1	1	1	3	100%
4	1	1	1	3	100%
5	1	1	1	3	100%
6	1	1	1	3	100%
7	1	1	1	3	100%
8	1	1	1	3	100%
9	1	1	1	3	100%

Table 10 (continued)

	Raters				
Item	1	2	3	Number in agreement	Percent Agreement
10	1	1	1	3	100%
11	1	1	1	3	100%
12	1	1	1	3	100%
13	1	1	1	3	100%
14	1	1	1	3	100%
15	1	1	1	3	100%
16	1	1	1	3	100%
17	1	1	1	3	100%
18	1	1	1	3	100%
19	1	1	1	3	100%
20	1	1	1	3	100%
21	1	1	1	3	100%
22	1	1	1	3	100%

Note: 1 indicates content valid, 0 indicates invalid.

Construct Validity

The same three inter-raters who evaluated each item on the SPoDGBLS (Appendix B) for content validity evaluated each item for construct validity. Using the same form developed by the researcher, panelists were presented with a column to circle yes if the item was construct valid and no if it was not (Appendix G). The mean was calculated for each item on the SPoDGBLS instrument to determine the percent agreement among the three inter-raters (Table 11). Results indicated that there was an 100% agreement among panelists for all items and each item was determined construct valid. Inter-rater responses for construct validation and CVI for each item (question) are found in (Appendix U).

Table 11.

Inter-rater Evaluation for Construct Validity

	Raters				
Item	1	2	3	Number in agreement	Percent Agreement
1	1	1	1	3	100%
2	1	1	1	3	100%
3	1	1	1	3	100%
4	1	1	1	3	100%
5	1	1	1	3	100%
6	1	1	1	3	100%
7	1	1	1	3	100%
8	1	1	1	3	100%
9	1	1	1	3	100%
10	1	1	1	3	100%
11	1	1	1	3	100%
12	1	1	1	3	100%
13	1	1	1	3	100%
14	1	1	1	3	100%
15	1	1	1	3	100%
16	1	1	1	3	100%
17	1	1	1	3	100%
18	1	1	1	3	100%
19	1	1	1	3	100%
20	1	1	1	3	100%
21	1	1	1	3	100%
22	1	1	1	3	100%

Note: 1 indicates construct valid, 0 indicates invalid.

Instrument Readability

Two Flesch-Kincaid tests (Reading Ease and Grade Level) were conducted to determine the readability of the SPoDGBLS (Appendix B). Flesch Reading Ease (FRE) scores can be interpreted as shown in the chart below.

"Reading Ease" Score	School level	Description of Style
90.0-100.0	5th grade	Very easy
80.0-90.0	6th grade	Easy
70.0-80.0	7th grade	Fairly easy
60.0-70.0	8th & 9th grade	Standard

(Continued)

"Reading Ease" Score	School level	Description of Style
50.0-60.0	10th to 12th grade	Fairly difficult
30.0-50.0	College	Difficult
0.0-30.0	College graduate	Very difficult

The following chart explains how Flesch-Kincaid Grade Level (FKGL) scores can be interpreted.

Grade-Based Score	K-12 Grade Level
0.0-1.0	Pre-kindergarten - First grade
1.0-2.0	First grade - Second grade
2.0-3.0	Second grade - Third grade
3.0-4.0	Third grade - Fourth grade
4.0-5.0	Fourth grade - Fifth grade
5.0-6.0	Fifth grade - Sixth grade
6.0-7.0	Sixth grade - Seventh grade
7.0-8.0	Seventh grade - Eighth grade
8.0-9.0	Eighth grade - Ninth grade
9.0-10.0	Ninth grade - Tenth grade
10.0-11.0	Tenth grade - Eleventh grade
11.0-12.0	Eleventh grade - Twelfth grade

The FRE test rates how easy the text is to read on a 100 - point scale. Scores in the "80-90" range are easily read by 11-12 year-old students (sixth grade students) and scores in the "60-70" range are easily read by 13-15 year-old students (seventh through ninth grade students). The FRE formula is 206.835 – (1.015 x average sentence length) – (84.6 x average number of syllables per word). This formula was used to determine that the reading ease score for the SPoDGBLS (Appendix B) was 67.8 (Table 12).

The FKGL test is based on the United States (U.S.) school grade level that is required to understand text. The FKGL formula is (0.39 x average sentence length) + (11.8 x average number of syllables per word) – 15.59. This formula was used to determine that the U.S. grade level readability score for the SPoDGBLS (Appendix B) was 5.6 (Table 12) (Flesch, 1948; Kincaid et al., 1975). Table 12 presents the results of both of the Flesch-Kincaid tests.

Table 12.

Flesch-Kincaid Readability Statistics

Counts	
Words	168
Characters	843
Paragraphs	23
Sentences	21
Averages	
Sentences per Paragraph	1
Words per Sentence	7.3
Characters per Word	4.7
Readability	
Flesch Reading Ease	67.8
Flesch-Kincaid Grade Level	5.6

Based on the results of this assessment, the findings indicated that the 67.8 reading ease score fell at the high end of the 8^{th} & 9^{th} grade standard readability range (60.0-70.0) which is very close to the "Fairly Easy" reading level for seventh grade students. The 5.6 grade level score fell below the sixth grade level (6.0) indicating the instrument was at an appropriate readability level for participants in the study.

4.3 Implementation Fidelity

Implementation fidelity is an important factor in interpreting the outcomes of an intervention. Three of the five dimensions of fidelity (i.e., adherence, exposure, and participant responsiveness) were evaluated in this study to ensure that instructional practices and protocols were followed as precisely and consistently as planned (Breitenstein et al., 2010; Dusenbury et al., 2003; Mellard, 2010; Veenman, Denessen, van den Akker, & Van der Rijt, 2005). The teacher filled out the Implementation Fidelity Log (Appendix H) to evaluate whether: (1) the intervention was delivered when it was intended; (2) participants were exposed to the full intervention; and (3) participants were actively participating in the intervention. Table 13 presents the implementation fidelity data.

Table 13.

Implementation Fidelity Data

Day	Adherence	Exposure	Participant Responsiveness	
		Time	Participants	Percent
1	no	0 min.	0	0%
2	yes	15 min.	18	85.7%
3	yes	15 min.	17	81.0%
4	yes	15 min.	4	19.0%
5	yes	15 min.	18	85.7%
6	no	0 min.	0	0%
7	yes	15 min.	19	90.5%
8	yes	15 min.	10	47.6%
9	no	0 min.	0	0%
10	yes	15 min.	21	100%
11	no	0 min.	0	0%
12	no	0 min.	0	0%
13	yes	15 min.	21	100%
14	no	0 min.	0	0%
15	yes	15 min.	21	100%
16	yes	15 min.	20	95.2%
17	yes	15 min.	18	85.7%
18	yes	15 min.	9	42.9%
19	yes	15 min.	2	9.5%
20	yes	15 min.	15	71.4%
21	yes	15 min.	1	4.8%
22	yes	15 min.	18	85.7%
23	yes	15 min.	5	23.8%
24	yes	15 min.	16	76.2%

Adherence was measured using the following formula: (actual days of adherence/planned days of adherence x 100). Exposure was measured using the following formula: (actual time of exposure/planned time of exposure x 100). Participant responsiveness was rated using the following scale: low engagement (0% - 33%), medium engagement (33% - 66%), and high engagement (66% - 100%). The ratings capture the degree to which participants were actively participating.

Results revealed that the intervention was delivered as intended for 18 out of 24 days and participants were exposed to the intervention for 270 out of 360 minutes. The findings indicated that the intervention was delivered 75% of the intended time and participants were exposed to 75% of the full intervention. Results also indicated that participant engagement levels were low for 10 days (41.66%), medium for 2 days (0.83%), and high for 12 days (50%).

Ensuring Fidelity

Student reports were checked weekly via the DreamBox insight dashboard and an intervention log (Appendix I) was kept to track how many minutes that participants were spending using the intervention. The goal was 60 minutes per week and 300 total minutes for 5 weeks. The classroom teacher was notified and asked to encourage participants to spend more time using the DGBL intervention when the weekly requirement was not being met. Table 14 presents participants' weekly and overall totals.

Table 14.

Participants' Time Spent Using the Intervention

	Time Spent in Minutes					
Participant	Week 1	Week 2	Week 3	Week 4	Week 5	Total
1	20	10	51	57	85	223
2	0	7	38	24	73	142
3	69	61	54	81	30	295
4	49	24	52	74	70	269
5	59	24	48	74	92	297
6	33	0	74	61	31	199
7	59	32	30	72	49	242
8	47	40	42	27	61	217
9	73	53	64	49	41	280
10	53	0	63	58	90	264
11	0	6	28	28	0	62
12	57	21	34	81	82	275
13	68	53	65	169	102	457
14	41	22	69	69	49	250
15	24	27	43	67	115	276
16	53	39	62	72	118	344
17	26	78	51	142	53	350
18	61	88	73	62	133	417
19	52	49	62	64	81	308
20	48	24	61	47	44	224
21	41	41	58	74	116	330

There was a steady incline in program usage over the 5 week DGBL intervention. Six participants met the 300-minute requirement and two participants were approaching (i.e., within ten minutes) it. Implementation fidelity was found to be acceptable, 28.6% (6 out of 21) of the participants met the DGBL intervention time requirement.

4.4 Data Collection

Pre Intervention Data Collection

Ratios and Proportional Relationships Pretest (Appendix A). Participants' Ratios and Proportional Relationships Pretest (Appendix A) data and associated demographics (e.g., gender, age, and race) were collected. The test data were used to estimate participants' math achievement levels before the intervention. Table 15 displays the Ratios and Proportional Relationships Pretest data.

Table 15.

Ratios and Proportional Relationships Pretest Data

Participant	Gender	Age	Race	Points Earned	Points Possible	Pretest Score %
1	F	12	C	8.33	21	39.7
2	F	12	H	13	21	61.9
3	F	11	AA	7.3	21	34.9
4	F	11	AA	9.66	21	46
5	F	11	API/NA	7.33	21	34.9
6	M	12	H	4.66	21	22.2
7	F	11	AA	5	21	23.8
8	M	11	AA	8.33	21	39.7
9	M	11	C	6.33	21	30.2
10	F	11	AA	9.33	21	44.4
11	F	11	AA	6.33	21	30.2
12	M	11	H	7.33	21	34.9
13	F	11	AA	9.33	21	44.4
14	F	11	H	14.33	21	68.3
15	F	11	H	5	21	23.8
16	F	11	C	11	21	52.4
17	F	11	AA	9	21	42.9
18	F	11	AA	15	21	71.4

Table 15 (continued)

Participant	Gender	Age	Race	Points Earned	Points Possible	Pretest Score %
19	F	11	C	5.33	21	25.4
20	F	11	H	6	21	28.6
21	F	11	A	13	21	61.9

Notes: African American = AA, Asian = A, Asian Pacific Islander/Native American = API/NA, Caucasian = C, Hispanic = H

Student's Perceptions of DGBL (Pre). At the onset of the study, pre SPoDGBLS (Appendix B) responses were collected from each participant. The pre SPoDGBLS responses were used as baseline data regarding participants' perceptions about their use of a digital game-based approach for learning mathematics. Table 16 summarizes participants' pre SPoDGBLS item responses.

Table 16.

SPoDGBLS (Pre) Item Summaries

Items	Strongly Disagree		Disagree		Neutral		Agree		Strongly Agree	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%
1. I like playing digital games.	0	(0.0)	0	(0.0)	2	(9.5)	8	(38.1)	11	(52.4)
2. I often play digital games.	0	(0.0)	2	(9.5)	6	(28.6)	8	(38.1)	5	(23.8)
3. Compared to other students my age, I play a lot of digital games.	0	(0.0)	3	(14.3)	8	(38.1)	7	(33.3)	3	(14.3)
4. I would describe myself as a gamer.	2	(9.5)	2	(9.5)	6	(28.6)	5	(23.8)	6	(28.6)
5. I play different types of digital games.	0	(0.0)	0	(0.0)	8	(38.1)	11	(52.4)	2	(9.5)
6. I would know how to handle digital games in math class.	0	(0.0)	0	(0.0)	5	(23.8)	10	(47.6)	6	(28.6)
7. It would be easy for me to use digital games in math class.	0	(0.0)	0	(0.0)	7	(33.3)	10	(47.6)	4	(19.0)
8. My interaction with digital games in math class would be clear and understandable.	0	(0.0)	0	(0.0)	7	(33.3)	11	(52.4)	3	(14.3)

Table 16 (continued)

Items	Strongly Disagree		Disagree		Neutral		Agree		Strongly Agree	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%
9. Digital game-based learning offers opportunities to experiment with knowledge.	0	(0.0)	1	(4.8)	7	(33.3)	10	(47.6)	3	(14.3)
10. Digital game-based learning offers opportunities to take control of the learning process.	0	(0.0)	0	(0.0)	7	(33.3)	11	(52.4)	3	(14.3)
11. Digital game-based learning offers opportunities to experience things you learn about.	0	(0.0)	0	(0.0)	8	(38.1)	13	(61.9)	0	(0.0)
12. Digital game-based learning offers opportunities to transfer knowledge between various subjects.	0	(0.0)	1	(4.8)	4	(19.0)	16	(76.2)	0	(0.0)
13. Digital game-based learning offers opportunities to interact with other students.	0	(0.0)	0	(0.0)	7	(33.3)	10	(47.6)	4	(19.0)
14. Digital game-based learning offers opportunities to think critically.	0	(0.0)	0	(0.0)	7	(35.0)	13	(65.0)	0	(0.0)
15. Digital game-based learning offers opportunities to motivate students.	0	(0.0)	1	(5.0)	3	(15.0)	14	(70.0)	2	(10.0)
16. Using digital games in math class would improve my performance.	0	(0.0)	2	(10.0)	6	(30.0)	8	(40.0)	4	(20.0)
17. Using digital games in math class would increase my learning productivity.	0	(0.0)	3	(14.3)	7	(33.3)	9	(42.9)	2	(9.5)
18. Using digital games in math class would increase my effectiveness.	0	(0.0)	3	(14.3)	12	(57.1)	4	(19.0)	2	(9.5)
19. Using digital games in math class would help me to achieve better grades.	0	(0.0)	3	(15.0)	6	(30.0)	8	(40.0)	3	(15.0)

Table 16 (continued)

Items	Strongly Disagree		Disagree		Neutral		Agree		Strongly Agree	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%
20. If I had the choice, I would choose to take classes in which digital games are used.	0	(0.0)	1	(4.8)	3	(14.3)	13	(61.9)	4	(19.0)
21. If I had to vote, I would vote in favor of using digital games in math class.	0	(0.0)	2	(9.5)	5	(23.8)	9	(42.9)	5	(23.8)
22. I am excited about using digital games in math class.	1	(4.8)	0	(0.0)	3	(14.3)	8	(38.1)	9	(42.9)

Post Intervention Data Collection

Ratios and Proportional Relationships Posttest. Participants' Ratios and Proportional Relationships Posttest (Appendix A) data and associated demographics (e.g., gender, age, and race) were collected from the division-level research administrator in an excel spreadsheet. The posttest data were used to estimate participants' math achievement levels after the intervention. Table 17 displays the Ratios and Proportional Relationships Posttest data.

Table 17

Ratios and Proportional Relationships Posttest Data

Participant	Gender	Age	Race	Points Earned	Points Possible	Posttest Score %
1	F	12	C	17	21	81
2	F	12	H	16	21	76.2
3	F	11	AA	12	21	57.1
4	F	11	AA	16	21	76.2
5	F	11	API/NA	18	21	85.7
6	M	12	H	12.33	21	58.7
7	F	11	AA	8	21	38.1
8	M	11	AA	16	21	76.2
9	M	11	C	9	21	42.9
10	F	11	AA	11.66	21	55.6
11	F	11	AA	4.33	21	20.6
12	M	11	H	14.33	21	68.3

Table 17 (continued)

Participant	Gender	Age	Race	Points Earned	Points Possible	Posttest Score %
13	F	11	AA	15	21	71.4
14	F	11	H	16	21	76.2
15	F	11	H	19	21	90.5
16	F	11	C	17	21	81
17	F	11	AA	16	21	76.2
18	F	11	AA	18	21	85.7
19	F	11	C	17	21	81
20	F	11	H	14.33	21	68.3
21	F	11	A	19	21	90.5

Notes: African American = AA, Asian = A, Asian Pacific Islander/ Native American= API/NA, Caucasian = C, Hispanic = H

Ratios and Proportional Relationships Posttest Cut Score. A cut score is the lowest score a student can earn to be considered proficient on an assessment. Any score below the predetermined score constitutes a failing grade. The cut score of 65 was provided to the researcher by the division-level research administrator for the Ratios and Proportional Relationships Posttest (Appendix A).

Student's Perceptions of DGBL (Post). At the conclusion of the study, post SPoDGBLS (Appendix C) responses were collected from each participant. The post SPoDGBLS responses were used as post-intervention data regarding participants' perceptions about their use of a digital game-based approach for learning mathematics. Table 18 summarizes participants' post SPoDGBLS item responses.

Table 18.

Post-Intervention SPoDGBLS Item Summaries

Items	Strongly Disagree		Disagree		Neutral		Agree		Strongly Agree	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%
1. I like playing digital games.	0	(0.0)	0	(0.0)	7	(33.3)	5	(23.8)	9	(42.9)
2. I often play digital games.	1	(4.8)	2	(9.5)	6	(28.6)	7	(33.3)	5	(23.8)
3. Compared to other students my age, I play a lot of digital games.	1	(4.8)	4	(19.0)	8	(38.1)	6	(28.6)	2	(9.5)

Table 18 (continued)

Items	Strongly Disagree		Disagree		Neutral		Agree		Strongly Agree	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%
4. I would describe myself as a gamer.	2	(9.5)	3	(14.3)	4	(19.0)	8	(38.1)	4	(19.0)
5. I play different types of digital games.	0	(0.0)	0	(0.0)	4	(19.0)	13	(61.9)	4	(19.0)
6. I would know how to handle digital games in math class.	1	(4.8)	1	(4.8)	4	(19.0)	8	(38.1)	7	(33.3)
7. It would be easy for me to use digital games in math class.	1	(4.8)	1	(4.8)	6	(28.6)	8	(38.1)	5	(23.8)
8. My interaction with digital games in math class would be clear and understandable.	0	(0.0)	1	(4.8)	8	(38.1)	10	(47.6)	2	(9.5)
9. Digital game-based learning offers opportunities to experiment with knowledge.	1	(4.8)	0	(0.0)	6	(28.6)	13	(61.9)	1	(4.8)
10. Digital game-based learning offers opportunities to take control of the learning process.	0	(0.0)	1	(5.0)	6	(30.0)	9	(45.0)	4	(20.0)
11. Digital game-based learning offers opportunities to experience things you learn about.	0	(0.0)	0	(0.0)	4	(20.0)	13	(65.0)	3	(15.0)
12. Digital game-based learning offers opportunities to transfer knowledge between various subjects.	0	(0.0)	0	(0.0)	9	(45.0)	8	(40.0)	3	(15.0)
13. Digital game-based learning offers opportunities to interact with other students.	0	(0.0)	3	(14.3)	6	(28.6)	8	(38.1)	4	(19.0)
14. Digital game-based learning offers opportunities to think critically.	1	(4.8)	0	(0.0)	7	(33.3)	10	(47.6)	3	(14.3)

Table 18 (continued)

Items	Strongly Disagree		Disagree		Neutral		Agree		Strongly Agree	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%
15. Digital game-based learning offers opportunities to motivate students.	1	(4.8)	0	(0.0)	5	(23.8)	12	(57.1)	3	(14.3)
16. Using digital games in math class would improve my performance.	0	(0.0)	2	(9.5)	6	(28.6)	9	(42.9)	4	(19.0)
17. Using digital games in math class would increase my learning productivity.	0	(0.0)	0	(0.0)	8	(38.1)	8	(38.1)	5	(23.8)
18. Using digital games in math class would increase my effectiveness.	0	(0.0)	1	(4.9)	9	(42.9)	8	(38.1)	3	(14.3)
19. Using digital games in math class would help me to achieve better grades.	0	(0.0)	1	(4.9)	10	(47.6)	7	(33.3)	3	(14.3)
20. If I had the choice, I would choose to take classes in which digital games are used.	0	(0.0)	1	(4.9)	7	(33.3)	11	(52.4)	2	(9.5)
21. If I had to vote, I would vote in favor of using digital games in math class.	0	(0.0)	0	(0.0)	8	(38.1)	9	(42.9)	4	(19.0)
22. I am excited about using digital games in math class.	0	(0.0)	0	(0.0)	5	(23.8)	11	(52.4)	5	(23.8)

Small Group, Semi-structured, Open-ended Interviews. The week immediately following the conclusion of the study, small group interviews were conducted virtually using an interview protocol (Appendix S). One male and one female were ranked in low, middle, and high interview groups according to their pre SPoDGBLS (Appendix B) ratings. Ratings were calculated by adding the participants' pre SPoDGBLS sum score to their post SPoDGBLS (Appendix C) sum score. The groups, demographic information, sums scores, and ratings of the interviewees can be found in Table 19.

Table 19.

Interview Groups, Demographics, Sum Scores, and Ratings.

Group	Gender	Age	Race	Pre Score	Post Score	Rating
High	M	11	Hispanic	88	85	173
High	F	11	African-American	93	103	196
Middle	M	12	Hispanic	73	69	142
Middle	F	11	African-American	85	87	172
Low	M	11	Caucasian	80	60	140
Low	F	11	Hispanic	67	70	137

Audio responses from each group were recorded and transcribed into three interview transcripts for use in data analysis.

4.5 Data Analysis

Ratios and Proportional Relationships Test

This study investigated the impact the DGBL intervention had on the test scores of the student participants. The participants were tested before and after the intervention. Statistical analyses were performed using JMP data analysis software. Descriptive statistics (e.g., mean, and standard deviation) were used to describe the data and inferential statistics were used to draw conclusions about the pre and post Ratios and Proportional Relationships Test scores. Statistical significance was determined by a significance level of $\alpha = .05$ and a confidence level of 95% (Gall, Gall, & Borg, 2007; McMillian, 2012). Figure 5 displays each participant's pre and post Ratios and Proportional Relationships Test scores.

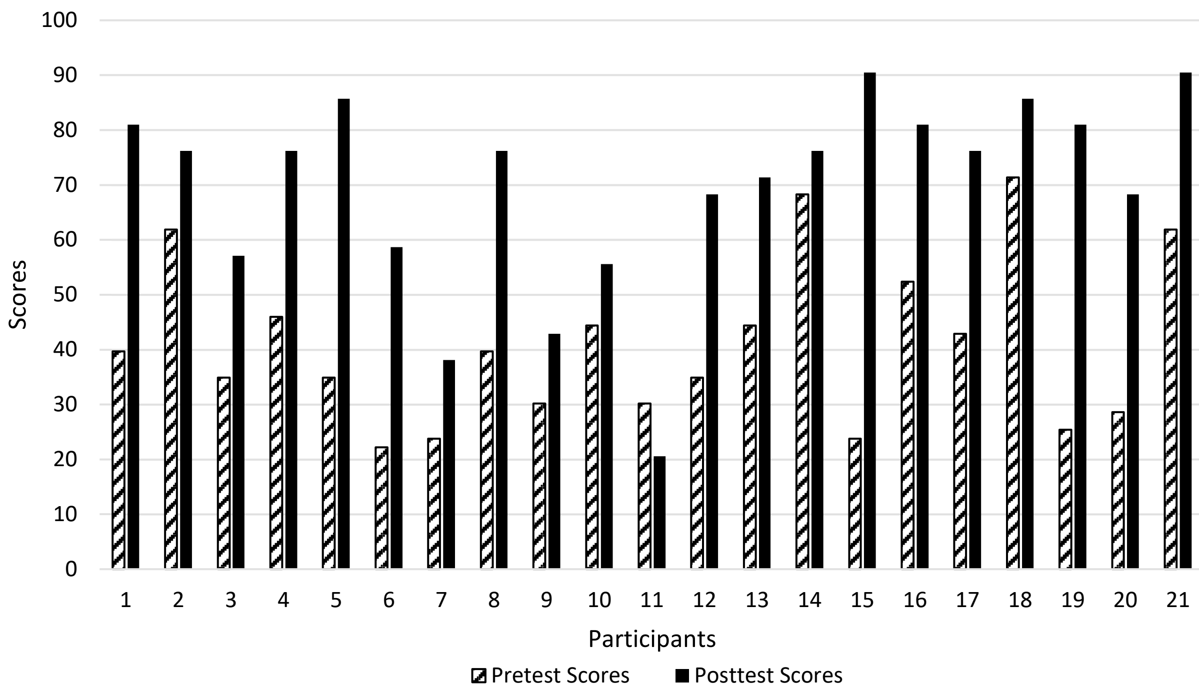


Figure 5: Participant Pre and Post Ratios and Proportional Relationships Test Scores.

The graphical representation in Figure 5 revealed that 95% (20 out of 21) of the participants showed improved scores following the intervention.

Descriptive statistics were used to describe the test data from the pre and post Ratios and Proportional Relationships Tests. The statistics are shown in Table 20.

Table 20.

Descriptive Statistics by Test

	N	*M*	*Mdn*	Mode	*SD*	Range	Min.	Max.
Pretest	21	41.04	39.7	34.9	14.86	49.2	22.2	71.4
Posttest	21	69.4	76.2	76.2	18.14	69.9	20.6	90.5

Notes: Amount = *N*, Mean = *M*, Median = *Mdn*, Standard Deviation = *SD*, Minimum = Min., Maximum = Max.

A two-tailed, paired *t*-test was conducted to compare the pre and post scores from each individual and a pre and post comparison of group means and the results are shown in Table 21 and 22.

Table 21

Participant Pre and Posttest Scores

Participant	Pretest	Posttest	Difference
1	39.7	81	41.3
2	61.9	76.2	14.3
3	34.9	57.1	22.2
4	46	76.2	30.2
5	34.9	85.7	50.8
6	22.2	58.7	36.5
7	23.8	38.1	14.3
8	39.7	76.2	36.5
9	30.2	42.9	12.7
10	44.4	55.6	11.2
11	30.2	20.6	-9.6
12	34.9	68.3	33.4
13	44.4	71.4	27
14	68.3	76.2	7.9
15	23.8	90.5	66.7
16	52.4	81	28.6
17	42.9	76.2	33.3
18	71.4	85.7	14.3
19	25.4	81	55.6
20	28.6	68.3	39.7
21	61.9	90.5	28.6

Results presented in Table 21 indicate that nearly all participants improved on the posttest. Participant 15's posttest score increased the most (+66.7 points) and participant 11's posttest score decreased (-9.6 points). This indicates a 280.3% increase for participant 15 and a 31.8% decrease for participant 11.

Table 22.

Mean, Standard Deviation, and t-test (Pre and Posttest)

	N	*M*	M/D	*SD*	Cohen's *d*	*t*	*p*
Pretest	21	41.04		14.86			
			28.36		1.91	7.63	0.0001
Posttest	21	69.4		18.14			

Notes: Amount = *N*, Mean = *M*, Difference in means = M/D, Standard Deviation = *SD*, T statistic = *t*, P value = *p*

Results presented in Table 22 indicate there was an overall mean gain of 28.36 (69.1% increase) and that this gain was statistically significant ($t(20) = 7.63$, $p = 0.0001$). The measure of effect size, based on the pretest standard deviation of 14.86, $d = 1.91$, indicated a gain of 1.91 standard deviations from the pretest mean. In addition, the 95% confidence interval for the DGBL intervention was $20.32 \leq \mu \leq 36.39$, indicating that the intervention had a large positive, significant effect on the test scores. These results indicate that DGBL shows potential for improving achievement for students that are identified as having learning difficulties in mathematics.

A two tailed, one sample t-test was conducted to compare participants' Ratios and Proportional Relationships Posttest (Appendix A) scores to the Ratios and Proportional Relationships Posttest cut score of 65. A cut score is the lowest score a student can earn to be considered proficient on an assessment. Figure 6 graphically displays each participant's posttest score in relation to the posttest cut score provided to the researcher by the division-level research administrator.

