

Game Based Learning: The Effects of DragonBox 12+ on Algebraic Performance of  
Middle School Students

by

Pamela Sveitlana Gibbs

December 2020

Presented to the

Division of Science, Information Arts, and Technologies

University of Baltimore

In Partial Fulfillment

of the Requirements for the Degree of

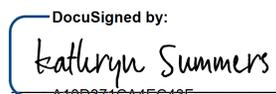
Doctor of Science

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## Abstract

Advancements in technology have increased so rapidly that calls for education reform centering on STEM have become louder and louder. Particularly, many researchers and educators are focusing on math, because of its pivotal role in STEM, and the low performance ratings of students within the United States. One of the potential reforms being assessed is digital game-based learning (DGBL), due to the increased popularity of videogames among children, and that learning through play has shown to contribute to the cognitive, physical, social, and emotional well-being of children (Ginsburg et al., 2007). The goal of this explanatory sequential mixed methods case study was to primarily understand if the DGBL intervention DragonBox 12+ affects student performance taking into consideration the factors of age and grade, while also measuring if a correlational relationship between a student's openness to technology and the duration of gameplay existed. Additionally, this study sought to assess teacher attitudes toward technology and gather their perspectives on DGBL. A sample of 11 students and 3 teachers participated in this research, which combined surveys, assessments, and contextual interviews to gather and measure data. Results of the Shapiro-Wilks test regarding age ( $p\text{-value} = .0108 < .05 = \alpha$ ) and grade ( $p\text{-value} = .0108 < .05 = \alpha$ ) were inclusive, due to the rejection of the null hypothesis that indicates sample normality. Results of the Wilcoxon Signed Rank Test regarding performance after exposure as determined by posttest assessment scores ( $M_{post} = .83$ ,  $SD_{post} = .12$ ) and pretest assessment scores ( $M_{pre} = .76$ ,  $SD_{pre} = .13$ ), ( $W(9) = 17$ ,  $p > .05$ ) were found to not be statistically significant, thereby indicating the intervention did not have an effect on performance. Results of the Attitudes Toward Math Learning Questionnaire (ATMLQ) and follow-up in-depth interview uncovered that students were open to technology and saw the benefit of DGBL to enhance learning, irrespective of whether they considered them fun. Analysis of data collected from teachers shed light on the factors such as competing priorities and requirements, time constraints, no formalized vetting process, and lack of training and/or support, that often prevent them from leveraging DGBL.

“Expand!  
You are not small.  
Your Foremothers did not do what they did so you could occupy small!”  
— **Malebo Sephodi**

Dedicated to  
the faith that sustains me,  
my husband who loves me,  
my children that inspire me,  
and the matriarchs that raised me.  
**DREAM. BIG. ALWAYS.**

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To my tribe of girlfriends who are the embodiments of magic, who remind me that you cannot pour from an empty cup, who pray with, celebrate and check me;

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## Table of Contents

List of Tables .....	iii
List of Figures .....	iv
Chapter 1: Introduction .....	5
The Rise of Videogames .....	5
Problem Statement .....	6
Purpose .....	8
Research Questions .....	8
Definition of Terms .....	9
Conclusion .....	10
Chapter 2: Literary Review .....	11
Understanding What Goes into Learning .....	11
Learning Theories .....	11
Digital Natives .....	24
Measuring Learning .....	27
When DGBL is Effective .....	40
When DGBL is Ineffective .....	49
Young Children .....	56
Conclusion .....	58
Chapter 3: Methodology .....	60
Structuring DGBL Research Study .....	60
Participants .....	62
Research Design .....	65
Setting .....	69
Sampling Procedure .....	70
Recruiting Participants .....	71
Intervention: The DragonBox 12+ application .....	72
Data Collection Instruments .....	74
Validity Check .....	78
Researcher's Position .....	79
Research Plan Analysis .....	79
Chapter 4: Results .....	81
Results of DGBL Study .....	81
Sample Analysis .....	81
Student Demographics .....	82
Student Performance .....	92
Attitudes to Technology in Mathematics Learning Questionnaire (ATMLQ) .....	96

Student In-Depth Interviews .....	100
Teacher Survey Results.....	114
Teacher In-Depth Interview .....	117
Conclusion .....	123
Chapter 5: Conclusion.....	125
Reforming Math for the Future.....	125
Outcomes of Research .....	127
Limitations and Considerations .....	134
Final Thoughts and Discussion.....	135
References.....	138
Appendix A: Student Participant Letter.....	152
Appendix B: Student Participant Flyer .....	153
Appendix C: University of Baltimore Student Consent Form.....	154
Appendix D: University of Baltimore Teacher Consent Form.....	158
Appendix E: Student Demographic Questionnaire.....	161
Appendix F: Student Assessment Pretest .....	164
Appendix G: Student Assessment Posttest .....	166
Appendix H: Student Assessment Pretest Answer Key.....	167
Appendix I: Student Assessment Posttest Answer Key.....	169
Appendix J: Attitudes to Technology in Mathematics Learning Questionnaire.....	170
Appendix K: Student In-Depth Interview Questionnaire .....	172
Appendix L: Teacher Survey .....	173
Appendix M: Teacher In-Depth Interview Questionnaire .....	176
Appendix N: Attitudes to Technology in Mathematics Learning Questionnaire Results .....	177
Appendix O: Wilcoxon Signed-Ranks Test Table.....	180
Appendix P: Wilcoxon Signed-Ranks Test .....	181

## List of Tables

Table 1 Student Age Descriptive Statistics t-Test .....	83
Table 2 Student Grade Descriptive Statistics t-Test .....	85
Table 3 Average Cost of Student Games .....	90
Table 4 List of Games Played by Students .....	91
Table 5 Platforms Used to Play Videogames .....	92
Table 6 Student Pre-Posttest Assessment Scores.....	93
Table 7 t-Test: Paired Two Sample for Means: Pre-Post Test Assessment.....	95
Table 8 Correlation Analysis: ATMLQ and Time Spent Playing Intervention.....	100

## List of Figures

Figure 1. Graph: Student participant age breakdown .....	83
Figure 2. Graph: Distribution of student participant age .....	83
Figure 3. Graph: Student participant grade breakdown .....	84
Figure 4. Graph: Distribution of student participant grade.....	85
Figure 5. Graph: Student participant racial demographic breakdown .....	86
Figure 6. Graph: Student participant gender breakdown .....	86
Figure 7. Graph: Student participants hours per day play .....	87
Figure 8. Graph: Student participant rate of play by gender.....	88
Figure 9. Graph: Student participants rate of play .....	88
Figure 10. Graph: Breakdown of student performance by percentage .....	93
Figure 11. Graph: Student pre-post assessment performance.....	93
Figure 12. Graph: Dimension 1 - Student confidence when learning math.....	97
Figure 13. Graph: Dimension 2 - Student confidence when using digital games and technology.....	98
Figure 14. Graph: Dimension 2 - Student confidence when using DGBL and applications as a medium to learn and understand mathematics.....	98

## Chapter 1: Introduction

### **The Rise of Videogames**

According to Tech Crunch magazine, though adults continue to make up a large part of the game playing community, there is an increasing popularity amongst children. According to a 2011 study conducted by the market research group NPD, 91 percent of U.S. children between the ages of 2-17 play video games, which amounts to a whopping 64 million in total. This growth was mainly attributed to the rise of digital games being made available on ubiquitous devices, particularly mobile devices. In fact, in 2009 it was found that eight percent of children within the 2-17 age range were playing games on mobile devices (Coldewey, 2011). Considering these statistics, the increased popularity of videogames among children, and the fact learning through game play “is an essential part of childhood and healthy brain development, because it contributes to the cognitive, physical, social, and emotional well-being of children” (Ginsburg et al., 2007), it comes as no surprise the growing calls to find a way to incorporate digital game play into education. Frequently-cited arguments held by researchers for using digital games in education are: “(a) computer games can invoke intense engagement in learners (Malone, 1981; Rieber, 1996) (b) computer games can encourage active learning or learning by doing (Garris, Ahlers, & Driskell, 2002) (c) empirical evidence exists that games can be effective tools for enhancing learning and understanding of complex subject matter (Ricci, Salas, & Cannon-Bowers, 1996), and (d) computer games can foster collaboration among learners (Kaptelin & Cole, 2002)” (Ke, 2008). Ultimately as discovered by researchers Lev Vygotsky and Jean Piaget, play is essential to the development and maintenance of the human psyche, irrespective of whether the player recognizes it or not, thereby DGBL use this as a way to further learning (Galarza, 2019),

On the other hand, there are those that question DGBL’s effectiveness due to a lack of evidence that establishes a causal relationship between academic performance and the use of such games for the purposes of learning. Among these arguments are concerns

that such technologies introduced into the classroom may not be effective for all students, serve as a distraction, and ultimately may not create the learning intended due to the fact that they are created for the purposes of learning and not for the purposes of fun, by which learning happens as a byproduct and not as a requirement (Ke, 2008). Despite this, the continual improvement of ubiquitous technologies which make digital gaming more accessible, the increased use of digital games by children, the need to increase student engagement in learning and the growing research that shows positive effect of digital gaming in learning show that research in this area is indeed necessary.

### **Problem Statement**

As it currently stands, the United States ranks 31st in math on the Programme for International Student Assessment (PISA) (FactsMaps, 2018), a cross-national test that measures reading ability, math and science literacy and other key skills amongst 15-year-olds in 71 developed and developing countries (DeSilver, 2017). An article in US News regarding the state of math in US cited that the "U.S. Department of Education released the results from the 2017 National Assessment of Educational Progress (NAEP)," of which "only 33 percent of eighth-graders tested proficient in math at grade level" (Venezky, 2018). The issue according to Andreas Schleicher, the director of education and skills at the Organization for Economic Co-operation and Development (OECD), pertains to the manner in which math is taught in the United States - breadth, not depth. He cites that U.S. students are often good at answering the first layer of a problem, but as soon as they have to go deeper and answer the more complex part of a problem, they have difficulties." Countries that rank higher than the U.S. tend to teach fewer subjects but go much deeper, thus increasing the chances of greater retention and the ability to apply their knowledge in multiple ways (Venezky, 2018). And if you consider students within the low-income urban area demographic, these statistics become worse.