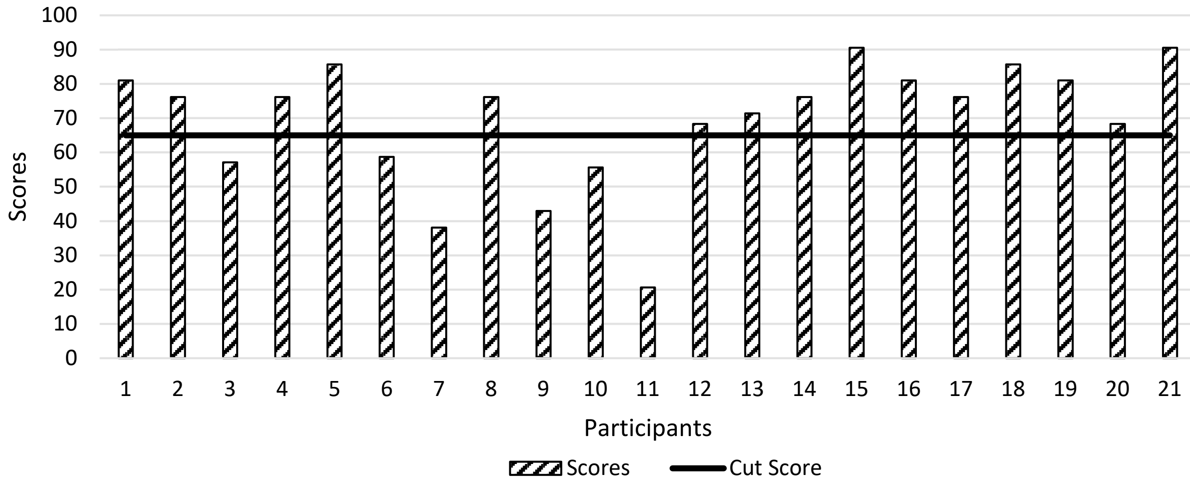


Figure 6: Ratios and Proportional Relationships Posttest Scores vs. Cut Score

The data in Figure 6 revealed that 15 participants (71.4%) scored above the cut score and 6 participants (28.6%) scored below it.

The *t*-test group comparison results of participant Ratios and Proportional Relationships Posttest mean scores with cut scores are shown in Table 23.

Table 23.

Cut Score, Mean, Difference, and t-test (Posttest)

	N	Cut Score	*M*	Δ	Cohen's *d*	*t*	*p*
Posttest	21	65	69.4	4.4	0.24	1.11	0.28

Notes: Amount = *N*, Mean = *M*, Difference = Δ, T statistic = *t*, P value = *p*

The Ratios and Proportional Relationships Posttest (Appendix A) was taken by the participants after they were exposed to the DGBL intervention. The mean posttest score was 69.4 and the 95% confidence limits were 61.14 and 77.66. A *t*-test on H_o: $\mu = 65$ produced $t(20) = 1.11$, which had an associated probability above the null hypothesis > 0.28, leading the researcher to fail to reject H_o and conclude that as a group, participants did not perform significantly higher than the cut score. The measure of effect size ($d = 0.24$) showed that the student participants performed 0.24 standard deviations above the cut score on the Ratios and Proportional Relationships Posttest (Appendix A). Although not statistically significant, the mean posttest score was practically significant because it was 4.4 points higher than the cut score. The mean of 69.4 was also a major improvement from the mean pretest score that was significantly (23.96 points) lower than the cut score.

Student's Perceptions of DGBL

This study investigated the changes that occurred in student perceptions of DGBL following the implementation of the mathematics intervention. The pre and post SPoDGBLS were used to measure changes in student perceptions of game-based learning following the intervention. Each survey consisted of 22 items (questions) and a 5-point Likert scale students used to rate their response to each item. Response ratings for each item were coded as follows: Strongly agree = 5, Agree = 4, Neutral = 3, Disagree =2, Strongly Disagree = 1. Items were designed to measure student perceptions across the following five constructs: 1) Experience with Digital Games, 2) Ease of Use, 3) Learning Opportunities, 4) Usefulness, and 5) Preference for Digital Games. As mentioned earlier in this chapter (page 59), reliability estimates for the Experience with Digital Games, Ease of Use, and Learning Opportunities constructs fell in the good range ($0.8 \leq \alpha < 0.9$) of internal consistency. The Usefulness and Preference for Digital Games constructs generated Cronbach's alpha scores of greater than 0.9 which indicated excellent internal consistencies. Descriptive statistics were used to describe the data and inferential statistics were used to draw conclusions about the comparisons between pre and post SPoDGBLS scores. Statistical significance was determined by a significance level of $\alpha = .05$ and a confidence level of 95% (Gall, Gall, & Borg, 2007; McMillian, 2012).

Experience with Digital Games. Experience with digital games is the amount of exposure an individual has had with digital games. Items 1-5 on both the pre SPoDGBLS (Appendix B) and post SPoDGBLS (Appendix C) measured participants' perceived experience with digital games. Table 24 displays the participant ratings for each of these items, as well as their sum score (5 to 25) reflecting an overall pre/post experience with digital games rating.

Table 24.

Coded Responses: Items 1-5

	Pre SPoDGBLS Items					Pre Sum	Post SPoDGBLS Items					Post Sum
Participant	1	2	3	4	5		1	2	3	4	5	
1	5	3	4	3	4	19	4	3	4	2	4	17
2	4	2	2	5	3	16	3	1	2	5	3	14
3	4	3	3	2	3	15	3	2	2	1	4	12
4	5	5	5	5	4	24	5	5	5	5	4	24
5	4	5	3	3	4	19	5	5	3	3	4	20
6	5	5	3	4	3	20	5	5	4	4	4	22
7	5	4	5	4	3	22	4	4	4	4	4	20
8	5	4	4	4	4	21	5	4	3	3	5	20
9	5	4	3	5	3	20	5	4	5	5	4	23
10	5	4	3	1	4	17	5	4	4	3	5	21
11	4	3	3	5	4	19	4	3	2	5	4	18
12	4	4	4	5	4	21	3	3	3	4	3	16
13	5	4	4	2	4	19	4	4	4	2	4	18
14	3	3	3	4	4	17	3	3	2	4	3	15
15	3	2	2	1	3	11	3	2	1	1	3	10
16	5	4	4	3	3	19	3	3	3	2	4	15
17	4	3	4	3	4	18	3	4	3	4	4	18
18	5	5	4	4	3	21	5	5	3	3	4	20
19	4	3	2	3	4	16	4	3	3	4	5	19
20	5	5	3	5	5	23	5	5	3	4	5	21
21	4	4	5	3	4	20	5	4	4	4	4	21

Table 24 revealed that participant 9's sum score increased the most (+3 points) and participant 12's sum score decreased the most (-5 points). This indicates a 15% increase for participant 9 and a 23.8% decrease for participant 12. There were no changes in participant 4 and 17's sum score. Figure 7 displays participants' pre and post SPoDGBLS sum scores for the Experience with Digital Games construct.

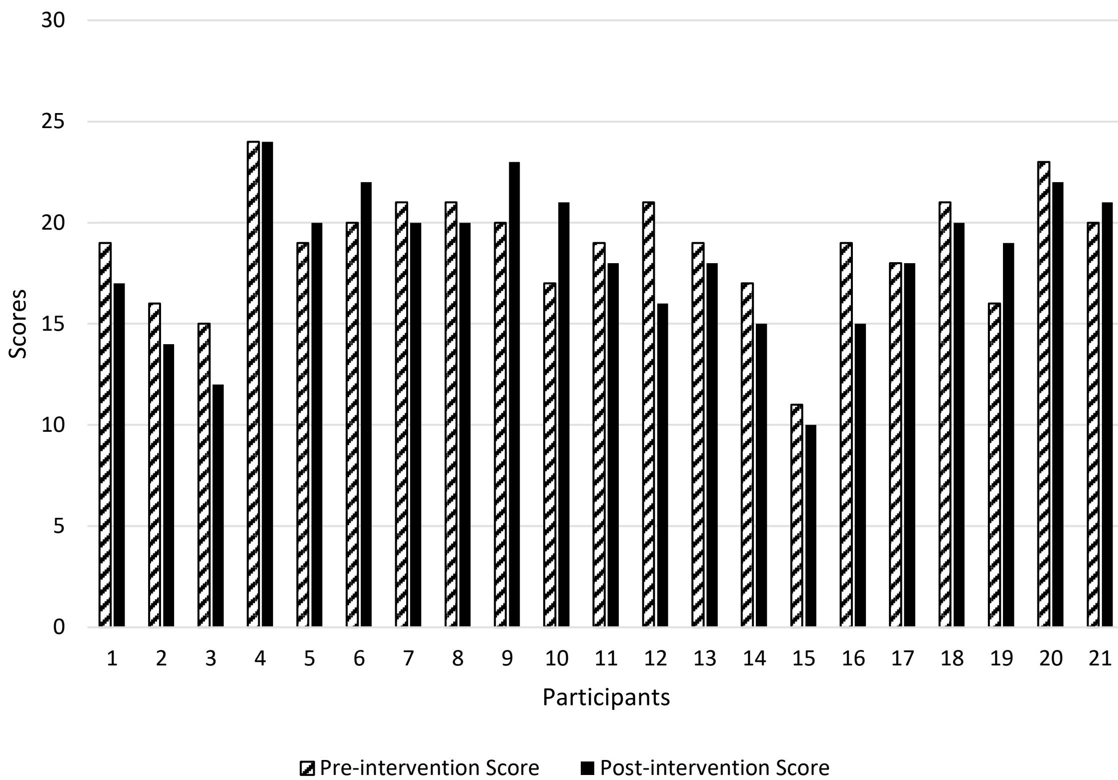


Figure 7: Experience with Digital Games Scores

The graphical representation in Figure 7 revealed that 28.6% (6 out of 21) of the participants' scores increased and 71.4% (15 out of 21) of the participants' scores did not increase after the intervention.

Descriptive statistics were used to describe the data for the Experience with Digital Games construct and are shown in Table 25.

Table 25.

Descriptive Statistics for Experience with Digital Games

	N	*M*	*Mdn*	Mode	*SD*	Range	Min.	Max.
SPoDGBLS (Pre)	21	18.86	19	19	2.89	13	11	24
SPoDGBLS (Post)	21	18.33	19	20	3.64	14	10	24

Notes: Amount = *N*, Mean = *M*, Median = *Mdn*, Standard Deviation = *SD*, Minimum = Min., Maximum = Max.

A two-tailed, paired *t*-test was conducted to compare the pre and post SPoDGBLS Experience with Digital Games scores and the results are shown in Table 26.

Table 26.

Mean, Standard Deviation, and t-test (Experience with Digital Games)

	N	*M*	M/D	*SD*	Cohen's *d*	*t*	*p*
SPoDGBLS (Pre)	21	18.86		2.89			
			-0.53		-0.18	-1.06	0.30
SPoDGBLS (Post)	21	18.33		3.64			

Notes: Amount = *N*, Mean = *M*, Difference in means = M/D, Standard Deviation = *SD*, T statistic = *t*, P value = *p*

Comparison of the mean pre SPoDGBLS (Appendix B) and post SPoDGBLS (Appendix C) scores was not found to be statistically significant ($t(20) = -1.06$, $p = 0.30$). The measure of effect size, based on the pre SPoDGBLS standard deviation of 2.89, $d = -0.18$, indicated a loss of 0.18 standard deviations from the post SPoDGBLS (Appendix B) mean. In addition, the 95% confidence interval for the DGBL intervention was $-1.56 \leq \mu \leq 0.51$, indicating that the intervention had a small negative, though not significant effect on the participants' perceived experience with digital games. Participants may have felt that they did not gain any additional experience using digital games after receiving the intervention.

Ease of Use. Davis (1989) defined ease of use as "the degree to which a person believes that using a particular system would be free of effort" (p. 320). Items 6-8 on the pre and post SPoDGBLS measured participants' perceived ease of use of digital games. Table 27 displays the participant ratings for each of these items, as well as their sum score (3 to 15) reflecting an overall pre/post ease of use rating.

Table 27.

Coded Responses: Items 6-8

	Pre SPoDGBLS Items			Pre Sum	Post SPoDGBLS Items			Post Sum
Participant	6	7	8		6	7	8	
1	4	4	4	12	5	3	4	12
2	5	3	4	12	4	3	3	10
3	4	4	4	12	4	4	3	11
4	3	4	5	12	3	4	4	11

Table 27 (continued)

	Pre SPoDGBLS Items			Pre Sum	Post SPoDGBLS Items			Post Sum
Participant	6	7	8		6	7	8	
5	5	5	5	15	5	5	4	14
6	3	4	4	11	4	5	5	14
7	4	4	4	12	4	4	4	12
8	4	3	4	11	4	4	4	12
9	5	5	5	15	5	5	5	15
10	5	5	3	13	5	5	3	13
11	4	4	4	12	4	4	4	12
12	3	4	3	10	3	3	3	9
13	4	4	4	12	5	4	4	13
14	3	3	3	9	4	5	4	13
15	4	3	3	10	5	4	3	12
16	4	5	4	13	2	2	3	7
17	4	3	3	10	3	3	3	9
18	5	3	4	12	5	3	4	12
19	3	4	3	10	3	3	3	9
20	5	3	4	12	1	1	2	4
21	4	4	3	11	4	4	4	12

Table 27 revealed that participant 14's sum score increased the most (+4 points) and participant 20's sum score decreased the most (-8 points). This indicates a 44.4% increase for participant 14 and a 66.6% decrease for participant 20. There were no changes in participant 1, 7, 9, 10, 11, and 18's sum score. Figure 8 displays participants' pre and post SPoDGBLS scores for the Ease of Use construct.

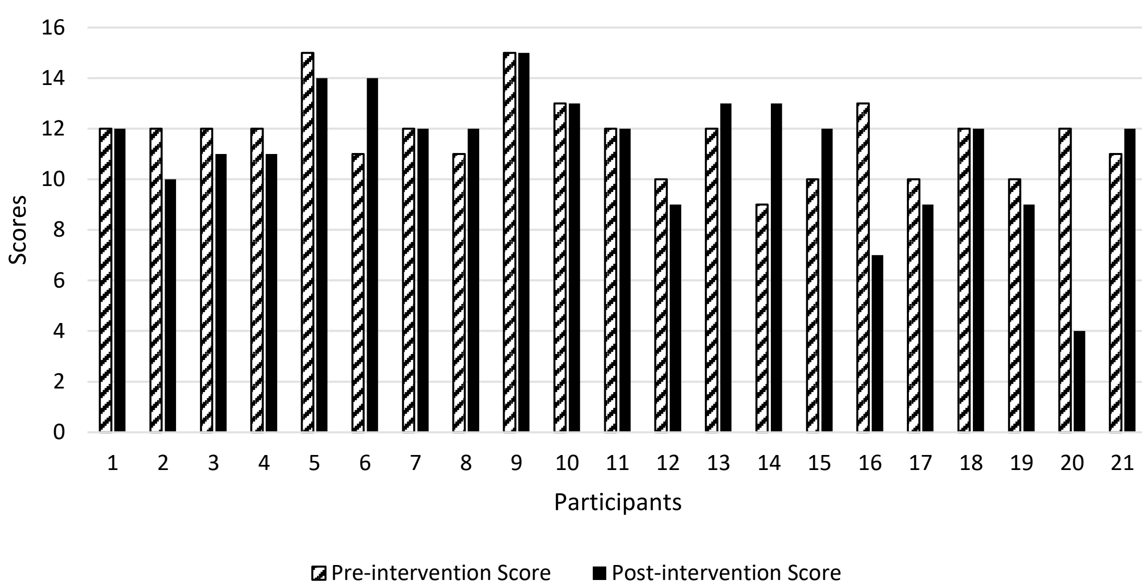


Figure 8: Ease of Use Scores

The graphical representation in Figure 8 revealed that 28.6% (6 out of 21) of the participants' scores increased and 71.4% (15 out of 21) of the participants' scores did not increase after the intervention.

Descriptive statistics were used to describe the data for the Ease of Use construct and are shown in Table 28.

Table 28.

Descriptive Statistics for Ease of Use

	N	*M*	*Mdn*	Mode	*SD*	Range	Min.	Max.
SPoDGBLS (Pre)	21	11.71	12	12	1.52	6	9	15
SPoDGBLS (Post)	21	11.24	12	12	2.55	11	4	15

Notes: Amount = *N*, Mean = *M*, Median = *Mdn*, Standard Deviation = *SD*, Minimum = Min., Maximum = Max.

A two-tailed, paired *t*-test was conducted to compare the pre and post SPoDGBLS Ease of Use scores and the results are shown in Table 29.

Table 29.

Mean, Standard Deviation, and t-test (Ease of Use)

	N	*M*	M/D	*SD*	Cohen's *d*	*t*	*p*
SPoDGBLS (Pre)	21	11.71		1.52			
			-0.47		-0.31	-0.83	0.41
SPoDGBLS (Post)	21	11.24		2.55			

Notes: Amount = *N*, Mean = *M*, Difference in means = M/D, Standard Deviation = *SD*, T statistic = *t*, P value = *p*

Comparison of the mean pre SPoDGBLS (Appendix B) and post SPoDGBLS (Appendix C) scores was not found to be statistically significant ($t(20) = -0.83$, $p = 0.41$). The measure of effect size, based on the pre SPoDGBLS (Appendix B) standard deviation of 1.52, $d = -0.31$, indicated a loss of 0.31 standard deviations from the post SPoDGBLS (Appendix B) mean. In addition, the 95% confidence interval for the DGBL intervention was $-1.67 \leq \mu \leq 0.72$, indicating that the intervention had a moderate negative, though not significant effect on the perceived ease of use of digital games. Participants may have felt that digital games were not notably easier to use after they received the intervention.

Learning Opportunities. Learning opportunities is the degree a particular system offers and individual opportunities for learning. Items 9-15 on the pre and post SPoDGBLS measured participants' perceived learning opportunities of digital games. Table 30 displays the participant ratings for each of these items, as well as their sum score (7 to 35) reflecting an overall pre/post learning opportunities rating.

Table 30.

Coded Responses: Items 9-15

	Pre SPoDGBLS Items							Pre Sum	Post SPoDGBLS Items							Post Sum
Participants	9	10	11	12	13	14	15		9	10	11	12	13	14	15	
1	4	4	3	4	5	4	4	28	4	4	4	4	3	5	4	28
2	5	5	4	4	3	3	4	28	4	2	4	3	5	3	4	25
3	3	4	3	4	5	4	2	25	4	3	4	4	4	4	3	26
4	4	4	4	4	4	3	4	27	4	4	4	3	5	4	4	28
5	3	3	4	4	5	4	4	27	4	4	4	4	4	4	4	28
6	4	4	4	4	4	4	4	28	5	5	5	5	4	4	4	32
7	4	4	4	4	4	0	0	20	4	4	4	4	4	4	4	28
8	4	4	4	4	4	4	4	28	4	3	4	4	2	4	5	26
9	5	4	4	4	4	4	4	29	4	5	5	5	5	4	5	33
10	5	5	3	4	5	3	4	29	4	5	5	5	5	5	5	34
11	4	4	3	3	3	3	3	23	4	3	3	3	3	3	4	23
12	3	4	4	4	4	4	5	28	3	3	3	3	4	4	3	23
13	4	5	4	4	3	4	4	28	4	5	4	4	2	4	3	26
14	3	3	4	4	4	3	4	25	4	4	4	3	3	4	4	26
15	3	3	3	2	3	3	3	20	3	4	3	3	3	3	4	23
16	3	4	4	3	3	4	5	26	3	3	4	3	3	3	4	23
17	4	3	3	4	4	4	3	25	3	4	3	3	4	3	3	23
18	4	3	3	3	3	4	4	24	3	4	4	4	4	5	4	28
19	3	3	4	3	4	4	4	25	3	3	4	3	4	3	3	23
20	2	3	3	4	4	4	4	24	1	0	0	0	3	1	1	6
21	4	4	4	4	3	3	4	26	4	4	4	4	2	3	4	25

Note: 0 indicates that the item was not answered.

Table 30 revealed that participant 7's sum score increased the most (+8 points) and participant 20's sum score decreased the most (-18 points). This indicates a 40% increase for participant 7 and a 75%

decrease for participant 20. There were no changes in participant 1 and 11's sum score. Figure 9 displays participants' pre and post SPoDGBLS scores for the Learning Opportunities construct.

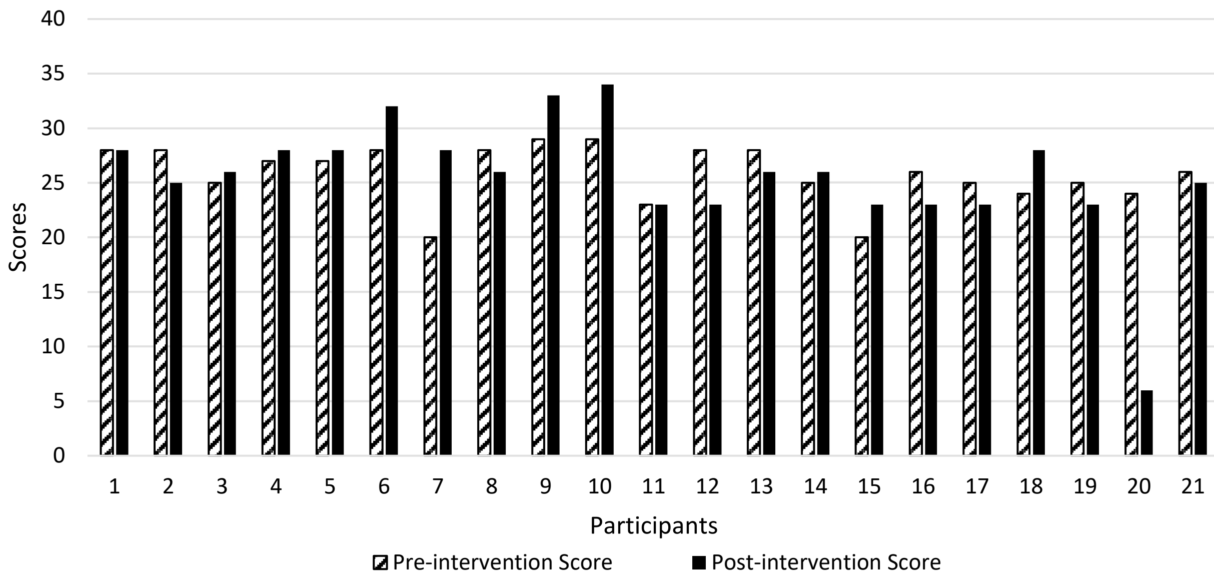


Figure 9: Learning Opportunities Scores

The graphical representation in Figure 9 revealed that 47.6% (10 out of 21) of the participants' scores increased and 52.4% (11 out of 21) did not increase after the intervention.

Descriptive statistics were used to describe the data for the Learning Opportunities construct and are shown in Table 31.

Table 31.

Descriptive Statistics for Learning Opportunities

	N	*M*	*Mdn*	Mode	*SD*	Range	Min.	Max.
SPoDGBLS (Pre)	21	25.86	26	28	2.61	9	20	29
SPoDGBLS (Post)	21	25.57	26	23	5.57	28	6	34

Notes: Amount = *N*, Mean = *M*, Median = *Mdn*, Standard Deviation = *SD*, Minimum = Min., Maximum = Max.

A two-tailed, paired *t*-test was conducted to compare the pre and post SPoDGBLS Learning Opportunities scores and the results are shown in Table 32.

Table 32.

Mean, Standard Deviation and t-test (Learning Opportunities)

	N	*M*	M/D	*SD*	Cohen's *d*	*t*	*p*
SPoDGBLS (Pre)	21	25.86		2.61			
			-0.29		-0.11	-0.25	0.80
SPoDGBLS (Post)	21	25.57		5.57			

Notes: Amount = *N*, Mean = *M*, Difference in means = M/D, Standard Deviation = *SD*, T statistic = *t*, P value = *p*

The mean pre SPoDGBLS (Appendix B) score was 25.86 and the mean post SPoDGBLS (Appendix C) score was 25.57, for a mean loss of 0.29. This difference was not statistically significant ($t(20) = -0.25$, $p = 0.80$). The measure of effect size, based on the pre SPoDGBLS (Appendix B) standard deviation of 2.61, $d = -0.11$, indicated a loss of 0.11 standard deviations from the post SPoDGBLS (Appendix B) mean. In addition, the 95% confidence interval for the DGBL intervention was $-2.63 \leq \mu \leq 2.06$, indicating that the intervention had a small negative, though not significant effect on the perceived learning opportunities of digital games. Participants may have felt that digital games did not increase their opportunities for learning after receiving the intervention.

Usefulness. Usefulness is the degree to which an individual believes that a particular system would enhance their performance. Items 16-19 on the pre and post SPoDGBLS measured participants' perceived usefulness of digital games. Table 33 displays the participant ratings for each of these items, as well as their sum score (4 to 20) reflecting an overall pre/post usefulness rating.

Table 33.

Coded Responses: Items 16-19

	Pre SPoDGBLS Items				Pre Sum	Post SPoDGBLS Items				Post Sum
Participant	16	17	18	19		16	17	18	19	
1	5	5	5	5	20	5	5	5	5	20
2	4	4	3	5	16	3	5	3	3	14
3	2	2	3	4	11	3	3	4	4	14
4	3	4	3	3	13	4	4	4	3	15
5	3	3	3	3	12	4	3	3	3	13
6	4	4	3	0	11	5	5	5	4	19
7	0	5	4	4	13	4	4	4	4	16
8	4	4	4	4	16	4	3	4	3	14
9	5	4	3	4	16	5	5	4	5	19
10	5	4	5	5	19	5	5	5	5	20
11	3	3	3	4	13	3	3	3	4	13
12	3	3	3	4	13	3	3	3	3	12
13	4	4	3	4	15	3	4	3	3	13
14	2	2	2	2	8	4	3	3	3	13
15	4	3	4	3	14	4	4	3	4	15
16	4	4	3	3	14	2	3	3	3	11
17	4	2	2	2	10	2	3	2	2	9
18	3	3	3	2	11	3	4	3	3	13
19	4	4	4	3	15	4	4	4	3	15
20	3	3	3	3	12	4	4	4	4	16
21	5	3	2	4	14	4	4	4	4	16

Note: 0 indicates that the item was not answered.

Table 33 revealed that participant 6's sum score increased the most (+8 points) and participant 16's sum score decreased the most (-3 points). This indicates a 72.7% increase for participant 6 and a 21.4% decrease for participant 16. There were no changes in participant 1, 11, and 19's sum score. Figure 10 displays participants' pre and post SPoDGBLS Usefulness scores.

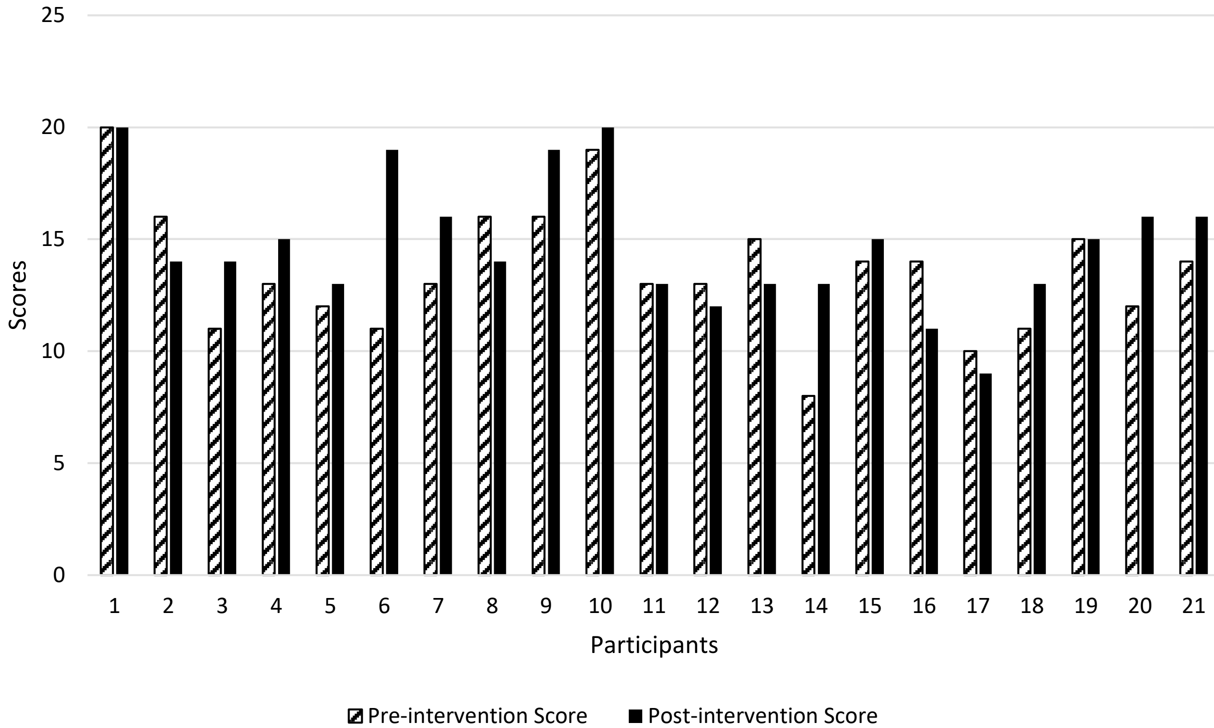


Figure 10: Usefulness Scores

The graphical representation in Figure 10 revealed that 57.1% (12 out of 21) of the participants' scores increased and 42.9% (9 out of 21) of the participants' scores did not increase after the intervention.