Even more alarming is that according to Pew Research Center report, only 29% of Americans rated their country's K-12 education in science, technology, engineering and mathematics (known as STEM) as above average or the best in the world while most

“Americans rank math as one of the most important skills children need today to get ahead” (Cary Funk & Rainie, 2015). Middle school is particularly important because this is the time when students are officially introduced to and learn Algebra. “Algebra is one of the few major domains of mathematics that students’ study from preschool to twelfth grade” (GreatSchools Staff, 2018). Furthermore, it is not only considered to be “a gatekeeper to higher-level math (geometry, algebra II, trigonometry, and calculus),” but multiple researchers have found that students who take more high-quality math in high school are more likely to declare STEM majors in college (GreatSchools Staff, 2018). “Students who struggle with algebra very often develop low self-esteem in regard to math (and often – crucially – with themselves as a whole), which makes it very difficult to turn things around” (Venezky, 2018).

Numbers like these have caused educators and researchers alike to look for alternative ways to educate children while increasing their interest in math. One such alternative, is utilizing videogames as a medium of learning for several reasons. First, research has shown that play, is a very important component of learning regarding children (Plass et al., 2015). Second, when play is coupled with a physical objects, otherwise referred to as "objects-to think-with" this serves to further encourage learning (Kablan, 2016). Third, and most important, number of students playing videogames is steadily increasing. The previously mentioned study conducted by the market research group NPD, stated that 91 percent or 64 million U.S. children between the ages of 2-17 play video games. Considering that these numbers were up by 13 percent from a previous study conducted in 2009, it is safe to assume that these numbers have not only increased but have done so at an alarming rate. The report attributed this exponential growth to children being able to play videogames on ubiquitous devices, particularly mobile devices (Coldewey, 2011). Additionally, a Teens, Technology, and Friendship study conducted by the Pew Research Institute (2015) to determined that 72% of teens ages 13 to 17 play video games on a computer, game console or portable device and use these

games as a way to establish relationships, spend time and engage in day to-day interactions with their peers and friends (Lenhart et al., 2015).

Though utilizing play for the purposes of learning is nothing new, the explosion of ubiquitous technologies, alarming state of the United States' math ranking and the ever-increasing popularity of videogames amongst children, has made calls for research into incorporating these games into learning curriculum, particularly math grows louder. Thus, for all these aforementioned reasons, an explanatory sequential mixed methods case study utilizing the game DragonBox 12+ to see its effect on middle school student Algebra performance is proposed.

### **Purpose**

The purpose of this research is to examine the effect of incorporating digital gaming, such as DragonBox12+ into Algebra 1 classrooms on student learning. The study utilizes an explanatory sequential mixed methods case study design with a total of 11 student participants, comprised of 7th, 8th, and 9th graders enrolled within the various schools throughout Northwest Arkansas and two teacher participants at Thaden School, a private middle and high school in Northwest Arkansas. Students ranged in socioeconomic status, race, gender, and math proficiency. Quantitative data was collected using three instruments: demographics, Attitudes to Technology in Mathematics Learning Questionnaire (ATMLQ), and interview questions for both students and teachers. Quantitative data was collected through the use of pre-posttest assessments created via participatory design by the teachers, for the purposes of measuring the differences in performance before and after exposure to the intervention. The central phenomena being explored is whether there is a need to modify the way learning for math in particular is carried out, to match the social and societal changes that exist outside of the classroom.

### **Research Questions**

The study seeks to find the understand and answer the following questions:

**RQ<sub>1</sub>:** Is there a significant difference in the performance of students as determined by pre-post-test scores after being exposed to the gaming intervention?

**RQ<sub>2</sub>:** Is there is a significant difference in the performance of students based upon age, as determined by pre-post-test scores?

**RQ<sub>3</sub>:** Is there a significant difference in the performance of students based on their grade as determined by pre-post-test scores?

**RQ<sub>4</sub>:** When introducing a serious game intervention, is there a correlational relationship between a student's openness to technology as determined by the Attitudes toward Math Learning Questionnaire and the amount of time students spend playing the serious game?

### **Definition of Terms**

Several key terms are used throughout the study. Their definitions follow:

**Digital game-based learning (DGBL):** DGBL refers to a game that was created for the purposes of learning, accessed via a digital medium which could be a mobile phone, tablet, video game console, or computer. Will be used interchangeably with serious games.

**Digital natives:** Are first generation K-12 students that have grown up with their lives entirely immersed in using some sort of digital device - computers, videogames, music devices, email, television, cell phones, or other toys and tools of the digital era (Prensky, 2001).

**Edutainment:** Computer based instruction designed to motivate via the game characteristics competition and goals, rules, challenging activities, choices, and fantasy elements. Were once considered the savior of education because of their ability to simultaneously entertain and educate. They teach the predetermined content, usually lower order thinking skills, extremely well and make little or no attempt at trying to teach gamers how to apply their knowledge, analyze their

understanding, synthesize their perceptions, or evaluate their learning (Charsky, 2010).