Descriptive statistics were used to describe the data for the Usefulness construct and are shown in Table 34.

Table 34.

Descriptive Statistics for Usefulness

	N	*M*	*Mdn*	Mode	*SD*	Range	Min.	Max.
SPoDGBLS (Pre)	21	13.62	13	13	2.85	12	8	20
SPoDGBLS (Post)	21	14.76	14	13	2.9	11	9	20

Notes: Amount = *N*, Mean = *M*, Median = *Mdn*, Standard Deviation = *SD*, Minimum = Min., Maximum = Max.

A two-tailed, paired *t*-test was conducted to compare the pre and post SPoDGBLS Usefulness scores and the results are shown in Table 35.

Table 35.

Mean, Standard Deviation, and t-test (Usefulness)

	N	*M*	M/D	*SD*	Cohen's *d*	*t*	*p*
SPoDGBLS (Pre)	21	13.62		2.85			
			1.14		0.4	1.96	0.06
SPoDGBLS (Post)	21	14.76		2.9			

Notes: Amount = *N*, Mean = *M*, Difference in means = M/D, Standard Deviation = *SD*, T statistic = *t*, P value = *p*

The mean pre SPoDGBLS (Appendix B) score was 13.62 and the mean post SPoDGBLS (Appendix C) score was 14.76, for a mean gain of 1.14. This difference was not statistically significant ($t(20) = 1.96$, $p = 0.06$). The measure of effect size, based on the pre SPoDGBLS (Appendix B) standard deviation of 2.85, $d = 0.4$, indicated a gain of 0.4 standard deviations from the pre SPoDGBLS (Appendix B) mean. In addition, the 95% confidence interval for the DGBL intervention was $-0.07 \leq \mu \leq 2.36$, indicating that the intervention had a moderate positive, though not significant effect on the perceived usefulness of digital games. Participants may have felt that digital games enhanced their performance after receiving the intervention.

Preference for Digital Games. Preference for digital games is an individual's positive feelings about and choice for digital games. In other words, do students have "positive feelings" about having digital games in math class? Items 20-22 on the pre and post SPoDGBLS (Appendix C) measured participants' perceived preference for digital games. Table 36 displays the participant ratings for each of these items, as well as their sum score (3 to 15) reflecting an overall pre/post preference for digital games rating.

Table 36.

Coded Responses: Items 20-22

	Pre SPoDGBLS Items			Pre Sum	Post SPoDGBLS Items			Post Sum
Participant	20	21	22		20	21	22	
1	4	5	4	13	4	3	4	11
2	4	3	5	12	3	3	4	10
3	4	2	4	10	3	3	5	11
4	5	5	5	15	5	5	5	15
5	4	4	4	12	4	4	4	12
6	4	5	5	14	4	4	4	12
7	4	5	5	14	4	5	5	14
8	4	4	4	12	4	4	5	13
9	4	4	5	13	4	5	4	13
10	5	4	5	14	5	5	5	15
11	4	4	4	12	3	4	4	11
12	3	4	3	10	3	3	3	9
13	4	5	5	14	4	3	3	10
14	2	2	3	7	4	4	4	12
15	4	4	4	12	3	4	3	10
16	4	3	5	12	2	3	3	8
17	4	3	3	10	3	3	4	10
18	3	3	4	10	3	3	4	10
19	5	4	5	14	4	4	3	11
20	5	3	1	9	4	4	4	12
21	3	4	4	11	4	4	4	12

Table 36 revealed that participant 14's sum score increased the most (+5 points) and participant 13 and 16's sum score decreased the most (-4 points). This indicates a 71.4% increase for participant 14 and a 33.33% decrease for participants 13 and 16. There were no changes in participant 4, 5, 7, 9, 17 and 18's sum score. Figure 11 displays participants' pre and post SPoDGBLS scores for the Preference for Digital Games construct.

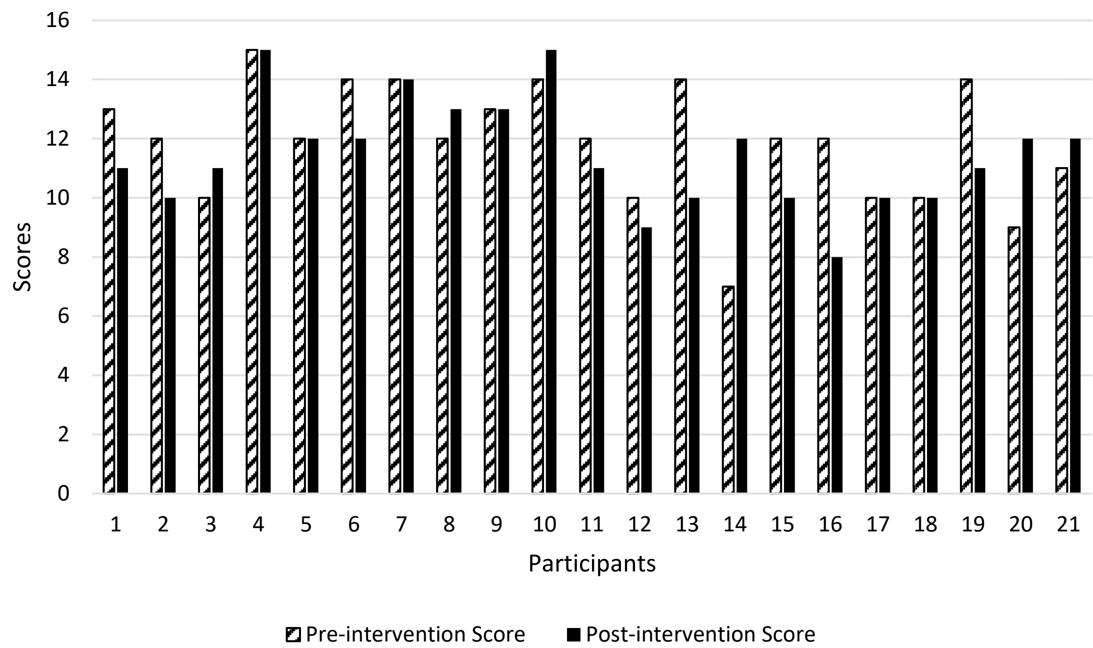


Figure 11: Preference for Digital Games Scores

The graphical representation in Figure 11 revealed that 28.6% (6 out of 21) of the participants' scores increased and 71.4% (15 out of 21) of the participants' scores did not increase after the intervention.

Descriptive statistics were used to describe the Preference for Digital Games construct and are shown in Table 37.

Table 37.

Descriptive Statistics for Preference for Digital Games

	N	*M*	*Mdn*	Mode	*SD*	Range	Min.	Max.
SPoDGBLS (Pre)	21	11.9	12	12	2.02	8	7	15
SPoDGBLS (Post)	21	11.48	11	10 & 12	1.83	7	8	15

Notes: Amount = *N*, Mean = *M*, Median = *Mdn*, Standard Deviation = *SD*, Minimum = Min., Maximum = Max.

A two-tailed, paired *t*-test was conducted to compare the pre and post SPoDGBLS Preference for Digital Games scores and the results are shown in Table 38.

Table 38.

Mean, Standard Deviation, and t-test (Preference for Digital Games)

	N	*M*	M/D	*SD*	Cohen's *d*	*t*	*p*
SPoDGBLS (Pre)	21	11.9		2.02			
			-0.42		-0.21	-0.91	0.37
SPoDGBLS (Post)	21	11.48		1.83			

Notes: Amount = *N*, Mean = *M*, Difference in means = M/D, Standard Deviation = *SD*, T statistic = *t*, P value = *p*

The mean pre SPoDGBLS (Appendix B) score was 11.9 and the mean post SPoDGBLS (Appendix C) score was 11.48, for a mean loss of 0.42. This difference was not statistically significant ($t(20) = -0.91$, $p = 0.37$). The measure of effect size, based on the pre SPoDGBLS (Appendix B) standard deviation of 2.02, $d = -0.21$, indicated a loss of 0.21standard deviations from the pre SPoDGBLS (Appendix B) mean. In addition, the 95% confidence interval for the DGBL intervention was $-1.41 \leq \mu \leq 0.55$, indicating that the intervention had a small negative, though not significant effect on the perceived preference for digital games. Participants may have felt less favorable about digital games after receiving the intervention.

The pre and post SPoDGBLS were used to investigate the changes that occurred in student perceptions of DGBL after the implementation of the mathematics intervention. Interpretations of the changes between the administrations of the pre and post SPoDGBLS are limited to capturing students' views of their experiences with the digital game-based approach to learning mathematics. A lower post sum score after 5 weeks experiencing the DGBL intervention could be due to a change in student's internal frame of reference of the construct that was being measured. The pre and post SPoDGBLS do not directly measure the amount of learning that occurred thus cannot be reported as evidence of success, effectiveness, or a change in learning.

Small Group, Semi-structured, Open-ended Interviews

Six participants were asked five open-ended interview questions. One male and one female were placed into three groups (low, middle, and high) according to their SPoDGBLS (Appendix B) ratings and interviewed together. Participants 1, 3, and 5 were the females from the low, middle, and high groups, respectively; participants 2, 4, and 6 were the males. As explained in Chapter 3 (page 53) Coder 1 and Coder 2 co-coded and analyzed the interview data using content analysis. The emerging codes and the sample responses in relation to the interview questions are reported in Tables 39 through 43.

Table 39.

Interview Question # 1: Tell me about your experience playing digital games.

Participant	Code	Sample Responses
1	Experience	Not often. Sometimes I do play. Like if I do it, I'll do like one hour.
2	Experience	Prodigy and DreamBox and that's it. I do play DreamBox when I'm told to but I normally play Prodigy. I play Prodigy a lot.
3	Experience	Three and a half to four hours. I usually just play things from the game store. I've used digital games in math before.
4	Experience	Probably, like, two and a half hours…, Rocket League, Minecraft, when I'm working, different things I don't know. Probably, like, five hours.
5	Experience	I play digital games a lot. I play it really often. I play it on my phone too. On a weekday maybe, like, two. Well I have a lot of, like, game DNA.
6	Experience	I play them pretty often. I do like DreamBox… Afterschool I probably play about an hour or two…at least an hour…

Table 40.

Interview Question # 2: What are some things that you find to be easy about using digital games in math class?

Participant	Code	Sample Response
1	Easy	I would be able to handle them… it's sometimes really easy. Sometimes they are, um, easy.
2	Easy	It's easier… so it will be, like, easier for them. I feel like it is easier for students… It's kind of easier for me to understand games.
3	Easy	It was easy…, Pretty easy. It's usually easy…
4	Easy	… it gets easy. Easy when you get the hang of it.
5	Easy	…it gets easier and easier. What makes them easy…, Easy.
6	Easy	Well it's easier to find it...., …you, um, just have to click one button to play your game..., We just have to write the answers down figure it out and then hit enter.

Table 41.

Interview Question # 3: Please describe how digital game-based learning (DGBL) can provide you with different ways to learn?

Participant	Code	Sample Response
1	Ways to learn	… so I can indicate what I need to work on more. Sometimes you're learning the same stuff that you're learning… So, like, I said, um, sometimes they explain how to do some math…
2	Ways to learn	It's Math and you got to answer the questions to level up., ... so they're playing games and learning at the same time., ...and if I'm interested in it.
3	Ways to learn	If you really read it early and understand you'll get it easier and faster., …but it depends on how easy the lessons are to understand. The lessons that you do are more adjusted for you and nobody else. As you progress the lessons get harder and you have to think more.
4	Ways to learn	If you don't understand it can explain how you can play it…, …so you don't learn more things., …but digital games they don't explain a lot.

Table 41 (continued)

Participant	Code	Sample Response
5	Ways to learn	…with learning, um, stuff better. … and learn more stuff..., and more difficult ones I might have to write them out., ….by using digital gaming it's kind of a different way because…
6	Ways to learn	… I feel like it does help me learn better…, …we can learn in our own time and, like, not wait for, … and, like, have more control over our learning pretty much. You, um, figure out the answers…

Table 42.

Interview Question # 4: What are the benefits of using digital games?

Participant	Code	Sample Response
1	Benefits	Sometimes in, like, those games I learn a little bit more… so I get a little bit more out of it… so I learned a little bit faster., … and it explained it a little bit., … and you're having more fun learning.
2	Benefits	… they probably listen more., … but it's, like, not a bad thing to add on. I feel like I would get a lot done., … and I feel, like, I would know what to do and stuff on certain games.
3	Benefits	It makes things interesting., … and that can motivate you to, like, do better., …it'll change math class a little.
4	Benefits	It can help you sometimes., … and learn new things. Games have multi-player so you can meet other people.
5	Benefits	…it really helped me out…, … and know the answer in my brain…, …and, like, really focus on it., …and getting to know it better.
6	Benefits	…you can learn better…, …and helps us learn the answer., …like, it makes it more fun and stuff like that .

Table 43.

Interview Question # 5: Tell me about your preference for playing digital games in math class.

Participant	Codes	Sample Response
1	Preference	…because sometimes they are fun., … it's much more funner playing games., …so, um, I'm kind of excited using digital games.
2	Preference	…and it all depends on what kind of game it is. A lot of kids, like, playing games. Because it's fun to me.
3	Preference	They're really fun. I don't play it all the time just sometimes when I'm bored. I can just control how much I play. You might get a little more excited to go to class.
4	Preference	I like playing digital games a lot. It's fine using digital games in math class. Sometimes I like digital games more.
5	Preference	A lot of kids like gaming more…, …and by them liking what they are doing… it makes it more fun in class to do what they like to do. I love doing digital games…
6	Preference	I feel digital games are more, like, fun..., You are doing something that you like… so you want to do it more. So yeah I, like, to do digital games. I like digital games…

The categories compiled from the three interview groups produced codes that aligned with each of the constructs targeted in the pre and post SPoDGBLS. The SPoDGBLS data indicated the changes in student perceptions of DGBL following implementation of the mathematics intervention and the content analysis of the interviews provided a mechanism for interpreting quantitative survey responses. Frequency counts were noted for the number of times participants in each group addressed a particular construct during the interviews. The counts provided a better understanding as to why certain participants provided positive, negative, or neutral responses to a construct associated with a specific item on the SPoDGBLS. Tables 44 through 46 summarize the content analysis for the low, middle, and high interview groups.

Table 44.

Summary of Content Analysis (Low Group)

Constructs	Frequency	Percent
Experience with Digital Games	12	17.65%
Ease of Use	18	26.47%
Learning Opportunities	11	16.18%
Usefulness	20	39.41%
Preference for Digital Games	7	10.29%

The low interview group addressed the Usefulness construct the most and the Preference for Digital Games construct the least.

Table 45.

Summary of Content Analysis (Middle Group)

Constructs	Frequency	Percent
Experience with Digital Games	15	31.25%
Ease of Use	7	14.58%
Learning Opportunities	10	20.83%
Usefulness	8	16.66%
Preference for Digital Games	8	16.66%

The middle interview group addressed the Experience with Digital Games the most and the Ease of Use construct the least.

Table 46.

Summary of Content Analysis (High Group)

Constructs	Frequency	Percentage
Experience with Digital Games	34	28.33%
Ease of Use	15	12.5%
Learning Opportunities	32	26.66%
Usefulness	16	13.33%
Preference for Digital Games	23	19.16%

The high interview group also addressed the Experience with Digital Games the most and the Ease of Use construct the least. Triangulation was achieved by comparing the results from the SPoDGBLS with the content analysis of the interviews.

4.6 Summary of Results

This study was guided by three research questions. This section summarizes the quantitative and qualitative data necessary to address each research question. The key findings for each research question concludes this chapter.

Research Question 1

The first research question, "To what extent are differences evident in students' Ratios and Proportional Relationships pre and post test scores following the implementation of digital game-based learning (DGBL) into regular math instruction?" was addressed by calculating descriptive statistics and conducting a two-tailed, paired *t*-test. Descriptive statistics were calculated for both the pre and posttests. The standard deviation, mean, and median scores were higher on the Ratios and Proportional Relationships Posttest (Appendix A) when compared to the pretest. The difference between the mean pretest (41.04) and the mean posttest (69.4) scores was 28.36 points which was statistically significant ($n = 21$; $t = 7.63$; $p = 0.0001$) at the 0.05 level. This indicated a 69.1% increase between the pre and posttest. The statistically significant finding is consistent with prior empirical research on DGBL achievement in mathematics (Ahmad & Latih, 2010; Ke, 2008; Kebritchi, Hirumi, & Bai, 2010; Lee, 2009; Pope, & Mangram, 2015; Swearingen, 2011; Wilson et al., 2006). The effect size was 1.91, which showed that the posttest scores were almost 2 standard deviations higher than the pretest scores. This result indicated that student participants had significantly higher scores on the posttest when compared to the pretest, which confirms the results found in the two-tailed, paired *t*-test.

Research Question 2

The second research question, "How do the post Ratios and Proportional Relationships Test scores of student participants differ from the Ratios and Proportional Relationships Posttest cut score?" was addressed by calculating descriptive statistics and conducting a two tailed, one sample *t*-test. The difference between the mean posttest score (69.4) and the posttest cut score (65) was 4.4 points which was not statistically significant ($n = 21$; $t = 1.11$; $p = 0.28$) at the 0.05 level. The effect size was 0.24, which showed that the student participants performed 0.24 standard deviations above the cut score on the posttest. This result indicated that student participants' posttest scores were not significantly higher than the posttest cut score, which confirms the results found in the two-tailed, one sample *t*-test.

Research Question 3

The third research question, "What changes in student perceptions of DGBL occur following implementation of the mathematics intervention?" was addressed by calculating descriptive statistics and conducting a two-tailed, paired *t*-test and a content analysis. The differences between the mean pre and post SPoDGBLS scores for all 5 constructs were not statistically significant at the 0.05 level. Student response ratings decreased for the Experience with Digital Games (-2.8%), Ease of Use (-4%), Learning Opportunities (-1.1%) and Preference for Digital Games (-3.5%) constructs and increased for the Usefulness construct (+8.4%). This result indicated that student participants' post SPoDGBLS (Appendix C) scores were not significantly higher or lower than the pre SPoDGBLS (Appendix B), which confirms the results found in the two-tailed, paired *t*-test.

The content analysis of the interviews showed that the low interview group rarely mentioned their preference for digital games (10.29%), instead, they focused mainly on the usefulness (39.41%) of digital games, which accurately reflected their responses on the SPoDGBLS. These results indicated that following the intervention the low interview group did not necessarily prefer digital games but they did perceive them as useful. The findings also showed that the middle and high interview groups rarely mentioned the ease of use ([14.58%] and [12.50%]) of digital games, instead, they focused mainly on their experience with digital games ([31.25%] and [28.33%]), which accurately reflected their responses on the SPoDGBLS. These results indicated that following the intervention both the middle and high interview groups did not believe that using digital games was effortless even though they perceived having beneficial experiences with digital games.

CHAPTER V: CONCLUSIONS, IMPLICATIONS, AND RECOMMENDATIONS

The purpose of this research study was to: (a) determine whether or not DGBL is a viable tool in helping students to improve achievement in middle school mathematics and (b) gauge their perceptions regarding the use of DGBL. This chapter provides conclusions about the research questions. It also provides implications for practice and recommendations for future research studies. The conclusions, implications, and recommendations were drawn from the findings presented in Chapter 4

5.1 Conclusions

The differences between students' Ratios and Proportional Relationships pre and post test scores were evident to a great extent (69.1% increase). On average, students' posttest scores were 28.36 points higher than their pretest scores. This indicates that DGBL can be successfully integrated into regular math instruction and have a positive impact on students' ability to learn and/or retain new math information.

Participants did not perform significantly higher than the cut score on the posttest. However, they did improve considerably on the posttest when compared to the pretest. On average, the participants scored 4.4 points higher than the cut score on the posttest and they scored 23.96 points lower than the cut score on the pretest. This indicates that DGBL is a viable tool that can be used to help students improve their achievement in middle school mathematics.

Participants' SPoDGBLS response ratings indicated that student perceptions of DGBL did not change significantly after receiving the intervention. Nonetheless, student response ratings increased for the Usefulness construct and the usefulness of digital games was the main focus of the low group interview. Therefore, a conclusion can be drawn that students found DGBL to be useful when it was incorporated into regular instruction and suggests that students believed that DGBL could enhance their math performance and effectiveness, increase their learning productivity, and help them to achieve better grades.

5.2 Implications for Practice

The findings of this study have specific implications for the use of DGBL in mathematics at the middle school level. Factors such as access to DGBL, instructional time, math curriculum, and academic tracking could have played a critical role in the outcome of this study. The implications are presented below.

Implication 1 - Access to DGBL

School and division leaders should invest in DGBL that can be regularly used by students on a daily basis. The participants involved in this study had daily access to DGBL inside and outside of their school building. A lack of daily access to DGBL for participants could have a negative effect on the results of this study if it is replicated.

Implication 2 - Instructional Time

The teacher who participated in this study had additional instructional time to incorporate DGBL because the math class met every day. It is implied that if DGBL is to be included into a math class scheduled to meet every other day that the teacher will have less instructional time to introduce new material to his or her students. Therefore, decreasing instructional time may have a negative impact on student performance.

Implication 3 – Math Curriculum

Sixth grade math teachers in Virginia use a Standards of Learning (SOL) Curriculum Framework as a guide to ensure that they are teaching the content that is measured with the end of the year 6^{th} grade Math SOL test. Each school division in the state also supplies its teachers with a sequence of instruction and pacing guide to help ensure that all concepts are taught in a timely manner. The curriculum framework suggests using appropriate technological tools and strategies in instruction but it is not specific on what types are to be used. The findings from this study demonstrated the efficacy of using

DGBL for teaching math. Therefore, it is implied that there is a need for math teachers to include DGBL into their curriculum.

Implication 4 - Academic Tracking

Students that participated in this study were preassigned to a Middle School Math Course 1 class by the administrative team of the middle school. They were grouped together according to similarities of performance level in mathematics. It is implied that ability-based tracking can allow for targeting those students who might benefit the most from DGBL.

5.3 Recommendations for Future Studies

Considering the limitations of this study, the researcher recommends the following for future research studies. Additional research regarding the benefits of DGBL in mathematics at the middle school level is needed because very little has been conducted. This study was conducted in one of the five regions of Virginia at a large suburban middle school. Future research could include student groups of other grade or performance levels, socioeconomic status (SES), or type of school, and be conducted in other regions of Virginia and across the United States. Participants where conveniently selected to participate in the study and constituted a small percentage of the sixth grade students at the middle school. The amount of participants could be increased and, if a specific group is not readily available or suitable for the study, participants could be selected randomly. A causal comparative research design could be considered to examine the difference between two different groups: those who will receive the DGBL intervention and those who will not.

References

Abbott, R. D., O'Donnell, J., Hawkins, J. D., Hill, K. G., Kosterman, R., & Catalano, R. F. (1998). Changing teaching practices to promote achievement and bonding to school. *The American Journal of Orthopsychiatry*, *68*(4), 542–552. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=cmedm&AN=9809114&site=eds-live&scope=site

Adams, D. A., Nelson, R. R., & Todd, P. A. (1992). Perceived Usefulness, Ease of Use, and Usage of Information Technology: A Replication. *MIS Quarterly*, (2), 227. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=edsgic&AN=edsgcl.12417576&site=eds-live&scope=site

Aguilar-Roca, N. M., Williams, A. E., & O'Dowd, D. K. (2012). The impact of laptop-free zones on student performance and attitudes in large lectures. *Computers & Education*, 59(4), 1300-1308. https://doi-org.ezproxy.lib.vt.edu/10.1016/j.compedu.2012.05.002

Ahmad, W., Shafie, A., & Latif, M. (2010). Role-Playing Game-Based Learning in Mathematics. *The Electronic Journal of Mathematics and Technology,* 4(2), 184-196. Retrieved from http://atcm.mathandtech.org/EP2009/papers_full/2812009_17098.pdf

Ahmad, W. F. B. W., & Latih, N. H. B. A. (2010, December). Development of a Mathematics courseware: Fractions. In *Proceedings of the Fifteenth Asian Technology Conference in Mathematics, Kuala Lumpur, Malaysia* (Vol. 17, p. 21). Retrieved from http://atcm.mathandtech.org/EP2010/regular/3052010_18223.pdf

Al-Gahtani, S. (2001). The applicability of TAM outside North America: An empirical test in the United Kingdom. *Information Resources Management Journal (IRMJ), 14*(3), 37-46. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=edsgao&AN=edsgcl.178534924&site=eds-live&scope=site

Alharbi, S., & Drew, S. (2014). Using the Technology Acceptance Model in Understanding Academics' Behavioural Intention to Use Learning Management Systems. *International Journal of Advanced Computer Science and Applications*, 5(1), 143-155. doi:10.14569/IJACSA.2014.050120

All, A., Nunez Castellar, E. P., & Van Looy, J. (2014). Defining best practices for assessing the effectiveness of digital game-based learning. In *64rd International Communication Association: Annual Conference, Proceedings*. Presented at the 64rd International Communication Association (ICA) Annual Conference.

Allen, J. P., Philliber, S., & Hoggson, N. (1990). School-based prevention of teen-age pregnancy and school dropout: Process evaluation of the national replication of the teen outreach program. *American Journal of Community Psychology*, *18*(4), 505-524. Retrieved from https://link.springer.com/article/10.1007/BF00938057

American Psychological Association. (2016). Ethical Principles of Psychologists and Code of Conduct. In A. E. Kazdin (Ed.), *Methodological issues and strategies in clinical research* (pp. 495-512). Washington, DC, US: American Psychological Association. http://dx.doi.org/10.1037/14805-030

Andrews, E. L. (2016, May 20). Stanford Study Shows How Digital Math Games Can Teach More Than Rote Skills Retrieved from http://go.galegroup.com.ezproxy.lib.vt.edu/ps/i.do?p=AONE&u=viva_vpi&id=GALE%7CA452835635&v=2.1&it=r&sid=ebsco

Annetta, L. A., Minogue, J., Holmes, S. Y., & Cheng, M. T. (2009). Investigating the impact of video games on high school students' engagement and learning about genetics. *Computers & Education*, *53*(1), 74-85. Retrieved from https://www.sciencedirect.com/science/article/pii/S0360131509000049

Armstrong, T. (2009). *Multiple intelligences in the classroom, 3rd edition.* Alexandria, VA: Association for Supervision and Curriculum Development. Retrieved from https://ebookcentral-proquest-com.ezproxy.lib.vt.edu/lib/vt/detail.action?docID=485498

Ausubel, D. P., & Youssef, M. (1965). The Effect of Spaced Repetition on Meaningful Retention. *The Journal of General Psychology*, *73*(1), 147-150. Retrieved from https://www.tandfonline.com/doi/abs/10.1080/00221309.1965.9711263

Baek, Y. K. (2008). What Hinders Teachers in Using Computer and Video Games in the Classroom? Exploring factors inhibiting the uptake of computer and video games. *Cyber Psychology & Behavior, 11*(6), 665-671. doi:10.1089/cpb.2008.0127

Baer, J. S., Ball, S. A., Campbell, B. K., Miele, G. M., Schoener, E. P., & Tracy, K. (2007). Training and fidelity monitoring of behavioral interventions in multi-site addictions research. *Drug and Alcohol Dependence, 87*(2), 107-118. doi:10.1016/j.drugalcdep.2006.08.028

Bailey, B., Cooper, T. E., & Briggs, K. S. (2012). The Effect of a Modified Moore method on Attitudes and Beliefs in Precalculus. *School Science and Mathematics, 112*(6), 377-383. https://doi.org/10.1111/j.1949-8594.2012.00152.x

Bandura, A. (1977). *Social learning theory*. Englewood Cliffs, NJ: Prentice Hall.