**Serious games:** Games that are focused on developing higher order thinking skills and knowledge of their players, however, they are designed to look more like commercial videogames. The educational aspect is implicit in the gameplay, rather than an explicit component as found in educational games (Charsky, 2010).

### **Conclusion**

Technology has transformed the way in which we live and operate in world. Thus, it should come as no surprise that calls for reforming education to match this change continue to grow louder and louder. In order to not only keep up with the times but remain competitive as the reliance on STEM related disciplines, education and careers, continue to grow exponentially, the United States must address the glaring disparities that exist when it comes to teaching math. The traditional methods of regurgitation, a teacher at a chalkboard while students take copious notes, complete practice problems followed by an assessment in the age of technology is no longer sustainable. And though there is no one size fits all answer, because reforming how math is taught is both complex as it is nuanced, an exploration of alternatives such as utilizing gaming for the purposes of learning have proven to have great potential and should be taken into serious consideration.

## Chapter 2: Literary Review

### **Understanding What Goes into Learning**

The use of play for the purposes of learning and development is by no means a new phenomenon. “Play is essential to development because it contributes to the cognitive, physical, social, and emotional well-being of children and youth. It encourages children to use their creativity while developing their imagination, dexterity, and physical, cognitive, and emotional strength,” while also being essential for the development of a healthy brain (Ginsburg et al., 2007). Furthermore, play helps to activate a child’s schemas in ways that allow for the transcendence of their immediate reality and ultimately symbolic thinking (Plass et al., 2015). Couple this with the pervasiveness of technology within our everyday lives, the constant ability to be digitally connected, the popularity of videogames as a form of entertainment and the growth of ubiquitous devices, emerges the school of thought that believes technology if properly harnessed has the power to transform learning. This has given rise to a growing field of research dedicated to understand whether or not videogames created for educational purposes - digital game based learning (DGBL) or serious games, affect, encourage, and foster learning (Plass et al., 2013). Though there is a growing body evidence that refutes the viability of DGBL, upon analyzing the learning theories of cognitivism, constructivism, and constructionism, the rise of digital natives, how learning is measured, followed by when DGBL is deemed effective and ineffective, it is clear that when properly implemented serious games have the potential to encourage learning.

### **Learning Theories**

Many theorists and philosophers have paved the way for how learning is understood, represented, and classified. Because digital-game based learning pulls aspects from these different factions of learning pedagogy - cognitivism, constructivism and constructionism, their unique perspectives regarding how learning is transferred and acquired may often times be conflated with one another despite them being different.

## Game Based Learning: Literary Review

**Cognitivism.** In the late 1950s, psychologists and educators began to shift their focus from a behavioral orientation - where the emphasis relies on observable responses resulting from stimulus - to more complex mental processes such as thinking, problem solving, language, concept formation and information processing which fall under cognitivism (Ertmer & Newby, 2013). Cognitivism is built off of the perspective that learning is associated with incremental changes between states of knowledge. It relies on mental activities that lead up to a response and recognizes “the roles that mental planning, goal-setting, and organizational strategies play” (Ertmer & Newby, 2013). This is because unlike behaviorists who believe that if something is not observable, it does not exist, cognitivists believe that the mind is a black box, which should be opened and understood. This theory focuses on the conceptualization of learning processes and addresses the issues of how information is received, organized, stored, and retrieved by the mind (Ertmer & Newby, 2013; Jonassen, 1991), thus it is often the theory deemed appropriate for explaining complex forms of learning such as reasoning, problem-solving, information-processing (Schunk, 2012). Cognitivism is based on two main assumptions - first that the memory system is an active, organized processor of information and second, that prior knowledge plays an important role in learning (Wu et al., 2012). To get a better understanding of this theory, one must understand the roles that attention, memory, and motivation play within the framework.

**Attention.** Attention is considered the first step in the learning process, because understanding, remembering and learning cannot be started without it being initiated (Thorne & Thomas, 2009). Attention allows humans to monitor interactions with the environment, link past (memories) situations with the present (sensations) to provide a sense of continuity of experience and helps with the control and planning for future actions. At any given moment, there are a multitude of stimuli vying to gain our attention; however, it is impossible to attend to them all. Thus attention in essence acts as a filtration system that allows for us to passively or actively process limited amounts of information from the massive amounts of information that comes through our senses,

## Game Based Learning: Literary Review

memories, and cognitive processes (Sternberg & Mio, 2008). Passive attention is unintentionally activated by events outside of our control that stand out from their environment, such as bright flashing lights, strong odors, or unexpected loud noises. Whilst active attention is intentional, involves effort and directed by alertness, concentration, interest and/or needs such as curiosity and hunger (Gaddes & Edgell, 1994). By dimming the lights (selectivity) on many stimuli from outside (sensations) and inside (thoughts and memories), certain stimuli that interest us (saliency determination) can be highlighted (Sternberg & Mio, 2008; Thorne & Thomas, 2009). This heightened awareness or alertness increases the likelihood of how quickly and accurately a response is created as a result of arousal, which jump starts the memory processes because we are more likely to remember information we paid attention to rather than information we ignored (Sternberg & Mio, 2008; Thorne & Thomas, 2009). The limit that attention places on the amount of information that humans process serves as a way to prevent cognitive load, which happens when the level of stimulus becomes too much, resulting in attention being divided and overwhelmed, thereby reducing the ability to focus and learn. Techniques such as providing strong cues, standardization and simplification eliminate the processing of unnecessary information thereby reducing cognitive load and expediting knowledge transfer (Ertmer & Newby, 2013; Schunk, 2012; Xie et al., 2017).

*Memory.* Aside from the important part attention plays, is the role of memory, which has broader implications for learning. Memory consists of three parts - sensory memory, working memory, long-term memory - that work in tandem to result in learning. As humans, we are confronted with an infinite amount of information on a regular basis; **sensory memory** filters out non-pertinent information, while storing the remaining information just long enough to be processed in working memory. **Working memory**, then takes this information and either organizes it in chunks in order to prevent cognitive load or discards of it. **Cognitive load** refers to the amount of information that working memory, due to limited capacity can maintain at the same time (Sweller, 1988). Additionally, to prevent the senses from being overwhelmed, it is important to have

## Game Based Learning: Literary Review

information enter through multiple channels, such as auditory, visual, and or touch. The more channels engaged, the higher the likelihood that the information will be remembered. The information that remains within working memory is eventually committed to **long-term memory**, where it is stored, organized into categories (chunked), and transformed into knowledge. To cognitivists, this process by which the knowledge process represents how schemas or symbolic mental constructions are developed (Cooper, 1993; Ertmer & Newby, 2013). This process and development of a schema is what is defined as learning; no longer are learners' passive as behaviorist suggest, instead they actively acquire knowledge through a variety of different modalities - text, pictures, sounds, experiences (Ulcsak & Wright, 2011). In other words, knowledge transfer occurs when learners receive new or existing information, ingest it, relate it to ideas or concepts they are familiar with, interpret it in a meaningful way, and store it in their memory for later retrieval. These **schemas** help to automate certain actions, and guide decisions that either attempt to identify the similarities and differences of novel information or maximize pleasure and avoid/minimize pain when dealing with things that are risky or have uncertain prospects probabilities. Based upon prior knowledge or schemas, humans are able to assess the present and in doing so assign weightings of utility (value) (Sternberg & Mio, 2008). Each of these interactions are based on schemas that are then evaluated and the relative costs and benefits of adopting each strategy are weighed prior to a decision being made (Leahey & Harris, 2000). As a result, people are able to analyze problems, filter out things that do not pertain to their goals, apply past learning, make observations, and create a hypothesis which they continuously test. This testing not only results in a modification of their behavior, but also which strategies they employ to achieve desired outcomes. This function is incredibly important because learning cannot occur if the information/schema that is stored in the memory is not organized in a meaningful manner that can be retrieved or built upon request. **Forgetting**, is one of those things that negatively affects memory which is the inability to retrieve information due to interference, memory loss, or missing

## Game Based Learning: Literary Review

or inadequate cues needed to access information interferes with not only memory and utility, but ultimately learning. (Mayer, 2009).

**Motivation.** Attention and memory are indeed important factors, however the thing that encourages and maintains them is motivation. According to the book, *Psychology: Concepts and Applications*, "the term motivation refers to factors that activate, direct, and sustain goal-directed behavior. Motives are the 'whys' of behavior - the needs or wants that drive behavior and explain what we do. We don't actually observe a motive; rather, we infer that one exists based on the behavior we observe" (Nevid, 2013). Motivation is typically classified as either extrinsic or intrinsic and comprises of three main components - activation, persistence, and intensity. **Extrinsic motivations** are those that come from external sources and often involve rewards such as trophies, money, social recognition, and/or praise. **Intrinsic motivations** arise from within, such as doing a complicated task purely for the personal gratification of solving a problem or personal achievement (Nevid, 2013). Each of these aforementioned motivations have an effect on attribution theory. **Attribution** or the idea that every individual explains success or failure of self and others by offering certain designations, which are either internal, external, under control, or not under control affects the level of persistence. The higher the level of intrinsic motivation, the more the control someone feels, thus increased internal attribution. The higher the extrinsic motivation, the less control, thus requiring higher external motivation (Huitt, 2011). The **activation** component of motivation deals with the decision to initiate a behavior, such as deciding to play a particular game or pursue a particular career. **Persistence** is the continued commitment toward achieving a particular goal, regardless of obstacles may occur such as working through a problem even when the solution is unknown. The last of these components, **intensity**, is the level of concentration and vigor that one places into pursuing a goal. If the level of intensity is high, goals are pursued with vigilance, as opposed to when it is low.