Bangser, M., & National High School Center. (2008). Preparing High School Students for Successful Transitions to Postsecondary Education and Employment. Issue Brief. *National High School Center*. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=eric&AN=ED502596&site=eds-live&scope=site

Baniqued, P. L., Lee, H., Voss, M. W., Basak, C., Cosman, J. D., Desouza, S., et al. (2013). Selling points: what cognitive abilities are tapped by casual video games? Acta Psychol. 142, 74–86. doi: 10.1016/j.actpsy.2012.11.009

Banks, J. A. (1993). *Multiethnic education: Theory and practice* (3rd ed.). Boston: Allyn & Bacon

Barab, S., Scott, B., Siyahhan, S., Goldstone, R., Ingram-Goble, A., Zuiker, S., & Warren, S. (2009). Transformational Play as a Curricular Scaffold: Using Videogames to Support Science Education. *Journal of Science Education and Technology, 18*(4), 305-320. Retrieved from http://www.jstor.org.ezproxy.lib.vt.edu/stable/20627710

Barab, S. A., Zuiker, S., Warren, S., Hickey, D., Ingram-Goble, A., Kwon, E-J., Kouper, I., & Herring, S. C. (2007). Situationally embodied curriculum: Relating formalisms and contexts. Science Education, 91(5), 750–782. https://doi.org/10.1002/sce.20217

Barak, M., Lipson, A., & Lerman, S. (2006). Wireless Laptops as Means for Promoting Active Learning in Large Lecture Halls. *Journal of Research on Technology in Education*, 38(3), 245-263. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=eric&AN=EJ728904&site=eds-live&scope=site

Barber, J. P., Liese, B., & Abrams, M. J. (2003). Development of the Cognitive Therapy Adherence and Competence Scale. *Psychotherapy Research, 13,* 205–221. Retrieved from https://www.tandfonline.com/doi/abs/10.1093/ptr/kpg019?journalCode=tpsr20

Barber, J. P., Sharpless, B. A., Klostermann, S., & McCarthy, K. S. (2007). Assessing intervention competence and its relation to therapy outcome: A selected review derived from the outcome literature. *Professional Psychology: Research and Practice*, *38*(5), 493-500. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=edsggo&AN=edsgcl.170234007&site=eds-live&scope=site

Barkand, J., & Kush, J. (2009). GEARS a 3D Virtual Learning Environment and Virtual Social and Educational World Used in Online Secondary Schools. *Electronic Journal of e-learning*, *7*(3), 215-224. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=eric&AN=EJ872406&site=eds-live&scope=site

Baroody, A., & Coslick, R. T. (1998). *Fostering Children's Mathematical Power: An Investigative Approach to K-8 Mathematics Instruction*. Mahwah, N.J.:Routledge.

Basen-Engquist, K., O'Hara-Tompkins, N., Lovato, C. Y., Lewis, M. J., Parcel, G. S., & Gingiss, P. (1994). The effect of two types of teacher training on implementation of smart choices: A tobacco prevention curriculum. *The Journal of School Health, 64*(8), 334. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=edsgih&AN=edsgcl.16501770&site=eds-live&scope=site

Becker, K. (2017). *Choosing and Using Digital Games in the Classroom: A Practical Guide*. Switzerland: Springer. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=edsebk&AN=1242511&site=eds-live&scope=site

Bellg, A. J., Borrelli, B., Resnick, B., Hecht, J., Minicucci, D. S., Ory, M., & Czajkowski, S. (2004). Enhancing treatment fidelity in health behavior change studies: best practices and recommendations from the NIH Behavior Change Consortium. *Health Psychology: Official Journal of The Division Of Health Psychology, American Psychological Association*, *23*(5), 443–451. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=cmedm&AN=15367063&site=eds-live&scope=site

Bennett, S., Maton, K., & Kervin, L. (2008). The digital natives debate: A critical review of the evidence. *British Journal of Educational Technology, 39*(5), 775-786. Retrieved from https://onlinelibrary.wiley.com/doi/full/10.1111/j.1467-8535.2007.00793.x

Berger, P. L., & Luckmann, T. (1980). *The Social Construction of Reality; A Treatise in the Sociology of Knowledge*. New York: Irvington Publishers, 1980. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=cat07058a&AN=vtp.752777&site=eds-live&scope=site

Betz, J. A. (1995). Computer games: Increase learning in an interactive multidisciplinary environment. *Journal of Educational Technology Systems*,*24*(2), 195-205. https://doi.org/10.2190/119M-BRMU-J8HC-XM6F

Birman, B., Bohrnstedt, G., Hannaway, J., O'Day, J., Osher, D., Phillips, G., & Salinger, T. (2013, October, 30). Three decades of education reform: Are we still "A Nation at Risk?" *American Institutes for Research.* Washington, DC. Retrieved from http://www.air.org/resource/three-decades-education-reform-are-we-still-nation-risk

Bolton, H. (2013). Developing standards using the language of teaching and learning. Per Linguam: *A Journal of Language Learning*, 28(2), 46. Retrieved from http://perlinguam.journals.ac.za/pub/article/view/530/571

Boniolo, B., & Spadaro, C. (2010). NEMO+ 3D, an integrated environment for advanced university teaching. *Journal of e-Learning and Knowledge Society*, *6*(1), 93-102. Retrieved from https://www.learntechlib.org/p/43410/

Botvin, E. M., Botvin, G. J., Baker, E., & Filazzola, A. D. (1990). A cognitive-behavioral approach to substance abuse prevention: One-year follow-up. *Addictive Behaviors, 15*(1), 47-63. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=cmedm&AN=2316411&site=eds-live&scope=site

Botvin, G. J., Baker, E., Dusenbury, L., Tortu, S., & Botvin, E. M. (1990). Preventing adolescent drug abuse through a multimodal cognitive-behavioral approach: Results of a 3-year study. *Journal of Consulting and Clinical Psychology,58*(4), 437-446. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=edsggo&AN=edsgcl.8884710&site=eds-live&scope=site

Bourgonjon, J. (2015). *Video Game Literacy: Social, Cultural and Educational perspectives* (Doctoral dissertation, Ghent University).

Bourgonjon, J., De Grove, F., De Smet, C., Van Looy, J., Soetaert, R., & Valcke, M. (2013). Acceptance of game-based learning by secondary school teachers. Computers & Education, 67, 21-35. Retrieved from https://doi-org.ezproxy.lib.vt.edu/10.1016/j.compedu.2013.02.010

Bouta, H., Retalis, S., & Paraskeva, F. (2012). Utilising a collaborative macro-script to enhance student engagement: A mixed method study in a 3D virtual environment. *Computers & Education, 58*(1), 501-517. https://doi-org.ezproxy.lib.vt.edu/10.1016/j.compedu.2011.08.031

Bragg, L. (2003, January). Children's perspectives on mathematics and game playing. In Mathematics education research: innovation, networking, opportunity: proceedings of the 26th annual conference of the Mathematics Education Research Group of Australasia, held at Deakin University (pp. 160-167). MERGA Inc.

Branson, R. K., Rayner, G. T., Cox, J. L., Furman, J. P., & King, F. J. (1975). *Interservice Procedures for Instructional Systems Development. Executive Summary and Model*. Florida State Univ. Tallahassee Center for Educational Technology. Retrieved from https://apps.dtic.mil/dtic/tr/fulltext/u2/a019486.pdf

Breitenstein, S. M., Gross, D., Garvey, C., Hill, C., Fogg, L., & Resnick, B. (2010). Implementation fidelity in community-based interventions. *Research in Nursing & Health*, *33*(2), 164–173. http://doi.org/10.1002/nur.20373

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

Education, 57(3), 1971-1988. Retrieved from https://www-sciencedirect-com.ezproxy.lib.vt.edu/science/article/pii/S0360131511000881

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational researcher*, *18*(1), 32-42. Retrieved from https://journals.sagepub.com/doi/abs/10.3102/0013189x018001032

Bruner, J. S. (1961). The Act of Discovery. *Harvard Educational Review, 31*(1), 21–32. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=ehh&AN=19708531&site=eds-live&scope=site

Bruner, J. S. (1972). Nature and uses of immaturity. *American Psychologist, 27*(8), 687-708. http://dx.doi.org/10.1037/h0033144

Buckley, K. E., & Anderson, C. A. (2006). A theoretical model of the effects and consequences of playing video games. *Playing video games: Motives, responses, and consequences*, 363-378. Retrieved from https://www.researchgate.net/profile/Craig_Anderson19/publication/251424046_A_Theoretical_Model_of_the_Effects_and_Consequences_of_Playing_Video_Games/links/580e7a4f08ae7525273d2826/A-Theoretical-Model-of-the-Effects-and-Consequences-of-Playing-Video-Games.pdf

Bush, G. W. (2001). No Child Left Behind. Retrieved from https://www2.ed.gov/nclb/overview/intro/execsumm.pdf

Busch, C., Conrad, F., & Steinicke, M. (2013). Digital Games and the Hero's Journey in Management Workshops and Tertiary Education. *Electronic Journal of E-Learning*, *11*(1), 3–15. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=ehh&AN=91531196&site=eds-live&scope=site

Cankaya, S., Uysal, O., & Kuzu, A. (2010, June). Constructivism in Educational Computer Games. In *EdMedia: World Conference on Educational Media and Technology* (Vol. 2010, No. 1, pp. 1303-1308). Association for the Advancement of Computing in Education (AACE).

Carroll, C., Patterson, M., Wood, S., Booth, A., Rick, J., & Balain, S. (2007). A conceptual framework for implementation fidelity. *Implementation Science*,*2*(1), 1. Retrieved from https://implementationscience.biomedcentral.com/track/pdf/10.1186/1748-5908-2-40

Carroll, K., Nich, C., & Rounsaville, B. (1998). Utility of Therapist Session Checklists to Monitor Delivery of Coping Skills Treatment for Cocaine Abusers. *Psychotherapy Research*, *8*(3), 307-320. Retrieved from https://www.tandfonline.com/doi/abs/10.1080/10503309812331332407

Carpenter, T. P., Fennema, E., Peterson, P. L., Chiang, C. P., & Loef, M. (1989). Using Knowledge of Children's Mathematics Thinking in Classroom Teaching: An Experimental Study. *American educational research journal*,*26*(4), 499-531. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=eric&AN=ED292683&site=eds-live&scope=site

Cazden, C. B. (1988). Classroom discourse: The Language of Teaching and Learning. Portsmouth, NH: Heinemann. Retrieved from https://www-jstor-org.ezproxy.lib.vt.edu/stable/pdf/4168163.pdf?refreqid=excelsior%3Ae42fd7ff9625fb4ee812481f9668b4a8

Champion, E. M. (2008). Otherness of Place: Game-based Interaction and Learning in Virtual Heritage Projects. *International Journal of Heritage Studies*, *14*(3), 210-228. Retrieved from https://www.tandfonline.com/doi/abs/10.1080/13527250801953686

Chau, P. Y. (1996). An Empirical Assessment of a Modified Technology Acceptance Model. *Journal of Management Information Systems, 13*(2), 185-204. https://doi.org/10.1080/07421222.1996.11518128

Chaudhary, A. G. (2008). Digital Game-Based Learning - Future of Education? Pranjana: *The Journal of Management Awareness*, 11(2), 1-15. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=bth&AN=44223387&site=eds-live&scope=site

Cheng, C. H., & Su, C. H. (2012). A Game-based learning system for improving student's learning effectiveness in system analysis course. Procedia-Social and Behavioral Sciences, 31, 669-675. https://doi.org/10.1016/j.sbspro.2011.12.122

Cheng, Y. M., Lou, S. J., Kuo, S. H., & Shih, R. C. (2013). Investigating elementary school students' technology acceptance by applying digital game-based learning to environmental education. *Australasian Journal of Educational Technology*, *29*(1), 96-110. https://doi.org/10.14742/ajet.65

Cheung, A., & Slavin, R. (2013). The Effectiveness of Educational Technology Applications for Enhancing Mathematics Achievement in K-12 Classrooms: A Meta-Analysis. *Educational Research Review, 9*(1), 88-113. https://doi-org.ezproxy.lib.vt.edud/10.1016/j.edurev.2013.01.001

Chin, A. (2007). T*he Authentic Confucius: A Life of Thought and Politics* (1st Scribner hardcover ed.). New York: Scribner.

Choudrie, J., & Dwivedi, Y. K. (2005). Investigating the Research Approaches for Examining Technology Adoption Issues. *Journal of Research Practice*, *1*(1), D1. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=edsdoj&AN=edsdoj.1c106c02f6704f6b86ab9d50b4fa4a9a&site=eds-live&scope=site

Churchill, D., & Churchill, N. (2008). Educational affordances of PDAs: A study of a teacher's exploration of this technology. *Computers & Education*, *50*(4), 1439-1450. Retrieved from https://www-sciencedirect-com.ezproxy.lib.vt.edu/science/article/pii/S0360131507000139?via%3Dihub

Creswell, J. W. (2014). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. SAGE Publications. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=cat07058a&AN=vtp.1285024&site=eds-live&scope=site

Christensen, T. K. (2008). The role of theory in instructional design: Some views of an ID practitioner. *Performance Improvement, 47*(4), 25-32. https://doi:10.1002/pfi.199

Cronbach, L. J.; Meehl, P.E. (1955). Construct Validity in Psychological Tests. *Psychological Bulletin*. 52 (4): 281–302. https://dx.doi.org/10.1037/h0040957

Cicchino, M. I. (2015). Using Game-Based Learning to Foster Critical Thinking in Student Discourse. *Interdisciplinary Journal of Problem-Based Learning, 9*(2), 57-74. https://doi.org/10.7771/1541-5015.1481

Clark, A. C., & Ernst, J. V. (2009a). Gaming in Technology Education: The Study of Gaming Can Teach Life Skills for the Twenty-First Century That Employers Want... These Include Analytical Thinking, Team Building, Multitasking, and Problem Solving under Duress. *The Technology Teacher*, 68(5), 21. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=edsgic&AN=edsgcl.193298066&site=eds-live&scope=site

Clark, A. C., & Ernst, J. (2009b). Gaming Research for Technology Education. *Journal of STEM Education: Innovations and Research*, 10(1), 25-30. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=a9h&AN=51650857&site=eds-live&scope=site

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

Education, *57*(3), 2178-2195. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=edsgao&AN=edsgcl.262281571&site=eds-live&scope=site

Clements, D. H., & Battista, M. T. (1990). Constructivist learning and teaching. *Arithmetic Teacher*, *38*(1), 34-35. Retrieved from https://www.researchgate.net/profile/Douglas_Clements/publication/258933053_TEAM-Tools_for_early_assessment_in_mathematics/links/56f712b508ae38d710a1c177/TEAM-Tools-for-early-assessment-in-mathematics.pdf

Collins, A. (1987). Cognitive Apprenticeship: Teaching the Craft of Reading, Writing, and Mathematics. Technical Report No. 403. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=eric&AN=ED284181&site=eds-live&scope=site

Combs, A. W. (1981). Humanistic education: Too Tender for a Tough World? *The Phi Delta Kappan*, *62*(6), 446-449. Retrieved from http://search.ebscohost.com.ezproxy.lib.vt.edu/login.apsx?direct=true&db+edsjr&AN=edsjr.20385941&site=eds-live&scope=site

Connolly, T. M., Stansfield, M., & Hainey, T. (2007). An application of games-based learning within software engineering. *British Journal of Educational Technology, 38*, 416-428. https://doi.org/10.1111/j.1467-8535.2007.00706.x

Conole, G., de Laat, M., Dillon, T., & Darby, J. (2008). ‘Disruptive technologies’, ‘pedagogical innovation’: What’s new? Findings from an in-depth study of students’ use and perception of technology. *Computers & Education, 50*(2), 511-524. Retrieved from https://www-sciencedirect-com.ezproxy.lib.vt.edu/science/article/pii/S036013150700111X

Coyne, P., Pisha, B., Dalton, B., Zeph, L. A., & Smith, N. C. (2012). Literacy by design: A universal design for learning approach for students with significant intellectual disabilities. *Remedial and Special Education, 33*(3), 162-172. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=edsgao&AN=edsgcl.342918945&site=eds-live&scope=site

Culp, K. M., Honey, M., & Mandinach, E. (2005). A retrospective on twenty years of education technology policy. *Journal of Educational Computing Research, 32*(3), 279–307. https://doi.org/10.2190/7W71-QVT2-PAP2-UDX7

Csikszentmihalyi, M. (1975). Play and Intrinsic Rewards. *Journal of Humanistic Psychology, 15*(3), 41–63. https://doi.org/10.1177/002216787501500306

Csikszentmihalyi, M. (1990). *Flow: The psychology of optimal experience* (1st ed.). New York: Harper & Row.

Dalgarno, B., & Lee, M. J. W. (2010). What are the learning affordances of 3-D virtual environments? *British Journal of Educational Technology, 41*(1), 10-32. https://doi.org/10.1111/j.1467-8535.2009.01038.x

Dalton, B., Proctor, C. P., Uccelli, P., Mo, E., & Snow, C. E. (2011). Designing for Diversity: The Role of Reading Strategies and Interactive Vocabulary in a Digital Reading Environment for Fifth-Grade Monolingual English and Bilingual Students. *Journal of Literacy Research*, *43*, 68-100. Retrieved from https://journals.sagepub.com/doi/abs/10.1177/1086296X10397872

Darling-Hammond, L., Zielezinski, M. B., & Goldman, S. (2014). Using technology to support at-risk students' learning. *Stanford Center for Opportunity Policy in Education. Online https://edpolicy.stanford.edu/publications/pubs/1241*. Retrieved from https://all4ed.org/wp-content/uploads/2014/09/UsingTechnology.pdf

Darrow, A. (2016). The Every Student Succeeds Act (ESSA): What it Means for Students With Disabilities and Music Educators. *General Music Today, 30*(1), 41-44. Retrieved from http://content.ebscohost.com/ContentServer.asp?T=P&P=AN&K=117638092&S=R&D=a9h&EbscoContent=dGJyMNLe80SeprY4v%2BvlOLCmr1Gep7NSs6e4TLSWxWXS&ContentCustomer=dGJyMPGsr1CyqbNNuePfgeyx43zx

Davis, F. D. (1989). Perceived Usefulness, Perceived Ease Of Use, and User Acceptance of Information Technology, *MIS Quarterly*, 13, 983-1003

De Garmo, C. (1896). *Herbart and the Herbartians*. New York: C. Scribner's sons. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=cat07248a&AN=crl.b1232566&site=eds-live&scope=site

De Grove, F., Bourgonjon, J., & Van Looy, J. (2012). Digital games in the classroom? A contextual approach to teachers' adoption intention of digital games in formal education. *Computers in Human behavior*, *28*(6), 2023-2033. Retrieved from https://www-sciencedirect-com.ezproxy.lib.vt.edu/science/article/pii/S0747563212001495

Dent, C. W., Sussman, S., Hennesy, M., Galaif, E. R., Stacy, A. W., Moss, M., & Craig, S. (1998). Implementation and Process Evaluation of a School-Based Drug Abuse Prevention Program: Project Towards No Drug Abuse. *Journal of Drug Education,28* (4), 361-375. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=eric&AN=EJ583274&site=eds-live&scope=site

Denoyelles, A., & Seo, K. (2012). Inspiring equal contribution and opportunity in a 3d multi-user virtual environment: Bringing together men garners and women non-gamers in Second Life (R). *Computers & Education, 58*(1), 21-29. https://doi-org.ezproxy.lib.vt.edu/10.1016/j.compedu.2011.07.007

Dewey, J. (1938). Experience and education. New York: Macmillan.

Dillenbourg, P. (1999). What do you mean by collaborative learning? *Collaborative-learning: Cognitive and computational approaches*, *1*, 1-15. Retrieved from https://telearn.archives-ouvertes.fr/hal-00190240/document

Ding, D., Guan, C., & Yu, Y. (2017). Game-based learning in tertiary education: A new learning experience for the generation Z. *International Journal of Information and Education Technology, 7*(2), 148. Retrieved from https://www.researchgate.net/profile/Chong_Guan/publication/299371961_Game-Based_Learning_in_Tertiary_Education_A_New_Learning_Experience_for_the_Generation_Z/links/5773475608ae07e45db24bda/Game-Based-Learning-in-Tertiary-Education-A-New-Learning-Experience-for-the-Generation-Z.pdf

Dingli, A., Seychell, D., & SpringerLink (Online service). (2015). *The New Digital Natives: Cutting the Chord*. Berlin, Heidelberg: Springer Berlin Heidelberg. Retrieved from https://link-springer-com.ezproxy.lib.vt.edu/content/pdf/10.1007%2F978-3-662-46590-5.pdf

Dini, K. (2012). On Video Games, Culture, and Therapy. Psychoanalytic Inquiry, 32(5), 496-505. https://doi.org/10.1080/07351690.2012.703586

Divjak, B., & Tomić, D. (2011). The impact of Game-based learning on the achievement of learning goals and motivation for learning mathematics-literature review. *Journal of Information and Organizational Sciences*, 35(1), 15-30. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=edsdoj&AN=edsdoj.4409622ccc1a435caecea2dff1e91663&site=eds-live&scope=site

Dolan, R. P., Burling, K., Harms, M., Strain-Seymour, E., Way, W. D., & Rose, D. H. (2013). A Universal Design for Learning-based Framework for Designing Accessible Technology-Enhanced Assessments. Retrieved from http://images.pearsonclinical.com/images/tmrs/DolanUDL-TEAFramework_final3.pdf

Dörner, R., Göbel, S., Effelsberg, W., Wiemeyer, J. (Eds.). (2016). Serious games: Foundations, Concepts and Practice. Cham: Springer International Publishing.

Dream Box Learning. (2018). *Why Dream Box Learning?* Retrieved from http://www.DreamBox.com/why-DreamBox

Driscoll, M. P. (2005). *Psychology of learning for instruction (3rd ed)*. Boston: Pearson Allyn and Bacon. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=cat07058a&AN=vtp.8130&site=eds-live&scope=site

Dusenbury, L., Brannigan, R., Falco, M., & Hansen, W. B. (2003). A review of research on fidelity of implementation: Implications for drug abuse prevention in school settings. *Health Education Research*, *18*(2), 237–256. https://doi.org/10.1093/her/18.2.237

Ebbinghaus, H., (1964). *Memory: A Contribution to Experimental Psychology*. New York: Dover Publications. Retrieved from https://psycnet-apa-org.ezproxy.lib.vt.edu/PsycBOOKS/toc/10011

Edirisingha, P., Nie, M., Pluciennik, M., & Young, R. (2009). Socialisation for learning at a distance in a 3-D multi-user virtual environment. *British Journal of Educational Technology,40*(3), 458-479. Retrieved from http://content.ebscohost.com/ContentServer.asp?T=P&P=AN&K=37605534&S=R&D=a9h&EbscoContent=dGJyMMTo50Seprc4v%2BvlOLCmr1Gep7FSsKq4S7GWxWXS&ContentCustomer=dGJyMPGsr1CyqbNNuePfgeyx43zx

El-Hussein, M. O. M., & Cronje, J. C. (2010). Defining Mobile Learning in the Higher Education Landscape. Educational Technology & Society, 13 (3), 12–21. Retrieved from https://www.jstor.org/stable/pdf/jeductechsoci.13.3.12.pdf?seq=1#page_scan_tab_contents

Eow, Y. L., & Baki, R. (2009). Form one students' engagement with computer games and its effect on their academic achievement in a Malaysian secondary school. *Computers & Education*, *53*(4), 1082-1091. Retrieved from https://www-sciencedirect-com.ezproxy.lib.vt.edu/science/article/pii/S0360131509001304

Epstein, R. M., & Hundert, E. M. (2002). Defining and assessing professional competence. *Journal of the American Medical Association, 287,* 226–235. Retrieved from https://jamanetwork-com.ezproxy.lib.vt.edu/journals/jama/fullarticle/194554

Erhel, S., & Jamet, E. (2013). Digital game-based learning: Impact of instructions and feedback on motivation and learning effectiveness. Computers & Education, 67, 156-167. https://doi-org.ezproxy.lib.vt.edu/10.1016/j.compedu.20123.02.019

Erickson, F. (1997). Culture in society and in educational practices. *Multicultural education: Issues and perspectives*, *3*, 32-60. Boston, MA: Allyn and Bacon.

Felder, R., & Brent, R. (2009). *Active learning: An introduction*. Retrieved from http://www4.ncsu.edu/unity/lockers/users/f/felder/public/Papers/ALpaper(ASQ).pdf

Finn, S. & Inman, J.G. (2004). Digital unity and digital divide: Surveying alumni to study effects of a campus laptop initiative. J*ournal of Research on Technology in Education*, 36(3), 297-317. https://doi.org/10.1080/15391523.2004.10782417

Fitz-Walter, Z., & Tjondronegoro, D. W. (2011, September). Exploring the opportunities and challenges of using mobile sensing for gamification and achievements. In *UbiComp 11: Proceedings of the 2011 ACM Conference on Ubiquitous Computing* (pp. 1-5). ACM Press. Retrieved from http://eprints.qut.edu.au/48632/

Fleiss, J. L. (1971). Measuring nominal scale agreement among many raters. *Psychological Bulletin*, *76*(5), 378–382. https://dx.doi.org/10.1037/h0031619

Flesch, R. (1948). A New Readability Yardstick. *Journal of Applied Psychology, 32*(3), 221-233. Retrieved from https://psycnet-apa-org.ezproxy.lib.vt.edu/fulltext/1949-01274-001.pdf

Fosnot, C. T. (2013). *Constructivism: Theory, perspective, and practice.* New York: Teachers College Press.

Frankel, J., & Wallen, N. (2009). How to Design and Evaluate Research in Education. (7th ed.). New York, NY: McGraw-Hill.

Freidhoff, J. R. (2008). Reflecting on the Affordances and Constraints of Technologies and Their Impact on Pedagogical Goals. *Journal of Computing in Teacher Education*, *24*(4), 117-122. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=eric&AN=EJ834074&site=eds-live&scope=site

Fried, C. B. (2008). In-class laptop use and its effects on student learning. *Computers & Education, 50*(3), 906-914. https://doi.org/10.1016/j.compedu.2006.09.006

Fromme, J., & Unger, A. (Eds.). (2012). *Computer games and new media cultures: A handbook of digital games studies*. Springer Science & Business Media. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=edsebk&AN=533507&site=eds-live&scope=site

Gall, J. P., Gall, M. D., & Borg, W. R. (2007). *Educational research: An introduction* (8th ed.). Boston, MA: Pearson Prentice Hall.

Gay, G. (2010). Culturally responsive teaching: Theory, research, and practice (2nd ed.). New York: Teachers College. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=cat07058a&AN=vtp.726710&site=eds-live&scope=site

Gee, J. P. (2009). Deep learning properties of good digital games: How far can they go? In U. Rittenfeld, M. Cody, & P. Vorderer (Eds.), *Serious Games: Mechanisms and Effects*. New York: Routledge, 67-82.

Gee, J. P. (2007a). *Good Video Games + Good Learning: Collected essays on video games, learning and literacy*. New York: Peter Lang. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=cat07058a&AN=vtp.105505&site=eds-live&scope=site

Gee, J. P. (2007b). *What Video Games Have to Teach Us About Learning And Literacy* (Rev. and updated.). New York: Palgrave Macmillan. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=cat07058a&AN=vtp.217620&site=eds-live&scope=site

Gersten, R., Jordan, N. C., & Flojo, J. R. (2005). Early Identification and Interventions for Students with Mathematics Difficulties. *Journal of Learning Disabilities*, *38*(4), 293-304. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=edsggo&AN=edsgcl.134625978&site=eds-live&scope=site

Glasgow, R. E., Lichtenstein, E., & Marcus, A. C. (2003). Why Don't We See More Translation of Health Promotion Research to Practice? Rethinking the Efficacy-to-Effectiveness Transition. *American journal of public health*, *93*(8), 1261-1267. Retrieved from http://eds.b.ebscohost.com/eds/pdfviewer/pdfviewer?vid=3&sid=037f2a54-b2e9-4a0c-ae73-aa856728c4bf%40sessionmgr102

Gordon, H. R. D. (2014). *The History and Growth of Career and Technical Education in America* (4th ed.). Prospect Heights, IL: Waveland Press.