The combined factors of attention and motivation create a state which is reoffered to as flow. **Flow** is a phenomenon that was coined by Mihály Csíkszentmihályi, which is

## Game Based Learning: Literary Review

a mental state of enjoyment where in a person becomes fully immersed and absorbed by performing an activity so much so that they lose focus of space and time. According to Csíkszentmihályi, “One cannot enjoy doing the same thing at the same level for long. We grow either bored or frustrated; and then the desire to enjoy ourselves again pushes us to stretch our skills or to discover new opportunities for using them” (Csíkszentmihályi, 2008). To better understand how flow takes place, the following nine things must occur:

1. Having clear and concise goals throughout the entire process;
2. Feedback is frequent and within the context of the situation;
3. There is a balance between the level of challenge and the level of skill – too little challenge results in boredom, too much results in frustration;
4. Concentration to the point that action and awareness merge – attention is fully focused on task at hand, ignoring irrelevant information;
5. The idea of control shifts from the fear of losing control to the sense of exercising control, which brings about calmness;
6. Losing one’s consciousness and the tendency to overthink; instead actions becomes automatic;
7. Experiencing the feeling of disappearance, due to getting lost one’s the actions;
8. Losing awareness of time and space;
9. Becoming autotelic, where in the goal becomes the experience (Csíkszentmihályi, 2008).

Cognitivism was founded upon experiments which are regarded to be scientifically sound and because of the heavy focus on mental structures, it is usually considered the more appropriate theory for explaining complex forms of learning such as reasoning, problem-solving, information-processing (Schunk, 1991). However, its main problem also serves as its advantage, in the fact that it deals with things unseen and unmeasurable, which makes it difficult to rely on anything other than inference. In 1974, a study was conducted by Loftus and Palmer to determine how accurately humans

## Game Based Learning: Literary Review

remember complex situations such as a car accident. In this study, they asked participants how fast the car was going, utilizing word manipulation - smashed, collided, bumped, contacted, and hit - and the question of whether there was broken glass. What they found was that based upon the verbiage used, memory can be extremely subjective and can potentially lead to self-fulfilling prophecies and internal validity issues (Loftus & Palmer, 1974). Another weakness of cognitivism is that it ignores how factors such as morals, genealogy, environment and upbringing can affect behavior. In a study conducted by Palmer and Hollins' to compare moral reasoning between male criminals and non-criminal male and females, it was determined that a difference in thinking pattern existed between those that were criminals and those that were not. Those that were classified as criminal, were more likely to feel rejected by their parents, particularly their fathers, and had less developed moral reasoning than their non-criminal counterparts. Thus results of this study suggest that moral reasoning can affect behavior (Palmer & Hollin, 2001). In 1993, a study by Brunner et al. determined that mutations in genetics can affect behavior and predispose some to displaying aggressive or violent behavior (Brunner et al., 1993). In 2001, Juby and Farrington conducted a study to determine the effects of environment on one's behavior and found that those from disrupted homes had higher delinquency rates than those from intact homes (Juby & Farrington, 2001).

**Constructivism.** Traditional didactic methods of teaching are the recognized and customary way of imparting knowledge. These methods involve transferring knowledge from the teacher to the student, just as it was earlier transferred to the teacher when they were being taught. Viewing learning this way is necessary if knowledge is objectivist, foundational and absolute (Harasim, 2012). However, a number of researchers have started to move away from this objectivist approach and understand that knowledge is essentially "situated" and therefore should not be separate from the situations in which it is constructed and actualized. This rising interest in situated knowledge or knowledge with regard to context, has led many researchers to closely examine the way individuals come to knowing, or relating. Consistent with this approach, other researchers have

## Game Based Learning: Literary Review

transferred their focus from the “study of general stages of human cognitive development to the study of individual or culturally related learning styles, and/or context dependent developmental paths” (Ackermann, 2001). That being said, constructivism by large is not a completely new approach to learning, rather it pulls from the philosophical and psychological viewpoints of theories that came before it and more specifically work done by Piaget, Vygotsky, and Bruner (Perkins, 1991).

Piaget who first to coin the term constructivism believed that cognitive development depended on several factors, with the first of which being biological maturation. Biological maturation according to Piaget is the fixed sequence of stages that children must go through in order to learn: sensorimotor (Birth to 2), preoperational (2 to 7), concrete operational (7 to 11), and formal operational (11 to adult). In other words, all human beings are born with basic mental structures, which evolve and become more complex as a child grows and passes through a succession of biological stages. Each experience they have within these stages is used as the basis or schema from which they build their new set of skills, determine how they sees the world and interpret future interactions or experience until they reach maturation (Schunk, 2012). In addition to this are the factors of experience with the physical environment, experience with the social environment, and equilibration. **Equilibrium** is defined as the biological drive to produce an optimal state of balance or adaptation between cognitive structures and the environment. This equilibrium or balance can either be gained through assimilation which refers to making the external reality fit with existing cognitive structures or accommodation, which allows for internal structures to be changed to provide consistency with external reality. Aside from Piaget, Vygotsky contributed three major themes to constructivism-social interaction, the more knowledgeable other, and the zone of proximal development. He believed that knowledge was constructed between two or more people, thus **social interactions** are imperative. And as a result of these social interactions, internalization or the regulating one’s actions and mental operations happen. He further suggests that learning occurs through the cultural transmission of tools, such

## Game Based Learning: Literary Review

as language (the most critical tool) and symbols and the zone of proximal development (ZPD). The **zone of proximal development** refers to the difference between what is done when alone versus the assistance from others; thus, interactions with others (more experienced or adults) promotes cognitive development (Schunk, 2012). In terms of Bruner's contribution to constructivism, there is an emphasis on how people interpret their world through the lens of similarities and differences between objects and events. Under this prism, learners compare new ideas they encounter with existing ones, and learn through the similarities and differences that emerge. Additionally, socio-cultural background and situation play very important roles in determining the type of information that a person will accept, learn, and use to build their schemas (Pagán, 2006). Lastly, although he never used the term constructivism, Dewey's understanding of the transaction between organism (human) and environment can be considered as a form of the construction processes that underlie all human activity. In this regard, knowledge is formed as a result of the relationship between the activities of the organism and the consequences these activities bring about (Vanderstraeten, 2002).