Granic, I., Lobel, A. M., & Engels, R. C. M. E. (2014). The benefits of playing video games. *American Psychologist, 69*(1), 66-78. Retrieved from https://psycnet.apa.org/doiLanding?doi=10.1037%2Fa0034857

Gray, L., Thomas, N., Lewis, L., & National Center for Education Statistics (2010). Teachers' Use of Educational Technology in U.S. Public Schools: 2009. First Look. NCES 2010-040. *National*

Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education. Washington, DC. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=eric&AN=ED509514&site=eds-live&scope=site

Gredler, M. E. (1997). *Learning and Instruction: Theory into Practice*. Prentice Hall.

Gros, B. (2007). Digital Games in Education: The Design of Games-Based Learning Environments. *Journal of Research on Technology in Education, 40*(1), 23-38. Retrieved from http://eds.a.ebscohost.com.ezproxy.lib.vt.edu/eds/pdfviewer/pdfviewer?vid=2&sid=9e20e0b1-8078-4092-81b7-015c7e6a6e76%40sessionmgr4008

Gulek, J., & Demirtas, H. (2005). Learning with technology: The impact of laptop use on student achievement. *The Journal of Technology, Learning and Assessment*, 3(2), 4-38. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=eric&AN=EJ983985&site=eds-live&scope=site

Hall, T. E., Meyer, A., & Rose, D. H. (2015). *Universal Design for Learning in the Classroom: Practical Applications.* New York: Guilford Press.

Hallford, N., & Hallford, J. (2002). *Swords & Circuitry: A Designer's Guide to Computer Role-Playing Games*. Roseville, CA: Prima Tech. Roseville

Hamari, J., & Eranti, V. (2011). Framework for designing and evaluating game achievements. Proceedings of DiGRA 2011 Conference: Think Design Play. Retrieved from https://pdfs.semanticscholar.org/4de7/75e4ffb6e1457af1e816baaa8c99cc4a0def.pdf

Hamari, J., & Nousiainen, T. (2015). Why Do Teachers Use Game-Based Learning Technologies? The Role of Individual and Institutional ICT Readiness. In proceedings of the 48th Annual Hawaii International Conference on System Sciences (HICSS), Hawaii, USA, January 5-8, 2015.

Retrieved from https://ieeexplore-ieee-org.ezproxy.lib.vt.edu/stamp/stamp.jsp?tp=&arnumber=7069737

Handelsman, J., Ebert-May, D., Beichner, R., Bruns, P., Chang, A., DeHaan, R., Gentile, J., Lauffer, S., Stewart, J., Tilghman, S., Wood, W. (2004). Scientific teaching. Science 304(5670), 521–522. Retrieved from https://science.sciencemag.org/content/304/5670/521.full

Hansen, W. B., Graham, J. W., Wolkenstein, B. H., & Rohrbach, L. A. (1991). Program Integrity as a Moderator of Prevention Program Effectiveness: Results for Fifth-Grade Students in the Adolescent Alcohol Prevention Trial. *Journal of Studies on Alcohol, 52*(6), 568-579. doi:10.15288/jsa.1991.52.568. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=edsggo&AN=edsgcl.13597174&site=eds-live&scope=site

Hansen, W. B. (1996). Pilot test results comparing the All Stars program with seventh grade DARE: Program integrity and mediating variable analysis. *Substance Use & Misuse*, *31*(10), 1359-1377.

Harachi, T. W., Abbott, R. D., Catalano, R. F., Haggerty, K. P., & Fleming, C. B. (1999). Opening the Black Box: Using Process Evaluation Measures to Assess Implementation and Theory Building. *American journal of community psychology*, *27*(5), 711-731. https://doi.org/10.1023/A:1022194005511

Harris, K. G., (2003, September) *Implementing No Child Left Behind: Virginia Revisits Educational Accountability.* Virginia Legislative Issue Brief Number, 34, 1-8. Retrieved from http://dls.virginia.gov/pubs/briefs/brief34.htm

Hawkins, J. D., Abbott, R., Catalano, R. F., & Gillmore, M. R. (1991). Assessing Effectiveness of Drug Abuse Prevention: Implementation Issues Relevant to Long-Term Effects and Replication. *Drug abuse prevention intervention research: Methodological issues*, 195. Retrieved from https://www.danya.com/dlc/research/pdf/Methodological-Issues.pdf#page=200

Hays, D. G., & Singh, A. A. (2012). *Qualitative Inquiry in Clinical and Educational Settings*. NewYork: Guilford Press.

Heo, M., Kim, N., & Faith, M. S. (2015). Statistical power as a function of Cronbach Alpha of instrument questionnaire items. *BMC Medical Research Methodology, 15*(1), 1-9. https://doi.org/10.1186/s12874-015-0070-6

Hmelo-Silver, C. E., Duncan, R. G., & Chinn, C. A. (2007). Scaffolding and Achievement in Problem-based and Inquiry Learning: A Response to Kirschner, Sweller, and Clark (2006). *Educational Psychologist, 42*(2), 99-107. https://doi.org/10.1080/00461520701263368

Hoffmann, K. F., Huff, J. D., Patterson, A. S., & Nietfeld, J. L. (2009). Elementary teachers' use and perception of rewards in the classroom. *Teaching and Teacher Education, 25*(6), 843-849. https://doi.org/10.1016/j.tate.2008.12.004

Holmes, J. (2015). Distributed teaching and learning systems in Dota 2. *Well Played*, *4*(2), 92-111. Retrieved from https://stars.library.ucf.edu/cgi/viewcontent.cgi?referer=&httpsredir=1&article=1115&context=ucfscholar#page=100

Howell, D. (2011). *Fundamental statistics for the behavioral sciences*. Cengage Learning.

Huitt, W., & Hummel, J. (2003). Piaget's theory of cognitive development. *Educational psychology interactive*, *3*(2). Retrieved from http://www.edpsycinteractive.org/topics/cognition/piaget.html

Hussain, S. Y. S., Tan, W. H., & Idris, M. Z. (2014). Digital Game-Based Learning For Remedial Mathematics Students: A New Teaching And Learning Approach In Malaysia. *International Journal of Multimedia Ubiquitous Engineering*, *9*(11), 325-338. Retrieved from https://www.researchgate.net/profile/Wee_Hoe_Tan/publication/269042449_Digital_Game-Based_Learning_for_Remedial_Mathematics_Students_A_New_Teaching_and_Learning_Approach_in_Malaysia/links/56ccd0f908ae85c8233bc25d.pdf

Hwang, G. J., & Wu, P. H. (2012). Advancements and trends in digital game-based learning research: a review of publications in selected journals from 2001 to 2010. *British Journal of Educational Technology*, *43*(1), E6-E10. Retrieved from http://eds.b.ebscohost.com.ezproxy.lib.vt.edu/eds/pdfviewer/pdfviewer?vid=2&sid=c881a5ae-25d3-47a1-a3d4-f30edb399d22%40pdc-v-sessmgr01

Iacovides, I., Aczel, J., Scanlon, E., Taylor, J., & Woods, W. (2011). Motivation, engagement and learning through digital games. *International Journal of Virtual and Personal Learning Environments (IJVPLE)*, *2*(2), 1-16.

Itin, C. M. (1999). Reasserting the philosophy of experiential education as a vehicle for change in the 21st century. *The Journal of Experiential Education*, *22*(2), 91-98. Retrieved from https://journals.sagepub.com/doi/abs/10.1177/105382599902200206?journalCode=jeea

Jakobsson, M. (2011). The achievement machine: Understanding Xbox 360 achievements in gaming practices. *Game Studies*, *11*(1), 1-22. Retrieved from http://gamestudies.org/1101/articles/jakobsson?report=reader

Johanningmeier, E. V., & Richardson, T. R. (2008). *Educational Research, The National Agenda, and Educational Reform: A History*. Charlotte, N.C: IAP-Information Age Pub.

Johnson, L. (1966). *Public Papers of the Presidents of the United States: Lyndon B. Johnson, 1965*. Best Books on.

Johnson, L., Adams Becker, S., Cummins, M., Estrada, V., Freeman, A., & Ludgate, H. (2013). Technology Outlook for Community, Technical, and Junior Colleges 2013-2018: An NMC Horizon Project Sector Analysis. *Austin, Texas: The New Media Consortium. Retrieved from* https://dev.haiti-now.org/wp-content/uploads/2017/05/2013-technology-outlook-community-colleges.pdf

Jones, G., Squires, T., & Hicks, J. (2008). Combining Speech Recognition/Natural Language Processing with 3d Online Learning Environments To Create Distributed Authentic and Situated Spoken Language Learning. *Journal of Educational Technology Systems, 36*(4), 375-392. Retrieved from http://content.ebscohost.com/ContentServer.asp?T=P&P=AN&K=33022688&S=R&D=iih&EbscoContent=dGJyMMvl7ESep7c4v%2BvlOLCmr1Gep7NSsai4SK%2BWxWXS&ContentCustomer=dGJyMPGsr1CyqbNNuePfgeyx43zx

Jukes, I., McCain, T., & Crockett, L. (2010). *Understanding the digital generation: Teaching and learning in the new digital landscape*. Corwin Press. Retrieved from https://go-gale-com.ezproxy.lib.vt.edu/ps/i.do?p=AONE&u=viva_vpi&id=GALE%7CA225458923&v=2.1&it=r&sid=ebsco

Kapp, K. M. (2012). *The Gamification of Learning and Instruction: Game-based Methods and Strategies for Training and Education*. John Wiley & Sons.

Kane, T. J. (2017). Making Evidence Locally: Rethinking Education Research Under the Every Student Succeeds Act. *Education Next*, *17*(2), 52+. Retrieved from https://go-gale-com.ezproxy.lib.vt.edu/ps/i.do?p=OVIC&u=viva_vpi&id=GALE%7CA488759524&v=2.1&it=r&asid=e1d0658b

Karafili, M., & Stana, A. (2012). The Learning of Mathematics Supported by GBL–A Novelty for Albanian Preschool System. *Journal of Educational and Social Research*, 297-307. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.660.5846&rep=rep1&type=pdf#page=297

Karsh, B. (2004). Beyond usability: Designing effective technology implementation systems to promote patient safety. *Quality and Safety in Health Care, 13*(5), 388-394. Retrieved from http://resolver.ebscohost.com.ezproxy.lib.vt.edu/openurl?genre=article&atitle=Beyond+usability

%3a+designing+effective+technology+implementation+systems+to+promote+patient+safety&title=Quality+and+Safety+in+Health+Care&issn=14753898&isbn=&volume=13&issue=5&date=20041001&au=Karsh%2c+B.T.&spage=388&pages=388-394&sid=EBSCO%3aGale+Health+and+Wellness%3aedsgcl.132930725&site=ftf-live

Katmada, A., Mavridis, A., & Tsiatsos, T. (2014). Implementing a Game for Supporting Learning in Mathematics. *Electronic Journal of e-Learning*, *12*(3), 230-242. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=eric&AN=EJ1035662&site=eds-live&scope=site

Kay, R. H., & Lauricella, S. (2011). Unstructured vs. Structured Use of Laptops in Higher Education. *Journal of Information Technology Education*, 10(1), 33-42. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=ehh&AN=60635505&site=eds-live&scope=site

Kaye, L. K., & Bryce, J. (2012). Putting the "Fun Factor" into Gaming: The Influence of Social Contexts on the Experiences of Playing Videogames. *International Journal of Internet Science*, *7*(1), 24-38. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=a9h&AN=90581995&site=eds-live&scope=site

Ke, F. (2008). A case study of computer gaming for math: Engaged learning from gameplay? *Computers & Education*, *51*(4), 1609-1620. Retrieved from https://www-sciencedirect-com.ezproxy.lib.vt.edu/science/article/pii/S0360131508000523?via%3Dihub

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

Kebritchi, M., Hirumi, A., & Bai, H. (2010). The effects of modern mathematics computer games on mathematics achievement and class motivation. *Computers & Education*, 55(2), 427-443. Retrieved from https://www-sciencedirect-com.ezproxy.lib.vt.edu/science/article/pii/S0360131510000412?via%3Dihub

Kickmeier-Rust, M. D., & Albert, D. (2010). Micro-adaptivity: Protecting immersion in didactically adaptive digital educational games. *Journal of Computer Assisted Instruction, 26,* 95-105. Retrieved from http://search.ebscohost.com.ezproxy.lib.vt.edu/login.aspx?direct=true&db=edsgao&AN=edsgcl.220623360&site=eds-live&scope=site

Kincaid, J., Fishburne, R., Rogers, R., & Chissom, B. (1975). Derivation of New Readability Formulas (Automated Readability Index, Fog Count, and Flesch Reading Ease formula) for Navy Enlisted Personnel. Research Branch Report 8-75. Chief of Naval Technical Training: Naval Air Station Memphis. Retrieved from https://stars.library.ucf.edu/istlibrary/56/

Klopfer, E., Osterweil, S., & Salen, K. (2009). Moving learning games forward. *Cambridge, MA: The Education Arcade*. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.687.5017&rep=rep1&type=pdf

Klopfer, E., Squire, K., & Jenkins, H. (2002). Environmental Detectives: PDAs as a window into a virtual simulated world. *Proceedings of IEEE International Workshop on Wireless and Mobile Technologies in Education* (pp. 95-98). Los Alamitos, CA, USA: IEEE Computer Society. Retrieved from https://ieeexplore-ieee-org.ezproxy.lib.vt.edu/document/1039227

Kvasz, L. (2006). The History of Algebra and the Development of the Form of its Language. *Philosophia Mathematica*, *14*(3), 287-317. https://doi.org/10.1093/philmat/nkj017

Lawshe, C. H. (1975). A Quantitative Approach to Content Validity. *Personnel Psychology*, *28*(4), 563–575. https://doi.org/10.1111/j.1744-6570.1975.tb01393.x

Lee, J. J., & Hammer, J. (2011). Gamification in Education: What, how, why bother? Academic Exchange Quarterly, 15(2), 1-5. Retrieved from https://www.researchgate.net/publication/258697764_Gamification_in_Education_What_How_Why_Bother

Lee, Y. L. (2009). Enhancement of Fractions from Playing a Game. In *Crossing divides: MERGA 32: Proceedings of the 32nd Annual Conference of the Mathematics* (Vol. 1, pp. 323-330). Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.587.2538&rep=rep1&type=pdf

Lester, J. C., Spires, H. A., Nietfeld, J. L., Minogue, J., Mott, B. W., & Lobene, E. V. (2014). Designing game-based learning environments for elementary science education: A narrative-centered learning perspective. Information Sciences, 264, 4-18. Retrieved from https://www-sciencedirect-com.ezproxy.lib.vt.edu/science/article/pii/S0020025513006385?via%3Dihub

Lepper, M. R. (1988). Motivational Considerations in the Study of Instruction. *Cognition and instruction*, *5*(4), 289-309. Retrieved from http://eds.b.ebscohost.com.ezproxy.lib.vt.edu/eds/detail/detail?vid=0&sid=4224dda4-c9ba-4645-b334-74b2ca9ba056%40pdc-v-sessmgr05&bdata=JnNpdGU9ZWRzLWxpdmUmc2NvcGU9c2l0ZQ%3d%3d#AN=edsjsr.3233574&db=edsjsr

Lepper, M. R., & Malone, T. W. (1987). Intrinsic Motivation and Instructional Effectiveness in Computer-Based Education. *Aptitude, learning, and instruction*, *3*, 255-286.

Levine, J. (2006). Chapter 1: Why Gaming? Library Technology Reports, 42(5), 10-17. Retrieved from https://journals.ala.org/index.php/ltr/article/view/4327/4986

Li, Q. (2012). Understanding Enactivism: A study of affordances and constraints of engaging practicing teachers as digital game designers. *Educational Technology Research and Development*, *60*(5), 785-806. Retrieved from http://eds.b.ebscohost.com.ezproxy.lib.vt.edu/eds/pdfviewer/pdfviewer?vid=0&sid=099eecf3-1e76-408d-8722-2d438a5760d8%40pdc-v-sessmgr05

Li, Q. (2007). Student and Teacher Views About Technology: A Tale of Two Cities? *Journal of Research on Technology in Education*, 39, 377-397. https://doi.org/10.1080/15391523.2007.10782488

Lim, C., Nonis, D., & Hedberg, J. (2006). Gaming in a 3D multiuser virtual environment: engaging students in Science lessons. *British Journal of Educational Technology, 37*(2), 211-231. https://doi.org/10.1111/j.1467-8535.2006.00531.x

Lin, C. H., & Liu, E. Z. F. (2009). A Comparison between Drill-Based and Game-Based Typing Software. In *Transactions on Edutainment III* (pp. 48-58). Springer Berlin Heidelberg. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=edb&AN=76846323&site=eds-live&scope=site

Lindroth, T., & Bergquist, M. (2010). Laptopers in an educational practice: Promoting the personal learning situation. *Computers & Education*, 54(2), 311-320. Retrieved from https://www-sciencedirect-com.ezproxy.lib.vt.edu/science/article/pii/S0360131509001900?via%3Dihub

Linn, R. L., Baker, E. L., & Betebenner, D. W. (2002). Accountability systems: Implications of requirements of the no child left behind act of 2001. *Educational Researcher, 31*(6), 3-16. Retrieved from http://eds.b.ebscohost.com.ezproxy.lib.vt.edu/eds/detail/detail?vid=0&sid=1256f60d-113d-4cea-8fe7-cf622f65761b%40pdc-v-sessmgr02&bdata=JnNpdGU9ZWRzLWxpdmUmc2NvcGU9c2l0ZQ%3d%3d#AN=edsgcl.282618414&db=edsgao

Liu, E. Z. F. (2011). Avoiding Internet Addiction When Integrating Digital Games into Teaching. *Social Behavior and Personality: an international journal*, *39*(10), 1325-1336. Retrieved from https://www-ingentaconnect-com.ezproxy.lib.vt.edu/content/sbp/sbp/2011/00000039/00000010/art00004%3bjsessionid=2l86kt3j6era5.x-ic-live-02

Lombardi, M. (2007). Authentic learning for the 21st century: An overview. *Educause Learning Initiative*, *1*, 1-12.

Lum, D. (1996). *Social Work Practice and People of Color: A Process-Stage Approach* (3rd ed.). Pacific Grove: Brooks/Cole Pub. Co.

Lynn, M. R. (1986). Determination and quantification of content validity. *Nursing Research, 35,* 382–385.

MacKenzie, J. R. (2014). Millennial Interior Design Students' Perceptions Concerning Game-Based Learning in A Lighting Design Course (Thesis, Colorado State University. Libraries). Retrieved from https://mountainscholar.org/bitstream/handle/10217/83994/MacKenzie_colostate_0053N_12520.pdf?sequence=1&isAllowed=y

Malone, T. W. (1981). Toward a Theory of Intrinsically Motivating Instruction. *Cognitive science*, *5*(4), 333-369. Retrieved from https://www.sciencedirect.com/science/article/abs/pii/S0364021381800171

Martino, S., Ball, S., Nich, C., Frankforter, T. L., & Carroll, K. M. (2009). Correspondence of motivational enhancement treatment integrity ratings among therapists, supervisors, and observers. *Psychotherapy Research: Journal of the Society for Psychotherapy Research*, *19*(2), 181–193. http://doi.org/10.1080/10503300802688460

Mayer, R. E. (2004). Should there be a three-strikes rule against pure discovery learning?: The case for guided methods of instruction. *American Psychologist, 59*(1), 14-19. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=edsggo&AN=edsgcl.112941446&site=eds-live&scope=site

McConnaughey, J., Nila, C. A., & Sloan, T. (1995). *Falling through the net: A survey of the "have nots" in rural and urban America.* Washington, DC: National Telecommunications and Information Administration, United States Department of Commerce.

McFarlane, A., Sparrowhawk, A., & Heald, Y. (2002). *Report on the educational use of games*. TEEM (Teachers evaluating educational multimedia), Cambridge. Retrieved from http://consilr.info.uaic.ro/uploads_lt4el/resources/pdfengReport%20on%20the%20educational%20use%20of%20games.pdf

McGinty, S. (2000). Case-method teaching: An overview of the pedagogy and rationale for its use in physical therapy education. *Journal of Physical Therapy Education (American Physical Therapy Association, Education Section), 14*(1), 48-51. Retrieved from http://eds.b.ebscohost.com.ezproxy.lib.vt.edu/eds/detail/detail?vid=0&sid=d3313975-8b7b-4acf-a506-ea04e23de587%40sessionmgr103&bdata=JnNpdGU9ZWRzLWxpdmUmc2NvcGU9c2l0ZQ%3d%3d#AN=107012495&db=c8h

McKnight, K., O'Malley, K., Ruzic, R., Horsley, M. K., Franey, J. J., & Bassett, K. (2016). Teaching in a digital age: How educators use technology to improve student learning. *Journal of Research on Technology in Education, 48*(3), 194-211. doi:10.1080/15391523.2016.1175856

McLeod, S. A. (2018). Lev Vygotsky. Simply Psychology. Retrieved from www.simplypsychology.org/vygotsky.html

McMillan, J. H. (2012). *Educational research: Fundamentals for the consumer* (6th ed.). Boston: Pearson.

Melero, J., Hernández-Leo, D., & Blat, J. (2011, October). A Review of Scaffolding Approaches in Game-based Learning Environments. In *European Conference on Games Based Learning* (p. 717). Academic Conferences International Limited. Retrieved from https://www.researchgate.net/profile/Javier_Melero/publication/259564364_A_Review_of_Scaffolding_Approaches_in_Game-based_Learning_Environments/links/02e7e52c8a9805cf65000000.pdf

Mellard, D. (2010). Fidelity implementation within a Response to Intervention (RtI) framework: Tools for schools. *National Center on Response to Intervention (NCRTI) www. rti4success. org*. Retrieved from https://webnew.ped.state.nm.us/wp-content/uploads/2018/03/Fidelity-of-Implementation-guidev5-1.pdf

Merchant, Z., Goetz, E., Keeney-Kennicutt, W., Kwok, O., Cifuentes, L., & Davis, T. (2012). The learner characteristics, features of desktop 3D virtual reality environments, and college chemistry instruction: A structural equation modeling analysis. *Computers & Education,59*(2), 551-568. https://doi.org/10.1016/j.compedu.2012.02.004

Merriam, S., & Caffarella, R. (1999). Learning in Adulthood: A Comprehensive Guide. San Francisco: Jossey-Bass. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=nlebk&AN=26069&site=eds-live&scope=site

Moreno, R. (2002). Who Learns Best with Multiple Representations? Cognitive Theory Implications for Individual Differences in Multimedia Learning. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=eric&AN=ED477070&site=eds-live&scope=site

Morrissey, S. R. (2010). Educate to innovate. *Chemical & Engineering News, 88*(4), 25-26.

Moursund, D. (1999). Project-Based Learning Using Information Technology. Eugene, OR: International Society for Technology in Education. Retrieved from https://www.researchgate.net/profile/David_Moursund/publication/247276594_Project-based_learning_using_information_technology/links/58c59e9645851538eb8afd94/Project-based-learning-using-information-technology.pdf

Moussaoui, S. E. (2017). The Every Student Succeeds Act and its Impact on Vulnerable Children. *Journal of Law and Education, 46*(3), 407-413. Retrieved from http://eds.a.ebscohost.com.ezproxy.lib.vt.edu/eds/detail/detail?vid=0&sid=5aa5620a-ca35-4dd2-add9-c60ff927dc28%40sessionmgr4007&bdata=JnNpdGU9ZWRzLWxpdmUmc2NvcGU9c2l0ZQ%3d%3d#AN=edshol.hein.journals.jle46.32&db=edshol

Mumtaz, S. (2001). Children's enjoyment and perception of computer use in the home and the school. Computers *& Education, 36*(4), 347-362. doi:10.1016/S0360-1315(01)00023-9

National Council of Teachers of Mathematics. (2016). Executive Summary: Principles and standards for school mathematics. Retrieved from http://www.nctm.org/uploadedFiles/Standards_and_Positions/PSSM_ExecutiveSummary.pdf

National Education Association. (2008). *Funding Gap: No Child Left Behind.* Retrieved from http://www.nea.org/assets/docs/fundinggap.pdf.

Neulight, N., Kafai, Y. B., Kao, L., Foley, B., & Galas, C. (2007). Children's Participation in a Virtual Epidemic in the Science Classroom: Making Connections to Natural Infectious Diseases. *Journal of Science Education and Technology*, *16*(1), 47-58. https://doi.org/10.1007/s10956-006-9029-z

Neville, D. O., Shelton, B. E., & McInnis, B. (2009). Cybertext redux: Using digital game-based learning to teach L2 vocabulary, reading, and culture. *Computer Assisted Language Learning*, *22*(5), 409-424. Retrieved from https://www.tandfonline.com/doi/abs/10.1080/09588220903345168

Nicol, D. J., & MacLeod, I. A. (2005). Using a shared workspace and wireless laptops to improve collaborative project learning in an engineering design class. *Computers & Education, 44*(4), 459-475. doi:10.1016/j.compedu.2004.04.008

Norton, B. (2013). *Identity and language learning: Extending the conversation*. Multilingual matters.

Obama, B. H. (2009, November 23). [Educate to Innovate]. Speech presented to a Joint Session of Congress, House of Representatives, Washington, DC. Retrieved from http://www.whitehouse.gov/photos-and-video/video/president-obama-kicks-educate-innovate

Oblinger, D. G., & Oblinger, J. L. (Eds.). (2005). *Educating the Net Generation.*Washington, DC: EDUCAUSE. Retrieved from http://www.educause.edu/research-and-publications/books/educating-net-generation

O'Donnell, C. L. (2008). Defining, Conceptualizing, and Measuring Fidelity of Implementation and Its Relationship to Outcomes in K–12 Curriculum Intervention Research. *Review of Educational Research*, *78*(1), 33-84. Retrieved from https://www-jstor-org.ezproxy.lib.vt.edu/stable/40071121?seq=1#metadata_info_tab_contents

Omale, N., Hung, W., Luetkehans, L., & Cooke-Plagwitz, J. (2009). Learning in 3-D multiuser virtual environments: Exploring the use of unique 3-D attributes for online problem-based learning. *British Journal of Educational Technology, 40*(3), 480-495. doi:10.1111/j.1467-8535.2009.00941.x

Ornstein, A.C., Levine, D.U., & Gutek, G.L. (2011). Foundations of Education (11th edition). Cengage Learning.

Ornstein, A., Levine, D. U., Gutek, G., & Vocke, D. (2015). *Foundations of Education* (13th edition). Nelson Education.

Ota, K. R., & DuPaul, G. J. (2002). Task Reengagement and Mathematics Performance in Children with Attention-Deficit Hyperactivity Disorder: Effects of supplemental computer instruction. *School Psychology Quarterly*, *17*(3), 242-57. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=eric&AN=EJ655071&site=eds-live&scope=site

Ott, M., & Pozzi, F. (2012). Digital games as creativity enablers for children. *Behaviour & Information Technology*, *31*(10), 1011-1019. https://doi.org/10.1080/0144929X.2010.526148

Palfrey, J. G., & Gasser, U. (2008). Book Review: *Born digital: Understanding the First Generation of Digital Natives*. New York: Basic Books.

Palmer, J., Bresler, L., & Cooper, D. E. (2001). *Fifty Major Thinkers on Education: From Confucius to Dewey*. New York; London;: Routledge.

Papastergiou, M. (2009). Digital Game-Based Learning in High School Computer Science Education: Impact on Educational Effectiveness and Student Motivation. *Computers & Education*, *52*(1), 1-12. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=eric&AN=EJ819452&site=eds-live&scope=site

Pareto, L., Arvemo, T., Dahl, Y., Haake, M., & Gulz, A. (2011, June). A teachable-agent arithmetic game's effects on mathematics understanding, attitude and self-efficacy. In *International Conference on Artificial Intelligence in Education* (pp. 247-255). Springer Berlin Heidelberg. Retrieved from https://link.springer.com/chapter/10.1007/978-3-642-21869-9_33

Patten, B., Sánchez, I. A., & Tangney, B. (2006). Designing collaborative, constructionist and contextual applications for handheld devices. *Computers & education*, *46*(3), 294-308. https://doi.org/10.1016/j.compedu.2005.11.011

Piaget, J. (1999). Play, Dreams and Imitation in Childhood. Routledge. Retrieved from https://ebookcentral-proquest-com.ezproxy.lib.vt.edu/lib/vt/detail.action?docID=1273074

Pilli, O., & Aksu, M. (2013). The effects of computer-assisted instruction on the achievement, attitudes and retention of fourth grade mathematics students in North Cyprus. *Computers & Education, 62*(3), 62-71. doi:10.1016/j.compedu.2012.10.010

Pope, H., & Mangram, C. (2015). Wuzzit trouble: The influence of a digital math game on student number sense. *International Journal of Serious Games, 2*(4). https://doi.org/10.17083/ijsg.v2i4.88

Powell, D. R., & Diamond, K. E. (2013). Implementation Fidelity of a Coaching-Based Professional Development Program for Improving Head Start Teachers' Literacy and Language Instruction. *Journal of Early Intervention,35*(2), 102-128. doi:10.1177/1053815113516678

Powell, R. (2000). Case-based teaching in homogeneous teacher education contexts: A study of preservice teachers' situative cognition. *Teaching and Teacher Education*, *16*(3), 389-410. https://doi.org/10.1016/S0742-051X(99)00068-2

Prasse, D. P. (2010). Why Adopt and Rti Model? RTI Action Network. Retrieved from http://www.rtinetwork.org/learn/what/whyrti

Presser, S., Couper, M., Lessler, J., Martin, E., Martin, J., Rothgeb, J., & Singer, E. (2004). Methods for Testing and Evaluating Survey Questions. *Public Opinion Quarterly*, *68*(1), 109-130. Retrieved from http://eds.b.ebscohost.com.ezproxy.lib.vt.edu/eds/pdfviewer/pdfviewer?vid=0&sid=da52bc44-86cc-4da6-b5be-6cdd403504a8%40sessionmgr102

Prensky, M. (2001). Digital natives, digital immigrants. On The Horizon, 9(5), 1-6. Retrieved from http://www.nnstoy.org/download/technology/Digital%20Natives%20-%20Digital%20Immigrants.pdf

Prensky, M. (2003a). Digital game-based learning. *Computers in Entertainment (CIE)*, *1*(1), 21-21.

Prensky, M. (2003b). Escape from planet jar-gon: Or, what video games have to teach academics about teaching and writing. *On the Horizon, 11*(3). https://doi.org/10.1108/oth.2003.27411cae.002

Prensky, M. (2011). The Reformers are Leaving our Schools in the 20th Century. Why most U.S. school reformers are on the wrong track, and how to get our kids' education right for the future. Retrieved from http://www.marcprensky.com/writing/+Prensky-The_Reformers_Are_Leaving_Our_Schools_in_the_20th_Century-please_distribute_freely.pdf

Prensky, M. R. (2012). *From Digital Natives to Digital Wisdom: Hopeful essays for 21st century learning*. Corwin Press.

Proctor, E., Silmere, H., Raghavan, R., Hovmand, P., Aarons, G., Bunger, A., Griffey, R., Hensley, M. (2011). Outcomes for Implementation Research: Conceptual Distinctions, Measurement Challenges, and Research Agenda. *Administration and Policy in Mental Health and Mental Health Services Research, 38*(2), 65-76. doi:10.1007/s10488-010-0319-7. Retrieved from http://eds.a.ebscohost.com.ezproxy.lib.vt.edu/eds/detail/detail?vid=0&sid=84b42266-b38c-4971-8336-30e9725a3c43%40sessionmgr4007&bdata=JnNpdGU9ZWRzLWxpdmUmc2NvcGU9c2l0ZQ%3d%3d#AN=edsgcl.250320081&db=edsgao

Rapini, S., (2012). Beyond Textbooks and Lectures: Digital Game-Based Learning In STEM Subjects, McLean, Virginia: Center for Excellence in Education. Retrieved from https://www.esa.org/esa/wp-content/uploads/2012/12/digital-gamebased-learning.pdf

Remarks by the President at Every Student Succeeds Act signing ceremony, Office of the Press Secretary, The White House (2015, December). Retrieved from https://obamawhitehouse.archives.gov/the-press-office/2015/12/10/remarks-president-every-student-succeeds-act-signing-ceremony

Resnick, L. (1987). The 1987 Presidential Address: Learning in School and out. *Educational Researcher, 16*(9), 13-54. Retrieved from http://www.jstor.org.ezproxy.lib.vt.edu/stable/1175725

Ronimus, M., Kujala, J., Tolvanen, A., & Lyytinen, H. (2014). Children's engagement during digital game-based learning of reading: The effects of time, rewards, and challenge. *Computers & Education, 71*, 237. doi:10.1016/j.compedu.2013.10.008

Russell, M., Bebell, D., & Higgins, J. (2004). Laptop Learning: A Comparison of Teaching and Learning in Upper Elementary Classrooms Equipped with Shared Carts of Laptops and Permanent 1:1 Laptops. *Journal of Educational Computing Research, 30*(4), 313-330. doi:10.2190/6E7K-F57M-6UY6-QAJJ. Retrieved from http://eds.a.ebscohost.com.ezproxy.lib.vt.edu/eds/pdfviewer/pdfviewer?vid=0&sid=dc669dde-ec70-49e8-89b4-ac228e45f353%40sessionmgr4007

Ryan, A. (1995) *John Dewey and the High Tide of American Liberalism*. WW Norton & Company.

Ryan, R. M., Rigby, C. S., & Przybylski, A. (2006). The motivational pull of video games: A self-determination theory approach. *Motivation and emotion*,*30*(4), 344-360. 10.1016/j.chb.2017.03.048

Salthouse, T. A. (2010). Influence of age on practice effects in longitudinal neurocognitive change. *Neuropsychology, 24*(5), 563-572. http://dx.doi.org/10.1037/a0019026

Sandars, J., & Morrison, C. (2007). What is the Net Generation? The challenge for future medical education. *Medical teacher*, *29*(2-3), 85-88. https://doi.org/10.1080/01421590601176380

Sardone, N. B., & Devlin-Scherer, R. (2010). Digital games for English classrooms. *Teaching English with Technology*, *10*(1), 35-50.

Sarkar, N., Ford, W., & Manzo, C. (2017). Engaging Digital Natives through Social Learning. *Journal of Systemics, Cybernetics and Informatics, 15*(2), 1-4. Retrieved from http://www.iiisci.org/Journal/CV$/sci/pdfs/EB015YQ17.pdf

Schaaf, R. (2012). Does Digital Game-Based Learning Improve Student Time-on-Task Behavior and Engagement in Comparison to Alternative Instructional Strategies? *The Canadian Journal of Action Research*, 13(1), 50-64.

Schrader, P. G., Lawless, K. A., & Deniz, H. (2010). Video Games in Education: Opportunities for Learning Beyond Research Claims and Advertising Hype. *Design and Implementation of Educational Games: Theoretical and Practical Perspectives: Theoretical and Practical Perspectives*, 293-314. IGI Global.

Seligman, M., & Csikszentmihalyi, M. (2000, January). *Positive psychology*. Retrieved from http://www.bdp-gus.de/gus/Positive-Psychologie-Aufruf-2000.pdf

Servilio, K. L. (2009). You Get to Choose! Motivating Students to Read through Differentiated Instruction. *Teaching Exceptional Children Plus*, *5*(5). Retrieved from http://content.ebscohost.com/ContentServer.asp?T=P&P=AN&K=42526086&S=R&D=ehh&EbscoContent=dGJyMNHr7ESeqLM4v%2BvlOLCmr1Gep7NSsqu4SbaWxWXS&ContentCustomer=dGJyMPGsr1CyqbNNuePfgeyx43zx

Sharma, M. (1997, July). Improving mathematics instruction for all. In *Fourth Lecture in Colloquium "Improving Schools from Within: Your Role*. (pp. 2-12).

Shuell, T. J. (1996). Teaching and learning in a classroom context. In D. C. Berliner & R. C. Calfee (Eds.), *Handbook of educational psychology* (pp. 726-764). New York, NY: Prentice Hall International.

Shute, V. J., Rieber, L., & Van Eck, R. (2011). Games... and... learning. Trends and issues in instructional design and technology. Retrieved from http://myweb.fsu.edu/vshute/pdf/shute%20pres_i.pdf

Sicart, M. (2008). Defining game mechanics. *The International Journal of Computer Game Research*, *8*(2), 1-14. Retrieved from http://gamestudies.org/0802/articles/sicart?viewType=Print&viewClass=Print

Simon, M. A. (1995). Reconstructing Mathematics Pedagogy from a Constructivist Perspective. *Journal for Research in Mathematics Education, 26*, 114-145. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=eric&AN=ED364406&site=eds-live&scope=site

Slavin, R. E., & Davis, N. (2006). *Educational Psychology: Theory and Practice*. Needham Heights, MA: Allyn and Bacon.

Smaldino, S. E., Lowther, D. L., & Russell, J. D. (2008). *Instructional Technology and Media for Learning* (9th ed.). Upper Saddle River, N.J: Pearson Merrill Prentice Hall.

Stigler, J. W., & Hiebert, J. (2004). Improving mathematics teaching. *Educational Leadership, 61(5)*, 12–16. Retrieved from https://www.researchgate.net/profile/James_Stigler/publication/228731157_Improving_mathematics_teaching/links/02e7e529e9b1081f6f000000/Improving-mathematics-teaching.pdf

Steffe, L. P., & Gale, J. (Eds.) (1995). Constructivism in education. Hillsdale, NJ: Erlbaum.

Stein, K. F., Sargent, J. T., & Rafaels, N. (2007). Intervention Research: Establishing Fidelity of the Independent Variable in Nursing Clinical Trials. *Nursing Research*, *56*(1), 54-62.

Suhr, K. A., Hernandez, D. A., Grimes, D., & Warschauer, M. (2010). Laptops and Fourth Grade Literacy: Assisting the Jump over the Fourth-Grade Slump. *The Journal of Technology, Learning and Assessment*, *9*(5). Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=eric&AN=EJ873679&site=eds-live&scope=site

Sungur, S., & Tekkaya, C. (2006). Effects of Problem-Based Learning and Traditional Instruction on Self-Regulated Learning. *The Journal of Educational Research, 99*(5), 307-317. Retrieved from https://www-jstor-org.ezproxy.lib.vt.edu/stable/27548142

Swearingen, D. K. (2011). *Effect of Digital Game Based Learning On Ninth Grade Students' Mathematics Achievement* (Doctoral dissertation, The University of Oklahoma). https://hdl.handle.net/11244/319486

Tan, W. H., Johnston-Wilder, S., & Neill, S. (2008, November). Examining the potential of game-based learning through the eyes of maths trainee teachers. In *Proceedings of the British Society for Research into Learning Mathematics Day Conference* (Vol. 28, No. 3, pp. 120-124).

Tang, S., Hanneghan, M., & El Rhalibi, A. (2007). Describing games for learning: terms, scope and learning approaches. In *The Fifth Annual International Conference in Computer Game Design and Technology,* Liverpool*, UK* (pp. 98-102).

Tavakol, M., & Dennick, R. (2011). Making sense of Cronbach's Alpha. *International Journal of Medical Education*, 2, 53-55. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4205511/

Teed, R. (2013, July 23). Game-based learning. Retrieved from http://serc.carleton.edu/introgeo/games/index.html

Thiese, M. S. (2014). Observational and interventional study design types; an overview. *Biochemia medica*, *24*(2), 199-210. Retrieved from https://doi.org/10.11613/BM.2014.022

Tobler, N. S., & Stratton, H. H. (1997). Effectiveness of school-based drug prevention programs: A meta-analysis of the research. *Journal of primary prevention*, *18*(1), 71-128. Retrieved from https://link.springer.com/article/10.1023/A:1024630205999

Tomlinson, C. A. (2001). *How to Differentiate Instruction in Mixed-ability Classrooms* (Vol. 2nd ed). Alexandria, VA: Assoc. for Supervision and Curriculum Development. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=nlebk&AN=70544&site=eds-live&scope=site

Tsai, F. H., Yu, K. C., & Hsiao, H. S. (2012). Exploring the Factors Influencing Learning Effectiveness in Digital Game-based Learning. Educational Technology & Society, 15(3), 240-250. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=ehh&AN=79816978&site=eds-live&scope=site

Tulving, E., (1972). Episodic and semantic memory. In *Organization of Memory* (pp. 381–403). New York: Academic

Turuk, M. C. (2008). The Relevance and Implications Of Vygotsky's Sociocultural Theory In The Second Language Classroom. *Annual Review of Education, Communication & Language Sciences*, *5*, 244–262. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=ehh&AN=44921138&site=eds-live&scope=site

Tylor, E. B. (1958). *Primitive culture*. New York: Harper.

Uysal, A., & Yildirim, I. G. (2016). Self-Determination Theory in Digital Games. In *Gamer Psychology and Behavior* (pp. 123-135). Springer International Publishing. Retrieved from https://www.researchgate.net/publication/303948263_Self-Determination_Theory_in_Digital_Games

Valadez, J. R., & Durán, R. P. (2007). Redefining the Digital Divide: Beyond Access to Computers and the Internet. *The High School Journal, 90*(3), 31–44. https://doi.org/10.1353/hsj.2007.0013

Van Broekhuizen, L. (2016). The Paradox of Classroom Technology: Despite Proliferation and Access, Students Not Using Technology For Learning. Alpharetta, GL: AdvancED. Retrieved from https://www.advanc-ed.org/sites/default/files/AdvancED_eleot_Classroom_Tech_Report.pdf

Van de Walle, J., Karp, K., & Bay-Williams, J. (2010). *Elementary and middle school mathematics: Teaching developmentally* (7th ed.). Boston: Allyn & Bacon. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=cat07058a&AN=vtp.750512&site=eds-live&scope=site

Van Eck, R. (2006). Digital game-based learning: It's not just the digital natives who are restless. EDUCAUSE Review, 41(2), 16-30. Retrieved from https://www.researchgate.net/profile/Richard_Van_Eck/publication/242513283_Digital_Game_Based_LEARNING_It's_Not_Just_the_Digital_Natives_Who_Are_Restless/links/0a85e53cd61cf43e29000000.pdf

VanSciver, J. H. (2005). Motherhood, Apple Pie, and Differentiated Instruction. *Phi Delta Kappan*, *86*(7), 534-535. Retrieved from http://eds.a.ebscohost.com.ezproxy.lib.vt.edu/eds/pdfviewer/pdfviewer?vid=0&sid=ff6aaee8-6de5-47f4-9d43-2f6984405957%40sessionmgr4006

Veenman, S., Denessen, E., van den Akker, A., & van der Rijt, J. (2005). Effects of a Cooperative Learning Program on the Elaborations of Students during Help Seeking and Help Giving. *American Educational Research Journal*, *42*(1), 115–151. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=eric&AN=EJ737120&site=eds-live&scope=site

Viera, A.J. and Garrett, J.M. (2005) Understanding Interobserver Agreement: The Kappa Statistic. *Family Medicine*, 37, 360-363.

Von Glasersfeld, E. (1995). A constructivist approach to teaching. In *Constructivism in education* (pp. 3-16). L. P. Steffe & J. Gale (Eds.) Hillsdale, NJ: Erlbaum.

Vrasidas, C., & Solomou, M. (2013). Using educational design research methods to examine the affordances of online games for teacher learning. *Educational Media International*, *50*(3), 192-205. https://doi.org/10.1080/09523987.2013.839151

Vygotsky, L. S. (1978). *Mind in Society: The development of higher psychological process.* Cambridge, MA: Harvard University Press.

Vygotsky, L. S. (2016). Play and Its Role in the Mental Development of the Child. *International Research in Early Childhood Education*, *7*(2), 3–25. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=eric&AN=EJ1138861&site=eds-live&scope=site

Waltz, J., Addis, M. E., Koerner, K., & Jacobson, N. S. (1993). Testing the integrity of a psychotherapy protocol: Assessment of adherence and competence. *Journal of Consulting and Clinical Psychology, 61*(4), 620–630. http://dx.doi.org/10.1037/0022-006X.61.4.620

Wang, H., & Sun, C. T. (2011, September). Game reward systems: gaming experiences and social meanings. In *Proceedings of DiGRA 2011 Conference: Think Design Play* (pp. 1-12). Retrieved from http://gamelearninglab.nctu.edu.tw/ctsun/10.1.1.221.4931.pdf

Wang, L. C., & Chen, M. P. (2010). The effects of game strategy and preference-matching on flow experience and programming performance in game-based learning. *Innovations in Education and Teaching International*,*47*(1), 39-52. https://doi.org/10.1080/14703290903525838

Wang, Q., Myers, M. D., & Sundaram, D. (2013). Digital natives and digital immigrants: Towards a model of digital fluency. *Business & Information Systems Engineering, 5*(6), 409-419. Retrieved from https://aisel.aisnet.org/cgi/viewcontent.cgi?article=1038&context=ecis2012

Wang, S. (2012). Applying a 3D situational virtual learning environment to the real world business—an extended research in marketing. British Journal of Educational Technology, 43(3), 411-427. https://doi.org/10.1111/j.1467-8535.2011.01194.x

Warschauer, M. (2012). The digital divide and social inclusion. *Americas Quarterly, 6*(2), 131–135.

Warschauer, M., & Matuchniak, T. (2010). New Technology and digital Worlds: Analyzing Evidence of Equity in Access, Use, and Outcomes. *Review of Research in Education, 34*(1), 179–225.

Watkins, W. H. (2008). Asa Grant Hilliard III: Scholar supreme. *Review of Educational Research, 78*(4), 994-1009. doi:10.3102/0034654308320965

Wells, J., and Lewis, L. (2006). Internet Access in U.S. Public Schools and Classrooms: 1994–2005 (NCES 2007-020). U.S. Department of Education. Washington, DC: National Center for Education Statistics. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=eric&AN=ED494307&site=eds-live&scope=site

Weltman, D. (2007). *A Comparison of Traditional And Active Learning Methods: An Empirical Investigation Utilizing A Linear Mixed Model.* ProQuest. Retrieved from http://hdl.handle.net/10106/734

Wheeler, M. A., Stuss, D. T., & Tulving, E. (1997). Toward a theory of episodic memory: The Frontal Lobes and Autonoetic Consciousness. *Psychological Bulletin, 121*(3), 331-354. doi:10.1037/0033-2909.121.3.331

White-Clark, DiCarlo, M., & Gilchriest (2008). “Guide on the side”: An instructional approach to meet mathematics standards. *The High School Journal*, 91(4), 40-45.

Whitton, N. (2010). *Learning with digital games: A practical guide to engaging students in higher education* (1st ed.). New York: Routledge. https://doi.org/10.4324/9780203872987

Wilson, A. J., Revkin, S. K., Cohen, D., Cohen, L., & Dehaene, S. (2006). An open trial assessment of "The Number Race", an adaptive computer game for remediation of dyscalculia. *Behavioral and Brain Functions:BBF, 2*(1), 20-20. doi:10.1186/1744-9081-2-20

Woo, J.-C. (2014). Digital Game-Based Learning Supports Student Motivation, Cognitive Success, and Performance Outcomes. *Educational Technology & Society*, 17 (3), 291–307. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=ehh&AN=98543306&site=eds-live&scope=site

Wood, D., Bruner, J. S., & Ross, G. (1976). The role of tutoring in problem solving. Journal of Child Psychology and Psychiatry, and Allied Disciplines, 17(2), 89-100. doi:10.1111/j.1469-7610.1976.tb00381.x

Wu, W. H., Hsiao, H. C., Wu, P. L., Lin, C. H., & Huang, S. H. (2012). Investigating the learning-theory foundations of game-based learning: a meta-analysis. *Journal of Computer Assisted Learning*, *28*(3), 265-279. https://doi.org/10.1111/j.1365-2729.2011.00437.x

Yang, Y. F. (2010). Developing a reciprocal teaching/learning system for college remedial reading instruction. *Computers & Education*, *55*(3), 1193-1201. Retrieved from https://www.sciencedirect.com/science/article/pii/S036013151000148X

Yang, Y. T. C. (2012). Building virtual cities, inspiring intelligent citizens: Digital games for developing students' problem solving and learning motivation. *Computers & Education*, *59*(2), 365-377. Retrieved from https://www.sciencedirect.com/science/article/pii/S0360131512000139

Young, M. F., Slota, S., Cutter, A. B., Jalette, G., Mullin, G., Lai, B., Simeoni, Z., Tran, M., & Yukhymenko, M. (2012). Our Princess Is in Another Castle: A Review of Trends in Serious Gaming for Education. Review of Educational Research, 82(1), 61-89. Retrieved from https://www-jstor-org.ezproxy.lib.vt.edu/stable/41408678

Yurov, K. M., Beasley, S. W., Kwak, M., & Floyd, K. S. (2014). An initial study of educational game applications supporting the STEM education in K-12 systems. Online Journal of Applied Knowledge Management, 2(1), 169-179. Retrieved from http://www.iiakm.org/ojakm/articles/2014/volume2_1/OJAKM_Volume2_1pp169-179.pdf

Zavaleta, J., Costa, M., Gouvea, M. T., & Lima, C. (2005, July). Computer games as a teaching strategy. In *Proceedings of the Fifth IEEE International Conference on Advanced Learning Technologies* (pp. 257-259). IEEE Computer Society.

Zheng, M., & Spires, H. A. (2014). Fifth Graders' Flow Experience in a Digital Game-Based Science Learning Environment. International Journal of Virtual and Personal Learning Environments (IJVPLE), 5(2), 69-86.

APPENDICES

Appendix A.

Ratios and Proportional Relationships Test

Ratios and Proportional Relationships Test

1 **There are 25 boys and 15 girls in a class. What is the ratio of girls to boys as a fraction in simplest form?**

A $\frac{5}{3}$

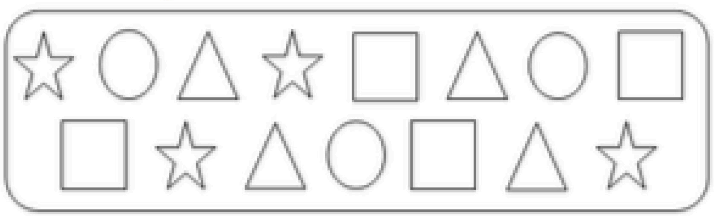
B $\frac{5}{9}$

C $\frac{3}{5}$

D $\frac{9}{5}$

2 Directions: Select the letter that best answers the question.

Which two shapes have a ratio of 3 to 4?



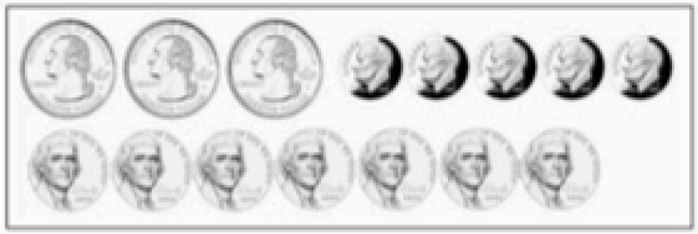
A star to circle

B rectangle to star

C circle to triangle

D triangle to rectangle

3 **Look at the set of coins.**



What is the ratio of dimes to quarters?

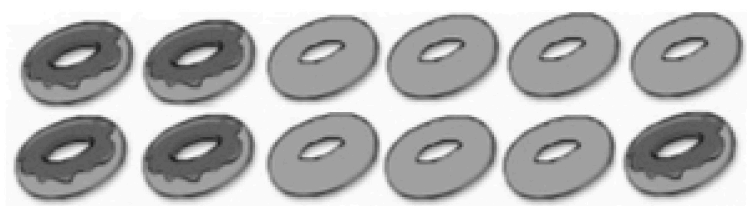
A 5:3
B 3:8
C 3:5
D 5:15

4 **The picture shows the number of stars Angie received from her piano teacher for practicing.**

What is the ratio of the number of striped stars to black stars?

A 4 to 10
B 6 to 10
C 4 to 3
D 3 to 4

5 **The picture shows the donuts that Marcus bought for his family.**



What is the ratio of the number of chocolate covered donuts to the total amount of donuts?

A 5:2
B 7:12
C 5:12
D 12:5

6 **A recipe calls for 2 tablespoons of flour for every tablespoon of sugar. Which table shows this relationship?**

A

Tablespoons of Sugar	Tablespoons of Flour
1	2
2	3
3	4
4	5

B

Tablespoons of Sugar	Tablespoons of Flour
2	1
3	2
4	3
5	4

C

Tablespoons of Sugar	Tablespoons of Flour
2	1
4	2
6	3
8	4

D

Tablespoons of Sugar	Tablespoons of Flour
1	2
2	4
3	6
4	8

7 **A used bookstore sells paperback books for $3.50 each. Which table represents this relationship?**

A

Number of Books	Total Price
1	$3.50
2	$7.00
6	$18.00
9	$31.50

B

Number of Books	Total Price
1	$3.50
4	$14.00
6	$18.50
7	$24.00

C

Number of Books	Total Price
2	$7.00
5	$17.50
8	$28.00
9	$31.50

D

Number of Books	Total Price
2	$7.00
5	$17.00
7	$24.00
8	$28.00

8 Directions: Type your answer in the box.

Patrick's truck can drive 7.5 miles on one gallon of gas. Patrick makes this table to show how far his truck will travel on a tank of gas.

Gas Use

Amount of Gas (gallons)	Distance (miles)
2	15
4	30
6	?
8	60

What number is missing from Patrick's table?

miles

9 Directions: Click and drag the answers to the correct box.

Avery is making chili for her sledding party and she has 11 cups of beans. The recipe says that 2 cups of beans feeds 6 people, so she makes this table to figure out how many people she can feed. Help Avery complete the table by matching the quantities to the correct places on the table.

Chili Beans

Number of Cups	Number of People
2	6
	12
4	
11	24
	33

10 **Look at the table.**

x	*y*
3	11
4	13
5	15
6	

Which value is missing in the table?

A 16
B 19
C 15
D 17

11 **The table shows the amount of time Jessie works and the amount of money she earns.**

Time (hr)	Amount Earned
4	$36
5	$45
6	?
7	$63

What is the missing value in the table?

A $48   B $52   C $54   D $60

12 Directions: Click on the correct answers.

Identify the tables that represent a proportional relationship between *x* and *y*.

x	1	2	3	4
y	17	34	51	68

x	8	10	20	30
y	4	2	10	15

x	1	2	3	4
y	2	3	6	8

x	1	6	9	11
y	3	18	27	33

13 **Which table shows a proportional relationship between *x* and *y*?**

A

x	*y*
3	16
4	20
6	24

B

x	*y*
9	21
12	27
16	35

C

x	*y*
4	16
5	25
6	36

D

x	*y*
2	12
3	18
4	24

14 Directions: Click on the correct answers.

Identify the tables that represent a proportional relationship between *x* and *y*.

x	2	4	6	8
y	9	18	27	36

x	30	24	18	12
y	10	8	6	4

x	5	7	13	18
y	25	35	60	90

x	3	7	9	11
y	27	63	81	99

15 **The table shows a proportional relationship between *y* and *x*.**

x	3	5	8	9	12
y	15	?	40	45	60

What is the missing value in the table?

A 20 B 25 C 30 D 35

16 Click and drag each amount to the correct box.

Sara is selling three chocolate chip cookies for $2.49 at the school fair. Complete the table to determine the cost of the given amount of cookies.

Number of Cookies	1	3	16	30	55
Cost (in dollars and cents)	$0.83	$2.49	$13.28	$24.90	$45.65

17 **Which table shows a proportional relationship between x and y?**

A

x	y
2	12
3	18
4	24
6	30

B

x	y
5	15
7	21
9	27
10	30

C

x	y
4	20
6	40
8	60
10	80

D

x	y
3	36
4	48
5	60
6	78

18 **The price of movie tickets at four theaters are shown.**

Theater A

Number of Tickets	Total Price
4	$32
6	$48
12	$96
15	$120

Theater B

Number of Tickets	Total Price
1	$6
5	$30
9	$54
16	$96

Theater C

Number of Tickets	Total Price
2	$18
8	$72
10	$90
17	$153

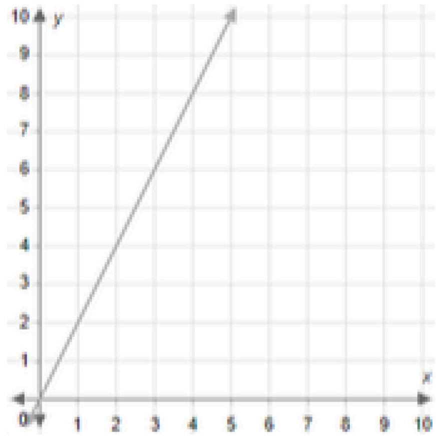
Theater D

Number of Tickets	Total Price
3	$24
7	$56
13	$104
14	$112

Which two theaters have the same price per ticket?