Strictly speaking, constructivism is not a theory, it is an epistemology or philosophical explanation about the nature of learning. Theories allow for hypotheses to be generated and tested; however, constructivists reject the notion that scientific truths exist and await discovery and verification. They argue that no statement can be assumed as true instead they should be viewed with reasonable doubt. The world can be mentally constructed in many different ways, so no theory has a lock on the truth. Rather than viewing knowledge as truth, they construe it as a working hypothesis. This is because constructivists unlike cognitive psychologists believe that the mind is a reference tool to the real world, view the mind as a tool that filters input from the world to produce its own unique reality. Thus, constructivism is more of an epistemology or philosophical explanation about the nature of learning, rather than a theory. As with the rationalists during the time of Plato, constructivists view the mind as the source of all meaning; however, like the empiricists they also believe that individual, direct experiences with the

## Game Based Learning: Literary Review

environment are considered critical. Constructivism does not share the belief cognitivists and behaviorists hold that knowledge is mind-independent and can be put onto a learner. Instead they incorporate that the real world exists and what we know of the world derives from our own interpretations of our personal experiences (Ertmer & Newby, 2013). A key assumption of constructivism is that people are active learners and develop knowledge for themselves (Geary, 1995). Humans construct learning from personal interpretations of the world based on personal experiences and interactions rather than acquiring them. Knowledge is not imposed from outside people but formed inside them, thus one person's constructions are true to that person but not necessarily to anyone else because people produce knowledge based on their own beliefs, culture and experiences in situations (Cobb & Bowers, 1999). All knowledge then is subjective and personal and a product of our cognitions (Simpson, 2002). Learning is situated in contexts (Bredo, 2006). Another constructivist assumption is that teachers should not teach in the traditional sense of delivering instruction to a group of students. Rather, they should structure situations such that learners become actively involved with content through manipulation of materials and social interaction. Students are encouraged be self-regulated and take active roles in their learning by setting goals, monitoring and evaluating progress, and going beyond basic requirements by exploring interests (Bruning et al., 2004; Geary, 1995). An example of this can be seen through the use of videogames, where learning is an interpretive and social experience that arises from player interaction with others, with the system, or with texts. The meaning making process that players go through affords them the ability to learn and adjust not only their behavior and approach but also their ways of interpretation. Thus, "games and gamified applications utilize game models and design methods to allow players to become active participants of the experience and consequently influence interpretations and behavior" (Tanes, 2016).

Though this school of thought provides interesting perspectives on learning, implementation may sometimes be problematic for the very reason it is regarded as great

## Game Based Learning: Literary Review

- experience is infinite, context based, and subject to constant change (Ertmer & Newby, 2013). These experiences are based on our explorations, inquiries, assessments and negotiating what we know with others, thus it is impossible to achieve a predetermined, appropriate meaning (Harasim, 2012). Moreover, because behavior is heavily reliant on situations, memory is not independent of context; every action is viewed as an interpretation of the present situation based on the history of previous actions. Knowledge no longer serves as a prepackaged schema, but as a flexible reference point. Learning becomes indirect and these reference points within the memory that are developed through action and engagement, especially if the environment is similar or the same, tend to increase the likelihood of efficiency with which successive tasks are performed (Ertmer & Newby, 2013). Furthermore, constructivism is a descriptive theory where in it provides an explanation of how learners come to know and understand but does not provide what should be learned or how to go about helping learners construct this knowledge (Draper, 2002). Therefore, the individual voices regardless of expertise become more important than those with the appropriate knowledge. In this world beliefs, opinions and preferences rather than argued reasoned judgements become paramount (McPhail, 2016). Learning then becomes a matter of credit collection rather than developing an identity. “And even though constructivism is typically practiced throughout college and within gaming, for most people learning something new, research shows that “direct, explicit instruction is more effective and more efficient than partial guidance” (McPhail, 2016). In fact, the most effective way to teach novice learners is through the worked example, where a step-by-step demonstration of how to complete a task or solve a problem is done. It is also suggested that though small groups and independent problems and projects can be effective as ways to practice recently learned skills and content, they are not the vehicles for making discoveries (Clark et al., 2012). Thus, limited guidance at the wrong time propelled by the mistaken assumption that learners are properly equipped to make sense of new information can be problematic. In fact, “the greatest problem for education occurs where an individualized form of

## Game Based Learning: Literary Review

psychological constructivism is accepted as a means to knowledge production: where an individual's construction of the world is deemed to be how the world is. In this situation epistemology is confused with ontology in that 'social construction is extended from knowledge to reality'" (McPhail, 2016).