A B and C　　B B and D　　C A and D　　D A and C

19 **The line shows a relationship between *x* and *y*.**



Which table shows the same relationship between *x* and *y* as the line?

A

x	y
0	0
3	6
6	9
9	12

B

x	y
0	0
6	3
12	6
18	9

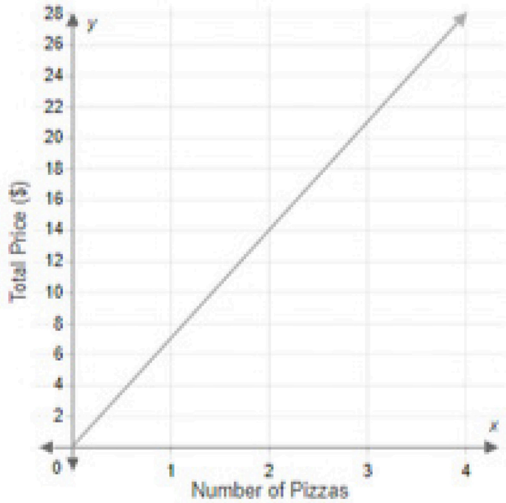
C

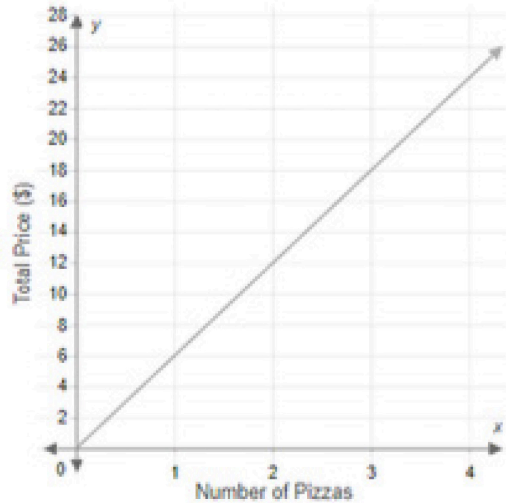
x	y
0	0
3	6
6	12
9	18

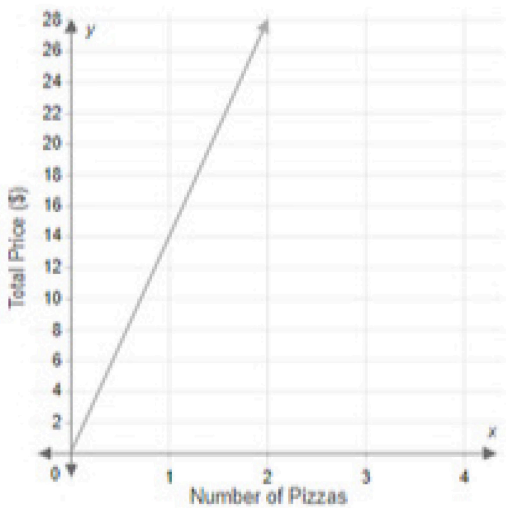
D

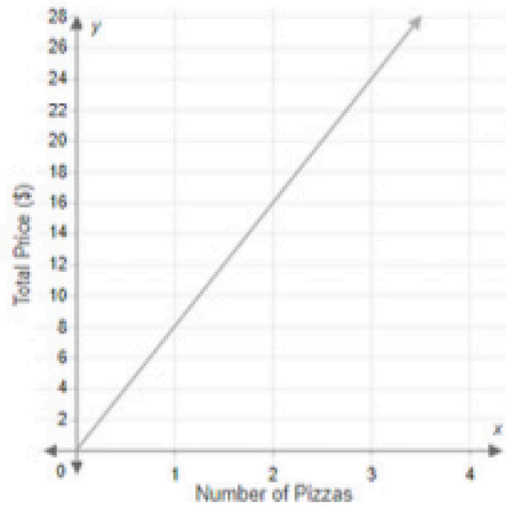
x	y
0	0
6	3
9	6
12	9

20 **The price of 3 pizzas at a restaurant is $21. If all pizzas are the same price, which graph shows the price of pizzas at the restaurant?**

A


C


B


D


Appendix B.

Students' Perceptions of Digital Game-Based Learning Survey (Pre)

Students' Perceptions of Digital Game-Based Learning Survey

In this survey, we are interested in learning about your experiences with the digital game-based approach to learning mathematics.

1. I like playing digital games.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
○	○	○	○	○

2. I often play digital games.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
○	○	○	○	○

3. Compared to other students my age, I play a lot of digital games.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
○	○	○	○	○

4. I would describe myself as a gamer.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
○	○	○	○	○

5. I play different types of digital games.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
○	○	○	○	○

6. I would know how to handle digital games in math class.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
○	○	○	○	○

7. It would be easy for me to use digital games in math class.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
○	○	○	○	○

8. My interaction with digital games in math class would be clear and understandable.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
○	○	○	○	○

9. Digital game-based learning offers opportunities to experiment with knowledge.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
○	○	○	○	○

10. Digital game-based learning offers opportunities to take control of the learning process.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
○	○	○	○	○

11. Digital game-based learning offers opportunities to experience things you learn about.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
○	○	○	○	○

12. Digital game-based learning offers opportunities to transfer knowledge between various subjects.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
○	○	○	○	○

13. Digital game-based learning offers opportunities to interact with other students.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
○	○	○	○	○

14. Digital game-based learning offers opportunities to think critically.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
○	○	○	○	○

15. Digital game-based learning offers opportunities to motivate students.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

16. Using digital games in math class would improve my performance.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

17. Using digital games in math class would increase my learning productivity.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

18. Using digital games in math class would increase my effectiveness.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

19. Using digital games in math class would help me to achieve better grades.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

20. If I had the choice, I would choose to take classes in which digital games are used.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

21. If I had to vote, I would vote in favor of using digital games in math class.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

22. I am excited about using digital games in math class.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

Appendix C.

Students' Perceptions of Digital Game-Based Learning Survey (Post)

Students’ Perceptions of Digital Game-Based Learning Survey

In this survey, we are interested in learning about your experiences with the digital game-based approach to learning mathematics.

1. I like playing digital games.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
○	○	○	○	○

2. I often play digital games.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
○	○	○	○	○

3. Compared to other students my age, I play a lot of digital games.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
○	○	○	○	○

4. I would describe myself as a gamer.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
○	○	○	○	○

5. I play different types of digital games.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
○	○	○	○	○

6. I would know how to handle digital games in math class.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
○	○	○	○	○

7. It would be easy for me to use digital games in math class.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

8. My interaction with digital games in math class would be clear and understandable.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
○	○	○	○	○

9. Digital game-based learning offers opportunities to experiment with knowledge.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
○	○	○	○	○

10. Digital game-based learning offers opportunities to take control of the learning process.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
○	○	○	○	○

11. Digital game-based learning offers opportunities to experience things you learn about.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
○	○	○	○	○

12. Digital game-based learning offers opportunities to transfer knowledge between various subjects.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
○	○	○	○	○

13. Digital game-based learning offers opportunities to interact with other students.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
○	○	○	○	○

14. Digital game-based learning offers opportunities to think critically.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
○	○	○	○	○

15. Digital game-based learning offers opportunities to motivate students.

Strongly Disagree Disagree Neutral Agree Strongly Agree

16. Using digital games in math class would improve my performance.

Strongly Disagree Disagree Neutral Agree Strongly Agree

17. Using digital games in math class would increase my learning productivity.

Strongly Disagree Disagree Neutral Agree Strongly Agree

18. Using digital games in math class would increase my effectiveness.

Strongly Disagree Disagree Neutral Agree Strongly Agree

19. Using digital games in math class would help me to achieve better grades.

Strongly Disagree Disagree Neutral Agree Strongly Agree

20. If I had the choice, I would choose to take classes in which digital games are used.

Strongly Disagree Disagree Neutral Agree Strongly Agree

21. If I had to vote, I would vote in favor of using digital games in math class.

Strongly Disagree Disagree Neutral Agree Strongly Agree

22. I am excited about using digital games in math class.

Strongly Disagree Disagree Neutral Agree Strongly Agree

Thank you for your participation in this study. The purpose of this research study is to: (a) determine whether or not DGBL is a viable tool in helping students to improve achievement in middle school mathematics and (b) gauge their perceptions regarding the use of DGBL. Anticipated findings from this study will provide insight into the benefits of using a digital game-based approach for learning mathematics. Your contribution is invaluable for helping educators help their students in the future. If you have further questions about the study, please contact the researcher, Valdez L. Mosley, at vlmosley@vt.edu or 804.513.5447. In addition, if you have any concerns about any aspect of the study or questions about your rights as a research subject, you may contact the Virginia Tech - Institutional Review Board (IRB) at (540) 231-3732 or irb@vt.edu.

Appendix D.

Letter Seeking Permission to Use Survey/Questionnaire Tool

Name: Dr. Jeroen Bourgonjon
Institution: Ghent University
Department: Educational Studies
Gent, Belgium
Jeroen.Bourgonjon@UGent.be

Dear Dr. Bourgonjon:

Good morning. My name is Valdez Mosley and I am a doctoral candidate in the Integrative STEM Education program at Virginia Polytechnic Institute and State University (Virginia Tech). Under the guidance of my committee chair, Dr. John G. Wells, I am conducting my doctoral dissertation titled: Learner Perceptions and Cognitive Outcomes of Digital Game-Based Learning in Mathematics. To meet the requirements of my research study, and with your permission, I would like to make minor modifications to [and reproduce] the student perception survey instrument in your doctoral dissertation titled: Video Game Literacy: Social, Cultural and Educational Perspectives. The adapted version of the survey will include proper citations and a copy will be sent to you at the end of the study.

If these are acceptable terms and conditions, please indicate so by replying to me via e-mail at vlmosley@vt.edu.

Sincerely,

Valdez L. Mosley

Appendix E.

Permission to Use/Adapt Survey Questionnaire

VIRGINIA TECH. **Valdez Mosley <vlmosley@vt.edu>**

Permission to use/adapt survey questionnaire

Jeroen Bourgonjon <jeroen.bourgonjon@ugent.be> Tue, Jun 12, 2018 at 4:24 AM
To: Valdez Mosley <vlmosley@vt.edu>

Dear Valdez,

It's always nice to meet fellow research travelers. Of course you can use the survey instrument!

I wish you all the best with your dissertation.

With friendly regards,

Jeroen

Op 6/06/2018 om 16:17 schreef Valdez Mosley:
[Quoted text hidden]

--
dr. Jeroen Bourgonjon
Coördinator voor UGent in De Krook

De Krook
Miriam Makebaplein 1
B-9000 Gent
België

Tel. +32 (0)9 264 8676 (direct)
Tel. +32 (0)9 264 8664
Fax. +32 (0)9 264 8688
Mail: Jeroen.Bourgonjon@UGent.be

Appendix F.

Items by Construct by Bourgonjon (2015)

Experience with games

1. I like playing video games
2. I often play video games
3. Compared to people of my age, I play a lot of video games
4. I would describe myself as a gamer
5. I play different types of video games

Ease of use

1. I would know how to handle video games in the classroom
2. It would be easy to for me to use video games in the classroom
3. My interaction with video games in the classroom would be clear and understandable

Learning Opportunities

1. Video games offer opportunities to experiment with knowledge
2. Video games offer opportunities to take control over the learning process
3. Video games offer opportunities to experience things you learn about
4. Video games offer opportunities to stimulate transfer between various subjects
5. Video games offer opportunities to interact with other students
6. Video games offer opportunities to think critically
7. Video games offer opportunities to motivate students

Usefulness

1. Using video games in the classroom would improve my performance
2. Using video games in the classroom would increase my learning productivity
3. Using video games in the classroom would enhance my effectiveness
4. Using video games in the classroom would help me to achieve better grades

Preference for video games

1. If I had the choice, I would choose to follow courses in which video games are used
2. If I had to vote, I would vote in favor of using video games in the classroom
3. I am enthusiastic about using video games in the classroom

Appendix G.

Content and Construct Inter-rater Validation Form

Thank you for agreeing to be an inter-rater for the study titled: Learner Perceptions and Cognitive Outcomes of Digital Game-Based Learning in Mathematics. I am asking for your help to establish content and construct validity of the *Students' Perceptions of Digital Game-Based Learning Survey* (SPoDGBLS) instrument. The directions for completing this form is listed below:

Content and Construct Validation Instructions: Read the purpose of the SPoDGBLS instrument below and then follow the directions for establishing content and construct validity for each item (question).

Purpose:

The SPoDGBLS instrument is focused on understanding perceptions of digital game-based learning. The goal of the SPoDGBLS instrument is to measure students' perceptions regarding the use of DGBL in mathematics.

Content Validity

To assess the SPoDGBLS instrument for content validity please evaluate the highlighted term in each question and decide whether or not it is content valid.

Construct Validity

To assess the SPoDGBLS instrument for construct validity please evaluate the highlighted term in each question and decide whether or not it is construct valid.

If you have determined that a highlighted term in a question is not content or construct valid, please provide an alternate term in the appropriate place in the last column of the table.

Please complete this by _______________ and return the electronic version to vlmosley@vt.edu. Thank you.

Question #	Question (Term(s))	Content-valid	Construct-valid	Alternate (Term(s))
1	I like playing digital games.	Yes or No	Yes or No	
2	I often play digital games.	Yes or No	Yes or No	
3	Compared to other students my age, I play a lot of digital games.	Yes or No	Yes or No	
4	I would describe myself as a gamer.	Yes or No	Yes or No	
5	I play different types of digital games.	Yes or No	Yes or No	
6	I would know how to handle digital games in math class.	Yes or No	Yes or No	
7	It would be easy to for me to use digital games in math class.	Yes or No	Yes or No	

8	My interaction with digital games in math class would be clear and understandable.	Yes or No	Yes or No	
9	Digital game-based learning offers opportunities to experiment with knowledge.	Yes or No	Yes or No	
10	Digital game-based learning offers opportunities to take control over the learning process.	Yes or No	Yes or No	
11	Digital game-based learning offers opportunities to experience things you learn about.	Yes or No	Yes or No	
12	Digital game-based learning offers opportunities to transfer knowledge between various subjects.	Yes or No	Yes or No	
13	Digital game-based learning offers opportunities to interact with other students.	Yes or No	Yes or No	
14	Digital game-based learning offers opportunities to think critically.	Yes or No	Yes or No	
15	Digital game-based learning offers opportunities to motivate students.	Yes or No	Yes or No	
16	Using digital games in math class would improve my performance.	Yes or No	Yes or No	
17	Using digital games in math class would increase my learning productivity.	Yes or No	Yes or No	
18	Using digital games in math class would increase my effectiveness.	Yes or No	Yes or No	
19	Using digital games in math class would help me to achieve better grades.	Yes or No	Yes or No	
20	If I had the choice, I would choose to take classes in which digital games are used.	Yes or No	Yes or No	
21	If I had to vote, I would vote in favor of using digital games in math class.	Yes or No	Yes or No	
22	I am excited about using digital games in math class.	Yes or No	Yes or No	

Appendix H.

Implementation Fidelity Log

Implementation Fidelity Log

Date (month/date/year)	Adherence (yes/no)	Exposure		Participant Responsiveness		
		Planned Time (Intervention)	Actual Time (Intervention)	Active Participants	Total Participants	Percent
		15 minutes				%
		15 minutes				%
		15 minutes				%
		15 minutes				%
		15 minutes				%
		15 minutes				%
		15 minutes				%
		15 minutes				%
		15 minutes				%
		15 minutes				%
		15 minutes				%
		15 minutes				%
		15 minutes				%
		15 minutes				%
		15 minutes				%
		15 minutes				%
		15 minutes				%
		15 minutes				%
		15 minutes				%
		15 minutes				%
		15 minutes				%
		15 minutes				%
		15 minutes				%

Appendix I.

Intervention Log

	A	B	C	D	E	F	G
1				Time Spent in Minutes			
2	Student	Week 1	Week 2	Week 3	Week 4	Week 5	Total
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
21							
22							
23							
24							
25							
26							
27							
28							
29							
30							
31							
32							
33							
34							
35							

Appendix J.

Institutional Review Board Approval Letter

Division of Scholarly Integrity and Research Compliance
Institutional Review Board
North End Center, Suite 4120 (MC 0497)
300 Turner Street NW
Blacksburg, Virginia 24061
540/231-3732
irb@vt.edu
http://www.research.vt.edu/sirc/hrpp

MEMORANDUM

DATE: January 31, 2020

TO: John Wells, Valdez Lamont Mosley

FROM: Virginia Tech Institutional Review Board (FWA00000572, expires October 29, 2024)

PROTOCOL TITLE: LEARNER PERCEPTIONS AND COGNITIVE OUTCOMES OF DIGITAL GAME BASED LEARNING IN MATHEMATICS

IRB NUMBER: **18-015**

Effective January 30, 2020, the Virginia Tech Institution Review Board (IRB) approved the New Application request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report within 5 business days to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at:

https://secure.research.vt.edu/external/irb/responsibilities.htm

(Please review responsibilities before beginning your research.)

PROTOCOL INFORMATION:

Approved As:	**Expedited, under 45 CFR 46.110 category(ies) 6,7**
Protocol Approval Date:	**January 30, 2020**
Protocol Expiration Date:	**January 29, 2021**
Continuing Review Due Date*:	**January 8, 2021**

*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

ASSOCIATED FUNDING:

The table on the following page indicates whether grant proposals are related to this protocol, and which of the listed proposals, if any, have been compared to this protocol, if required.

Date*	OSP Number	Sponsor	Grant Comparison Conducted?

* Date this proposal number was compared, assessed as not requiring comparison, or comparison information was revised.

If this protocol is to cover any other grant proposals, please contact the HRPP office (irb@vt.edu) immediately.

Appendix K.

Parent Consent Form

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
Parent Consent Form

Title of Project: Learner Perceptions and Cognitive Outcomes of Digital Game-Based Learning in Mathematics (IRB #18-015)
Program: Integrative STEM Education

Principal Investigator: Dr. John G. Wells
Email Address: jgwells@vt.edu
Telephone: (540) 231-8471

Co-Investigator: Valdez L. Mosley
Email address: vlmosley@vt.edu
Telephone: (804) 513-5447

Key Information: The following is a short summary of this research study to help you decide whether or not you would like your child to participate. A more detailed list of information is presented later on in this form.

We are inviting your child to participate in this research study because they are among those students at [redacted] who are receiving traditional math instruction together with digital game-based learning (DGBL). The DGBL is used with all students during the last 15 minutes of each class day to supplement the traditional math instruction and is intended to help students improve their middle school mathematics abilities. Our study will investigate the potential of DGBL for helping students to improve their mathematics abilities, as well as their perceptions about using digital gaming for learning math.

What should you know about being in a research study?

- The researcher will explain the research study to you and your child.
- It is up to you whether or not you choose to allow your child to participate in the study.
- You can decide not to allow your child to participate in the study.
- Your decision to not allow their participation will not be held against him or her.
- You can agree to allow your child to participate in the study and later change your mind.
- You can ask as many questions that you want before making your decision.

What should I know about <u>this</u> research study?
The purpose of this study is to: (a) determine whether or not digital game-based learning (DGBL) is a viable tool in helping students to improve achievement in middle school mathematics and (b) gauge their perceptions regarding the use of DGBL. Your child's participation in this research study will last 5 weeks. Your child:

a) will be asked to complete mathematics DGBL lessons during the last 15 minutes of each math class.
b) will take a pre and post intervention survey about their experience.
c) may also be chosen to answer interview questions regarding their perceptions of a digital game-based approach for learning mathematics. (More detailed information about the study procedures can be found under ***"Procedures"***.)

There are no risks or benefits to your child for participating in this study. We cannot promise or guarantee any benefits to others from your child participating in this research. However, we anticipate that findings from this study will provide insight into the potentials of using a DGBL approach to support the learning of middle school mathematics. As a [redacted] student, your child's decision to participate or not participate in this study will have no effect on their grades or relationship with Virginia Tech.

Detailed Information:
I. Introduction

This parent consent form describes a research study that is being conducted at [redacted]. The study will include approximately 30 general education students (male/female). Your child is invited to participate in this study because there is a potential that digital game-based learning (DGBL) will benefit students in their learning of math.

DGBL is defined as: a type of instructional approach where digital games are played on digital devices for educational purposes. The DGBL tool that will be used for this study is called DreamBox, which is an application installed on all student computers; its game-based curriculum is aligned to the current Virginia Mathematics Standards of Learning (SOL). The online games are adaptive and give the students the opportunity to complete targeted, individualized assignments at their own pace.

Please note: All students will receive traditional math instruction from their teacher and be exposed to digital game-based learning (DGBL) during enrichment time, regardless of whether they are involved in the study or not. This study intervention <u>will not</u> affect your child's regular math instruction; <u>it will</u> provide additional time with math content and an alternative approach to math learning. It cannot be known how or if student grades in math will be affected; whether this has the potential to improve participants' math abilities is the point of the research study.

Your consent and data release consent forms, along with your child's assent form are needed before he or she can be allowed to participate in the study. To help you make a decision, please read the following information about the purpose of the research, the procedures followed in conducting the research, what to expect if you allow your child to participate in this study, and how to contact the VT IRB should you have any questions, concerns, or need additional information.

II. Purpose of this Research Project

The purpose of this research study is to: (a) determine whether or not DGBL is a viable tool in helping students to improve achievement in middle school mathematics and (b) gauge their perceptions regarding the use of DGBL. Anticipated findings from this study will provide insight into the benefits of using a digital game-based approach for learning mathematics.

III. Procedures

The sources of data collection utilized in this study will include the Ratios and Proportional Relationships Test, the *Students' Perceptions of Digital Game-Based Learning Survey*, and small group, semi-structured, open-ended interviews. The study will last for 5 weeks and the pre and post intervention data will be collected and recorded in two stages as outlined below. All identifying information or data collected from participants will be kept confidential and protected from unauthorized disclosure. To ensure the confidentiality of participant data, each participant will be assigned a pseudonym (for instance, John Doe = Student 1). The child's information collected as part of the research, even if identifiers are removed, will not be used or distributed for future research studies. The results of this research study will be presented as part of the researcher's dissertation.
Pre intervention data collection:

- Ratios and Proportional Relationships Pretest. Participants' sixth grade Ratios and Proportional Relationships Pretest data from middle school and associated demographics (e.g., gender, age, and race) will be recorded in a password protected Excel file by the division-level research administrator and saved on a password protected computer. The test data will be used to estimate participants' math achievement levels and record select demographic data. The research administrator will provide us with the password protected Excel file and password, which will be saved on the researcher's password protected computer.
- Student's Perceptions of DGBL. Administered through SurveyMonkey, the survey will be used to collect baseline data regarding participants' perceptions about their use of a digital game-based approach for learning mathematics. Student survey responses will be recorded when the intervention begins the seventh week of the first marking period during math class and saved directly into the researcher's password protected SurveyMonkey account.

Intervention:

- Participants will complete mathematics DGBL lessons during the last 15 minutes of each math class for a minimum total of 60 minutes per week of the 5-week study.

Post intervention data collection:

- Ratios and Proportional Relationships Posttest. Following administration of the Ratios and Proportional Relationships Posttest scores will be recorded in a password protected Excel file by the division-level research administrator and saved on a password protected computer. The research administrator will provide us with the password protected Excel file and password, which will be saved on the researcher's password protected computer.
- Ratios and Proportional Relationships Posttest Cut Score. The division-level research administrator will provide us with the cut score for comparison with participant Ratios and Proportional Relationships Posttest scores.
- Student's Perceptions of DGBL. Administered through SurveyMonkey, the survey will be used to collect post intervention data regarding participants' perceptions about their use of a digital game-based approach for learning mathematics. Student survey responses will be recorded the third week of the second marking period during math class and saved directly into the researcher's password protected SurveyMonkey account.
- Small Group, Semi-structured, Open-ended Interviews. During the week immediately following the conclusion of the study, small group interviews will be conducted using an interview protocol to collect in-depth information regarding student perceptions of a digital game-based approach for learning mathematics. The small group interview protocol will be designed to cross-check the data obtained from the *Students' Perceptions of Digital Game-Based Learning Survey*. An interview script will be developed to guide the interview process. The 22 items (questions) from the *Students' Perceptions of Digital Game-Based Learning Survey* will be referenced to create five open-ended interview questions. Interview questions will be exploratory in nature and will be developed to address the following five constructs of the *Students' Perceptions of Digital Game-Based Learning Survey*: 1) Experience with digital games, 2) Ease of use, 3) Learning opportunities, 4) Usefulness, and 5) Preference for digital games. Each interview question will be reviewed for alignment with the corresponding construct addressed by specific survey questions on the *Students' Perceptions of Digital Game-Based Learning Survey*. Interview probes will be written to encourage interviewees to elaborate further about their responses. In order to select interviewees, study participants will be ranked in low,

middle, and high groups according to *Students' Perceptions of Digital Game-Based Learning Survey* ratings. One male and one female will be randomly selected from each group to be interviewed together. The 30-minute, small group interviews will be conducted over three days during an extended lunch block, between 10:30 a.m. and 12:30 p.m. Each of the three interviews will take place via a video meeting. Audio responses will be recorded during the video meeting, transcribed by the researcher into three interview transcripts for use in data analysis, and saved on the researcher's password protected computer.

After the 5 week study and data collection is complete, participants' pre and post data from both the Ratios and Proportional Relationships Test and the *Students' Perceptions of Digital Game-Based Learning Survey* will be used to determine whether the differences were statistically significant after the intervention was implemented.

IV. Risks

There are no risks (emotional, social, economic, legal or physical) or rewards for participating, nor are there consequences for not participating. Participants should report any concerns to the research team.

V. Benefits and Compensation

There is no promise or guarantee of benefits or compensation for participating in this study.

VI. Confidentiality

The research team will not share information that identifies the participants, school, or school district participating in this study. All non-identifying information or data collected will be kept confidential and protected from unauthorized disclosure.

The research team will have access to all non-identifying information and documents and retain them for a minimum of five years after the study is complete. At no time, will identifiable results be released to anyone other than the research team without your written consent. The Virginia Tech (VT) Institutional Review Board (IRB), Human Research Protection Program, and other authorized representatives of Virginia Tech may view the study's data for auditing purposes. The IRB is responsible for the oversight of the protection of human subjects involved in research.

VII. Freedom to Withdraw

Participation in this research study is voluntary. Participants may refuse to participate or withdraw from the study at any time without penalty or loss of benefits to which they are otherwise entitled. If your child decides to leave the research early, please, contact the researcher so that the researcher can discontinue all of the research activities involving their participation in the study. Data collected to the point of withdrawal will be deleted.

VIII. Questions or Concerns

Should you or your child have any questions, concerns, or complaints about this study, you may contact any member of the research team using the contact information listed at the beginning of this document.

This research has been reviewed and approved by the Virginia Tech Institutional Review Board (IRB). You may communicate with them at 540-231-3732 or irb@vt.edu if:

- You have questions about your child's rights as a research subject.
- Your questions, concerns, or complaints are not being answered by the research team.
- You cannot reach the research team.
- You want to talk to someone besides the research team to provide feedback about this research.

IX. Participant's Responsibilities

The participant's responsibilities, beyond the regular requirements of Middle School Math Course 1, are to engage with DreamBox for a minimum of 60 minutes per week (as scheduled during math class) - and to take a pre and post *Students' Perceptions of Digital Game-Based Learning Survey* about their experiences using digital game-based learning during math class. Six participants will be chosen to answer interview questions regarding their perceptions of a digital game-based approach for learning mathematics.

X. Parent/guardian's Consent

I have read the Consent Form and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent for my child to participate in this research study.

Your signature documents your permission to allow your child to participate in this research. We will provide you with a signed copy of this form for your records.

____ Date__________
Parent/guardian signature

____
Parent/guardian printed name

____ Date__________
Researcher signature

____
Researcher printed name

Appendix L.

Student Assent Form

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
Student Assent Form

Title of Project: Learner Perceptions and Cognitive Outcomes of Digital Game-Based Learning in Mathematics (IRB #18-015)
Program: Integrative STEM Education

Principal Investigator: Dr. John G. Wells
Email Address: jgwells@vt.edu
Telephone: (540) 231-8471

Co-Investigator: Valdez L. Mosley
Email address: vlmosley@vt.edu
Telephone: (804) 513-5447

Key Information: The following is a short summary of this research study to help you decide whether or not you would like to participate. A more detailed list of information is presented later on in this form.

We are inviting you to participate in this research study because you are among students at [redacted] who are receiving traditional math instruction together with digital game-based learning (DGBL). The DGBL is used with all students during the last 15 minutes of each class day to supplement the traditional math instruction and is intended to help students improve their middle school mathematics abilities. Our study will investigate the potential of DGBL for helping students to improve their mathematics abilities, as well as their perceptions about using digital gaming for learning math.

What should I know about being in a research study?

- The researcher will explain the research study to you.
- It is up to you whether or not you choose to participate in the study.
    - You can decide not to participate in the study; your decision to not participate will not be held against you.
    - You can agree to participate in the study and later change your mind.
- You can ask as many questions that you want before you make your decision.

What should I know about this research study?
The purpose of this study is to: (a) determine whether or not digital game-based learning (DGBL) is a viable tool in helping students to improve achievement in middle school mathematics and (b) gauge their perceptions regarding the use of DGBL. Your participation in this research study will last 5 weeks. You:

a) will be asked to complete mathematics DGBL lessons during the last 15 minutes of each math class.
b) will take a pre and post intervention survey about your experience.
c) may also be chosen to answer interview questions regarding your perceptions of a digital game-based approach for learning mathematics. (More detailed information about the study procedures can be found under ***"Procedures"***.)

There are no risks or benefits to you for participating in this study. We cannot promise or guarantee any benefits to others from you participating in this research. However, we anticipate that findings from this study will provide insight into the potentials of using a DGBL approach to support the learning of middle school mathematics. As a [redacted] student, your decision to participate or not participate in this study will have no effect on your grades or relationship with Virginia Tech.

Detailed Information:
I. Introduction

This student assent form describes a research study that is being conducted at [redacted]. This study will include approximately 30 general education students (male/female). You are invited to participate in this study because there is a potential that DGBL will benefit students in their learning of math.

DGBL is defined as: a type of instructional approach where digital games are played on digital devices for educational purposes. The DGBL tool that will be used for this study is called DreamBox, which is an application installed on all student computers; its game-based curriculum is aligned to the current Virginia Mathematics Standards of Learning (SOL). The online games are adaptive and give the students the opportunity to complete targeted, individualized assignments at their own pace.

Please note: All students will receive traditional math instruction from their teacher and be exposed to digital game-based learning during enrichment time, regardless of whether they are involved in the study or not. This study intervention will not affect your regular math instruction; it will provide additional time with math content and an alternative approach to math learning. It cannot be known how or if student grades in math will be affected; whether this has the potential to improve participants' math abilities is the point of the research study.

Your assent, along with your parent's consent form are needed before you can be allowed to participate in the study. To help you make a decision, please read the following information about the purpose of the research, the procedures followed in conducting the research, what to expect if you choose to participate, and how to contact the VT IRB should you have any questions, concerns, or need additional information.

II. Purpose of this Research Project

The purpose of this research study is to: (a) determine whether or not DGBL is a viable tool in helping students to improve achievement in middle school mathematics and (b) gauge their perceptions regarding the use of DGBL. Anticipated findings from this study will provide insight into the benefits of using a digital game-based approach for learning mathematics.

III. Procedures

The sources of data collection utilized in this study will include the Ratios and Proportional Relationships Test, the *Students' Perceptions of Digital Game-Based Learning Survey*, and small group, semi-structured, open-ended interviews. The study will last for 5 weeks and the pre and post intervention data will be collected and recorded in two stages as outlined below. All identifying information or data collected from participants will be kept confidential and protected from unauthorized disclosure. To ensure the confidentiality of participant data, each participant will be assigned a pseudonym (for instance, John Doe = Student 1). The child's information collected as part of the research, even if identifiers are removed, will not be used or distributed for future research studies. The results of this research study will be presented as part of the researcher's dissertation.

Pre intervention data collection:

- Ratios and Proportional Relationships Pretest. Participants' sixth grade Ratios and Proportional Relationships Pretest data from middle school and associated demographics (e.g., gender, age, and race) will be recorded in a password protected Excel file by the division-level research administrator and saved on a password protected computer. The test data will be used to estimate participants' math achievement levels and record select demographic data. The research administrator will provide us with the password protected Excel file and password, which will be saved on the researcher's password protected computer.

- Student's Perceptions of DGBL. Administered through SurveyMonkey, the survey will be used to collect baseline data regarding participants' perceptions about their use of a digital game-based approach for learning mathematics. Student survey responses will be recorded when the intervention begins the seventh week of the first marking period during math class and saved directly into the researcher's password protected SurveyMonkey account.

Intervention:

- Participants will complete mathematics DGBL lessons during the last 15 minutes of each math class for a minimum total of 60 minutes per week of the 5-week study.

Post intervention data collection:

- Ratios and Proportional Relationships Posttest. Following the administration of the Ratios and Proportional Relationships Posttest scores will be recorded in a password protected Excel file by the division-level research administrator and saved on a password protected computer. The research administrator will provide us with the password protected Excel file and password, which will be saved on the researcher's password protected computer.
- Ratios and Proportional Relationships Posttest Cut Score. The division-level research administrator will provide us with the cut score for comparison with participant Ratios and Proportional Relationships Posttest scores.
- Student's Perceptions of DGBL. Administered through SurveyMonkey, the survey will be used to collect post intervention data regarding participants' perceptions about their use of a digital game-based approach for learning mathematics. Student survey responses will be recorded the third week of the second marking period during math class and saved directly into the researcher's password protected SurveyMonkey account.
- Small Group, Semi-structured, Open-ended Interviews. During the week immediately following the conclusion of the study, small group interviews will be conducted using an interview protocol to collect in-depth information regarding student perceptions of a digital game-based approach for learning mathematics. The small group interview protocol will be designed to cross-check the data obtained from the *Students' Perceptions of Digital Game-Based Learning Survey*. An interview script will be developed to guide the interview process. The 22 items (questions) from the *Students' Perceptions of Digital Game-Based Learning Survey* will be referenced to create five open-ended interview questions. Interview questions will be exploratory in nature and will be developed to address the following five constructs of the *Students' Perceptions of Digital Game-Based Learning Survey*: 1) Experience with digital games, 2) Ease of use, 3) Learning opportunities, 4) Usefulness, and 5) Preference for digital games. Each interview question will be reviewed for alignment with the corresponding construct addressed by specific survey questions on the *Students' Perceptions of Digital Game-Based Learning Survey*. Interview probes will be written to encourage interviewees to elaborate further about their responses. In order to select interviewees, study participants will be ranked in low, middle, and high groups according to *Students' Perceptions of Digital Game-Based Learning Survey* ratings. One male and one female will be randomly selected from each group to be interviewed together. The 30-minute, small group interviews will be conducted over three days during an extended lunch block, between 10:30 a.m. and 12:30 p.m. Each of the three interviews will take place via a video meeting. Audio responses will be recorded during the video meeting,

transcribed by the researcher into three interview transcripts for use in data analysis, and saved on the researcher's password protected computer.

After the 5 week study and data collection is complete, participants' pre and post data from both the Ratios and Proportional Relationships Test and the *Students' Perceptions of Digital Game-Based Learning Survey* will be used to determine whether the differences were statistically significant after the intervention was implemented.

IV. Risks

There are no risks (emotional, social, economic, legal or physical) or rewards for participating, nor are there consequences for not participating. Participants should report any concerns to the research team.

V. Benefits and Compensation

There is no promise or guarantee of benefits or compensation for participating in this study.

VI. Confidentiality

The research team will not share information that identifies the participants, school, or school district participating in this study. All non-identifying information or data collected will be kept confidential and protected from unauthorized disclosure.

The research team will have access to all non-identifying information and documents and retain them for a minimum of five years after the study is complete. At no time, will identifiable results be released to anyone other than the research team without your written consent. The Virginia Tech (VT) Institutional Review Board (IRB), Human Research Protection Program, and other authorized representatives of Virginia Tech may view the study's data for auditing purposes. The IRB is responsible for the oversight of the protection of human subjects involved in research.

VII. Freedom to Withdraw

Participation in this research study is voluntary. Participants may refuse to participate or withdraw from the study at any time without penalty or loss of benefits to which they are otherwise entitled. If you decide to leave the research early, contact the researcher so that the researcher can discontinue all of the research activities involving your participation in the study. Data collected to the point of withdrawal will be deleted.

VIII. Questions or Concerns

Should you have any questions, concerns, or complaints about this study, you may contact any member of the research team using the contact information listed at the beginning of this document.

This research has been reviewed and approved by the Virginia Tech Institutional Review Board (IRB). You may communicate with them at 540-231-3732 or irb@vt.edu if:

- You have questions about your rights as a research subject.
- Your questions, concerns, or complaints are not being answered by the research team.
- You cannot reach the research team.
- You want to talk to someone besides the research team to provide feedback about this research.

IX. Participant's Responsibilities

The participant's responsibilities, beyond the regular requirements of Middle School Math Course 1, are to engage with DreamBox for a minimum of 60 minutes per week (as scheduled during math class) - and to take the pre and post *Students' Perceptions of Digital Game-Based Learning Survey* about their experiences using digital game-based learning during math class. Six participants will be chosen to answer interview questions regarding their perceptions of a digital game-based approach for learning mathematics.

X. Participant's Consent

I have read the Assent Form and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary assent to participate in this research study.

Your signature documents your permission to participate in this research. We will provide you with a signed copy of this form for your records.

____ Date__________
Student signature

____
Student printed name

____ Date__________
Researcher signature

____
Researcher printed name

Verbal assent from student.

☐ **Yes**

☐ **No**

Date: _____________
Initials: ___________

Appendix M.

Data Release Consent Form

Dear Parent/Guardian,

Your child has been selected to participate in the research study titled: *Learner Perceptions and Cognitive Outcomes of Digital Game-Based Learning in Mathematics*. The purpose of this study is to determine if the additional DGBL part of instruction benefits students learning of math. As part of the evaluation process, the research team (Dr. John G. Wells and Mr. Valdez L. Mosley) looks for changes in Ratios and Proportional Relationships Test scores. We are requesting your consent to collect and use your student's 2020/21 de-identified (names removed) Ratios and Proportional Relationships Test scores and demographics, as provided by [redacted] to assist with this research.

If you consent to allow the research team to collect and use your student's data, please sign below and return the consent form to your student's math teacher. We will provide you with a signed copy of this form for your records.

Student's name (please print): ____

School: [redacted]

Signature of parent or guardian: ____

Date: ____________________

Appendix N.

Memorandum

Memo

To: Parents/Guardians
From: Valdez L. Mosley
Date:
Re: Learner Perceptions and Cognitive Outcomes of Digital Game-Based Learning in Mathematics

---

Dear Parent/Guardian:

This is a follow up memo regarding research being conducted at [redacted]. You should already have received a packet of information about this research, including informed consent documents (parent consent, student assent, and data release consent form) to be signed.

Your child is invited to participate in this research study because they are among those students at school who are receiving traditional math instruction together with digital game-based learning (DGBL). The DGBL will be used with all students during the last 15 minutes of each class day to supplement the traditional math instruction and is intended to help students improve their middle school mathematics abilities, as well as their perceptions about using digital gaming for learning math.

If you <u>have</u> already completed and returned the informed consent documents, please accept my thanks and disregard this letter as no further involvement is required.

If you <u>have not</u> completed the informed consent documents, please take the time to decide whether or not you would like your child to participate.

If you grant permission for your student to participate, please, sign all informed consent documents and return them to your student's math teacher.

Thank you very much.

Sincerely,

Valdez L. Mosley

Appendix O.

Research Timeline

Timeline for research activities/Suggested deadline by month	**Oct. 2020**	**Nov. 2020**	**Dec. 2020**
Recruitment and selection of research participants.			
Study begins.			
Ratios and Proportional Relationships Pretest data is collected and stored.			
Research participants take the *Students' Perceptions of Digital Game-Based Learning Survey*.			
Research participants receive digital game-based learning alongside daily math instruction.			
Ratios and Proportional Relationships Posttesting occurs and data is collected and stored.			
Ratios and Proportional Relationships Posttest cut score is collected.			
Research participants take the *Students' Perceptions of Digital Game-Based Learning Survey.*			
Participants are dismissed from the research study/study ends.			
Small group, semi-structured, open-ended interviews are conducted.			
Data is analyzed.			

Appendix P.

School Division Permission to Conduct Research

Dear Virginia Tech Institutional Review Board:

On behalf of [redacted], I would like to inform you of our support for the research proposal, *Learner Perceptions and Cognitive Outcomes of Digital Game-Based Learning in Mathematics*. The purpose of this research study is to: (a) determine whether or not DGBL is a viable tool in helping students to improve achievement in middle school mathematics and (b) gauge their perceptions regarding the use of DGBL. Anticipated findings from this study will provide insight into the potential benefits or drawbacks of using a DGBL approach for learning mathematics.

I understand that:

- participants will complete DreamBox Learning (DreamBox) lessons for a minimum of 60 minutes per week of the 5-week study.
- the intervention will be implemented during the last 15 minutes of each math class.
- the intervention will not affect participants' regular math instruction; it will provide them with additional math content and an alternative approach to math learning.
- it cannot be known how or if participants' grades in math will be affected; whether this has the potential to improve participants' math abilities is the point of the research study.

To support this proposed research, we have agreed to assist Dr. John G. Wells (Principal Investigator at Virginia Tech) and Valdez L. Mosley (graduate researcher) in the following ways to ensure the successful implementation of this research study:

- Allow the subject pool for this study to be drawn from sixth grade students enrolled at [redacted] who scored below the cut score on the Ratios and Proportional Relationships Pretest administered at the beginning of middle school.
- Allow potential subjects to be emailed digital packets that contain informed consent documents (parent consent, student assent, and data release consent form) providing details about the research study. Potential subjects will return the digital packets to their math teacher.
- Allow the recruitment of approximately 30 general education students (male/female) for participation in the study intervention during math class for 5 weeks during the 2020-2021 school year.
- Provide de-identified Ratios and Proportional Relationships Test scores and associated demographics of participating students. No identifying student information will be associated with the data provided.
- Allow participating students to take a pre and post *Students' Perceptions of Digital Game-Based Learning Survey* about their experiences using the digital game-based approach for learning mathematics during math class.
- Allow the graduate researcher direct access to student reports from the DreamBox insight dashboard.
- Allow the graduate researcher to ask six participants interview questions regarding their perceptions of a digital game-based approach for learning mathematics.

The extent of involvement for [redacted], specifically [redacted], is limited to allowing advertising for and the recruitment of sixth grade students interested in participating in the research study. Participants will be informed that participation is voluntary and they may withdraw from this study at any time without penalty. They will also be informed that there is no promise or guarantee of benefits or compensation for participating in this study. Furthermore, it is understood that my granting permission to advertise does not in any way obligate students to participate. It is with this understanding that I support Dr. Wells and Mr. Mosley and look forward to working with them on this project. If you have any questions, please do not hesitate to call. I can be reached at [redacted].

Sincerely,

____ Date__________
Research Specialist signature

____
Research Specialist printed name

Appendix Q.

School Permission to Conduct Research

Dear Virginia Tech Institutional Review Board:

On behalf of [redacted], I would like to inform you of our support for the research proposal, *Learner Perceptions and Cognitive Outcomes of Digital Game-Based Learning in Mathematics*, submitted to [redacted]. The purpose of this research study is to: (a) determine whether or not DGBL is a viable tool in helping students to improve achievement in middle school mathematics and (b) gauge their perceptions regarding the use of DGBL. Anticipated findings from this study will provide insight into the potential benefits or drawbacks of using a DGBL approach for learning mathematics.

I understand that:

- participants will complete DreamBox Learning (DreamBox) lessons for a minimum of 60 minutes per week of the 5-week study.
- the intervention will be implemented during the last 15 minutes of each math class.
- the intervention <u>will not</u> affect participants' regular math instruction; <u>it will</u> provide them with additional math content and an alternative approach to math learning.
- it cannot be known how or if participants' grades in math will be affected; whether this has the potential to improve participants' math abilities is the point of the research study.

To support this proposed research, we have agreed to assist Dr. John G. Wells (Principal Investigator at Virginia Tech) and Valdez L. Mosley (graduate researcher) in the following ways to ensure the successful implementation of this research study:

- Allow the subject pool for this study to be drawn from sixth grade students enrolled at [redacted] who scored below the cut score on the Ratios and Proportional Relationships Pretest administered at the beginning of middle school.
- Allow potential subjects to be emailed digital packets that contain informed consent documents (parent consent, student assent, and data release consent form) providing details about the research study. Potential subjects will return the digital packets to their math teacher.
- Allow the recruitment of approximately 30 general education students (male/female) for participation in the study intervention during math class for 5 weeks during the 2020-2021 school year.
- Ask the [redacted] to provide de-identified Ratios and Proportional Relationships Test scores and associated demographics of participating students. No identifying student information will be associated with the data provided.
- Ask participating students to take a pre and post *Students' Perceptions of Digital Game-Based Learning Survey* about their experiences using the digital game-based approach for learning mathematics during math class.
- Allow the graduate researcher direct access to student reports from the DreamBox insight dashboard.
- Allow the graduate researcher to ask six participants interview questions regarding their perceptions of a digital game-based approach for learning mathematics.

The extent of involvement for [redacted] is limited to allowing advertising for and the recruitment of sixth grade students interested in participating in the research study. Participants will be informed that participation is voluntary and they may withdraw from this study at any time without penalty. They will also be informed that there is no promise or guarantee of benefits or compensation for participating in this study. Furthermore, it is understood that my granting permission to advertise does not in any way obligate students to participate. It is with this understanding that I support Dr. Wells and Mr. Mosley and look forward to working with them on this project. If you have any questions, please do not hesitate to call. I can be reached at [redacted].

Sincerely,

____ Date__________
Principal signature

____
Principal printed name

Appendix R.

Teacher Permission to Conduct Research

Dear Virginia Tech Institutional Review Board:

I would like to inform you of my support for the research proposal, *Learner Perceptions and Cognitive Outcomes of Digital Game-Based Learning in Mathematics*, submitted to [redacted]. The purpose of this research study is to: (a) determine whether or not DGBL is a viable tool in helping students to improve achievement in middle school mathematics and (b) gauge their perceptions regarding the use of DGBL. Anticipated findings from this study will provide insight into the potential benefits or drawbacks of using a DGBL approach for learning mathematics.

I understand that:

- participants will complete DreamBox Learning (DreamBox) lessons for a minimum of 60 minutes per week of the 5-week study.
- the intervention will be implemented during the last 15 minutes of each math class.
- the intervention will not affect participants' regular math instruction; it will provide them with additional math content and an alternative approach to math learning.
- it cannot be known how or if participants' grades in math will be affected; whether this has the potential to improve participants' math abilities is the point of the research study.

To support this proposed research, I have agreed to assist Dr. John G. Wells (Principal Investigator at Virginia Tech) and Valdez L. Mosley (graduate researcher) in the following ways to ensure the successful implementation of this research study:

- Email potential subjects digital packets that contain informed consent documents (parent consent, student assent, and data release consent form) providing details about the research study. Potential subjects will return the digital packets to me and I will give them to the graduate researcher.
- Allow the graduate researcher direct access to my student reports from the DreamBox insight dashboard.
- Fill out an *Implementation Fidelity Log* for the 5-week study.
- Have students spend a minimum of 60 minutes per week with DreamBox during math class for 5 weeks.
- Provide study participants with the link to the *Students' Perceptions of Digital Game-Based Learning Survey* (SPoDGBLS) about their experiences using the digital game-based approach for learning mathematics during the seventh week of the first marking period.
- Provide study participants with the link to the SPoDGBLS about their experiences using the digital game-based approach for learning mathematics during the third week of the second marking period.

The extent of my involvement is limited to providing all students, whether participating in the study or not, traditional math instruction and exposure to digital game-based learning opportunities. My students will be informed that participation is voluntary and they may withdraw from this study at any time without penalty. They will also be informed that there is no promise or guarantee of benefits or compensation for participating in this study. It is with this understanding that I support Dr. Wells and Mr. Mosley and look forward to working with them on this project. If you have any questions, please do not hesitate to call. I can be reached at [redacted].

Sincerely,

____ Date__________
Teacher signature

____
Teacher printed name

Appendix S.

Small Group Interview Protocol

Time of interview:

Date:

Place:

Interviewer:

Interviewees: Participant A (female) and Participant B (male)

Introductions and Purpose of the Research Project

- Hi – Good morning. I am Valdez Mosley, a doctoral candidate in the Integrative STEM Education program at Virginia Tech.
- In digital packets emailed to you and your parents, you were informed of the purpose, procedures, and requirements of the research study.
- You will recall that the purpose of the research study is to: (a) determine whether or not DGBL is a viable tool in helping students to improve achievement in middle school mathematics and (b) gauge their perceptions regarding the use of DGBL.
- I have received signed consent forms from your parent/guardian, saying that you can participate in this study and also a signed assent form from you indicating you agree to participate.
- I would like to thank you again for participating and also thank you for allowing me to interview you.
- This interview should take approximately 30 minutes. I will ask questions based on what you indicated on the Student's Perceptions of Digital Game-Base Learning Survey (SPoDGBLS). All identifying information or data collected from you today will be kept confidential and protected from unauthorized disclosure.
- The time is (specify the time), let's begin.

Interview Questions

1. **Question/Statement:** Tell me about your experience playing digital games.

   - Potential probes:

     a) Do you play digital games? (if yes) What types of digital games do you play? (if no) Instead of playing digital games, what activity would you rather do? If you had to play a digital game, what type would you play?

     b) On the SPoDGBLS you indicated liking/disliking/neither liking nor disliking (neutral) digital gaming. Can you explain more about your answer?

     c) You indicated that, compared to other students your age, you play a lot of/very little/neither a little nor a lot of (neutral) digital games. Can you explain more about how often you play digital games? How many hours would you say that you play them on a weekday? For example – a Monday. How about on a weekend day? For example – a Saturday.

     d) You described yourself as a gamer/non-gamer/neither a gamer nor a non-gamer (neutral). Can you explain more about why you put yourself in that category?

2. **Question/Statement:** What are some things that you find to be easy about using digital games in math class?

   - Potential probes:

     a) You indicated that you would know/not know/neither know nor not know (neutral) how to handle digital games in math class. Can you explain more about why you would feel this way?

     b) You indicated that it would be easy/difficult/neither easy nor difficult (neutral) for you to use digital games in math class. Can you explain more about why you feel this way? Do you feel that digital games are easy (or difficult) to start? Can you explain more about why you feel this way?

c) You indicated that your interaction with digital games in math class would be/would not be/neither would be nor would not be (neutral) clear and understandable. Can you explain more about why you feel this way? Do you think that they are easy (or difficult) to read? Can you explain more about why you feel this way?

d) Do you think that digital games are easy (or difficult) to understand? Can you explain more about why you feel this way?

e) Do you think that digital games are easy (or difficult) to navigate (i.e., figure out what to do)? Can you explain more about why you feel this way?

f) Do you think that digital games are easy (or difficult) to play? Can you explain more about why you feel this way?

3. **Question/Statement:** Please describe how digital game-based learning (DGBL) can provide you with different ways to learn?

- Potential probes:

  a) You indicated that DGBL offers/fails to provide/neither offers nor fails to provide (neutral) opportunities to experiment with knowledge. Can you explain more about why you feel this way? Do you feel that DGBL allows you to use what you already know to gain new knowledge? (yes/no) Can you explain more about why you feel this way?

  b) You indicated that DGBL offers/fails to provide/neither offers nor fails to provide (neutral) opportunities to take control over the learning process. Can you explain more about why you feel this way? Do you feel that DGBL allows you to be in control over your learning? (yes/no) Can you explain more about why you feel this way?

c) You indicated that DGBL offers/fails to provide/neither offers nor fails to provide (neutral) opportunities to experience things you learn about. Can you explain more about why you feel this way?

d) You indicated that DGBL offers/fails to provide/neither offers nor fails to provide (neutral) opportunities to transfer knowledge between various subjects. Can you explain more about why you feel this way?

e) You indicated that DGBL offers/fails to provide/neither offers nor fails to provide (neutral) opportunities to interact with other students. Can you explain more about why you feel this way? Do you feel that DGBL allows you to learn from other students? (yes/no) Can you explain more about why you feel this way?

f) You indicated that DGBL offers/fails to provide/neither offers nor fails to provide (neutral) opportunities to think critically. Can you explain more about why you feel this way?

g) You indicated that DGBL offers/fails to provide/neither offers nor fails to provide (neutral) opportunities to motivate students. Can you explain more about why you feel this way? Do you feel that DGBL can enhance learning motivation? (yes/no) Can you explain more about why you feel this way?

4. **Question/Statement:** What are the benefits of using digital games in math class?

- Potential probes:

a) You indicated that using digital games in math class would improve/not improve/neither improve nor not improve (neutral) your performance. Can you explain more about why you feel this way?

b) You indicated that using digital games in math class would increase/decrease/neither increase nor decrease (neutral) your learning productivity? Can you explain more about why you feel this way?

c) You indicated that using digital games in math class would increase/decrease/neither increase nor decrease (neutral) your effectiveness. Can you explain more about why you feel this way? Do you feel that using digital games in math class could help you reach your learning objectives and goals? (yes/no) Can you explain more about why you feel this way?

d) You indicated that using digital games in math class would help/hinder/neither help nor hinder (neutral) you to achieve better grades. Can you explain more about why you feel this way?

5. **Question/Statement:** Tell me about your preference for playing digital games in math class?

- Potential probes:

a) You indicated that, if you had a choice, you would choose/choose not/neither choose nor not choose (neutral) to take classes in which digital games are used. Can you explain more about why you would make that choice?

b) You indicated that, if you had to vote, you would vote in favor of/against/neither in favor of nor against (neutral) using digital games in math class. Can you explain more about why you would vote that way?

c) You indicated that you are excited/not excited/neither excited nor not excited (neutral) about using digital games in math class? Can you explain more about why you feel this way?

Conclusion and wrap up

- Before we wrap things up, are there any last comments or questions for me at this time?
- Thanks again for meeting with me today and allowing me to interview you.
- Remember all identifying information or data collected from you will be kept confidential and protected from unauthorized disclosure.
- The time is (specify the time), thank you so much for your time. Have a great day. Goodbye.

Appendix T.

Inter-rater Responses for Content Validation

Item	Expert #1	Expert #2	Expert #3	Number in agreement	Percent Agreement	Item CVI
1	X	X	X	3	100%	1.0
2	X	X	X	3	100%	1.0
3	X	X	X	3	100%	1.0
4	X	X	X	3	100%	1.0
5	X	X	X	3	100%	1.0
6	X	X	X	3	100%	1.0
7	X	X	X	3	100%	1.0
8	X	X	X	3	100%	1.0
9	X	X	X	3	100%	1.0
10	X	X	X	3	100%	1.0
11	X	X	X	3	100%	1.0
12	X	X	X	3	100%	1.0
13	X	X	X	3	100%	1.0
14	X	X	X	3	100%	1.0
15	X	X	X	3	100%	1.0
16	X	X	X	3	100%	1.0
17	X	X	X	3	100%	1.0
18	X	X	X	3	100%	1.0
19	X	X	X	3	100%	1.0
20	X	X	X	3	100%	1.0
21	X	X	X	3	100%	1.0
22	X	X	X	3	100%	1.0

Note: X indicates that the item content was accepted as valid, 0 indicates that it was rejected.

Appendix U.

Inter-rater Responses for Construct Validation

Item	Expert #1	Expert #2	Expert #3	Number in agreement	Percent Agreement	Item CVI
1	X	X	X	3	100%	1.0
2	X	X	X	3	100%	1.0
3	X	X	X	3	100%	1.0
4	X	X	X	3	100%	1.0
5	X	X	X	3	100%	1.0
6	X	X	X	3	100%	1.0
7	X	X	X	3	100%	1.0
8	X	X	X	3	100%	1.0
9	X	X	X	3	100%	1.0
10	X	X	X	3	100%	1.0
11	X	X	X	3	100%	1.0
12	X	X	X	3	100%	1.0
13	X	X	X	3	100%	1.0
14	X	X	X	3	100%	1.0
15	X	X	X	3	100%	1.0
16	X	X	X	3	100%	1.0
17	X	X	X	3	100%	1.0
18	X	X	X	3	100%	1.0
19	X	X	X	3	100%	1.0
20	X	X	X	3	100%	1.0
21	X	X	X	3	100%	1.0
22	X	X	X	3	100%	1.0

Note: X indicates that the item construct was accepted as valid, 0 indicates that it was rejected.