**Constructionism.** Constructionism is very similar to constructivism in that it derives from the theory however, it plays a different role in learning and instruction. Though the term constructionism was never formally used in Dewey's definition, his understanding of the transaction between organism (human) and environment is considered to be the base the constructionism framework. In this regard, knowledge is formed as a result of the relationship between the activities of the organism and the consequences these activities bring about (Vanderstraeten, 2002). According to him, learning is only effective when it is a social and interactive process where students are actively participating and creating their own learning. Seymour Papert, a student of and greatly influenced by Piaget and Dewey pointed out in his *Mindstorms: Children, Computers, and Powerful Ideas* (1980) book, "the N Word as opposed to the V word - shares Constructivism's connotation to learning as building knowledge structures irrespective of the circumstances of learning. It then adds the idea that this happens especially felicitously in a context where the learner is consciously engaged in constructing a public entity whether it's a sand castle on the beach or a theory of the universe that can be shared with others" (Papert, 1980). In other words, under constructionism, knowledge is not merely a commodity to be transferred, coded, remembered, and re-applied, rather it is an individual experience to be constructed. As with Dewey, Papert further believed that the world does not exist waiting to be revealed, instead it gets increasingly transformed through the personal experience, thus individuals as the creators of their own cognitive tools and external realities based on the situations and interactions they experience.

The main difference however focuses on the dynamics of change rather than internal stability as constructivism suggests. For constructionist being smart means being

## Game Based Learning: Literary Review

situated, connected, and understanding the variations in the environment then sharing knowledge to others. It is built upon the belief that the best learning occurs when learners seek for themselves the particular knowledge they require. This is because when complex issues arise learners are encouraged and motivated to problem solve, thereby learn as they construct. Furthermore, it extends the “idea of manipulative materials to the idea that learning is most effective when part of an activity the learner experiences as constructing is a meaningful product” (Papert, 1980). Additionally constructionism takes up John Dewey's idea that the ability to make mistakes is a requirement to learning, where in learning takes place via trial and error (Fino, 2017). In his book *Play and Work in the Curriculum*, he explains that there is this desire to choose material and applications that eliminate mistakes, restricts initiative, reduces judgment to a minimum, and compels using methods so divergent from the complex situations that occur in real life (Dewey, 2001; Fino, 2017). Thus, an unexpected response is not seen as a bad thing or failure, but a positive step in the desired direction. Thus learners are encouraged to think about why the unexpected result occurred; thus, unexpected results and debugging become accepted as important and useful steps in the learning process and are tested and modified until they are deemed appropriate (Fino, 2017). This encouragement of debugging and constructing is part of the reason why technology is often associated with constructionism. However, constructionism is not a technocentric approach to learning, technology such as digital game-based learning interventions and videogames are instead tools that provide optimal environments where constructivism can be easily executed (Fino, 2017). In such environments users are able to create meaningful tools, engage in exploration and discovery, share knowledge on a public platform, and collaborate with others to move forward (Holbert et al., 2014).

The issue with constructionism like constructivism is that it denies human knowledge can be absolute or concrete; instead, it is fluid and based on the learner. However, several well-known studies regarding young infants being shown a toy that was then placed behind a screen disprove this. After repeating this step with a second toy, the

## Game Based Learning: Literary Review

screen was removed either revealing the expected amount (two toys) or a surprising amount (one toy). Regardless of whether the location and the objects being used were changed to prevent remembering, infants looked longer at the improbable condition, thus indicating that they expected the mathematically correct amount and their numerical expectations remained unchanged (Peterson, 2012). This was not something that was taught; this was an innate awareness within their beings. Furthermore, constructionism can be problematic when dealing with the many variables and differences that exist between cultures; basing knowledge off one's perceptions and the interpretation they have constructed can result in things being very one-sided. This is because in social construction, new concepts are developed through complex historical processes in which systems of references are established and then passed on to a new generation. These mental models are deeply and unconsciously imbedded into our psyches. Thus, they affect the way we view the world, attach meanings to things, and learn. For example, although members of cultures that use numbers cultures may count the same number of items, the way they conceptualize the ontology underlying the separation between objects can vary quite drastically. Thus, the number depends upon its praxis. For languages like English, numbers are conceived "of material objects as spatiotemporal particulars and sets as aggregates that are built up from these independent units in successive iterations. In this case, garden hoe is a spatiotemporally distinct object and a collection of hoes are added, one by one, to reach a count" (Peterson, 2012). For a West African language like Yoruba material objects as sorted particulars which are number determined by subtracting individual members of the set from the set as a whole (Peterson, 2012).

### **Digital Natives**

Play, is a very important component of learning regarding children. In 1962 Piaget describes play as an being essential part of a child's stages of cognitive development. According to him, the more abstract, symbolic, and social play becomes, the more a child's cognitive development has matured. It helps to activate a child's schemas in ways that allow for the transcendence of their immediate reality and

## Game Based Learning: Literary Review

ultimately symbolic thinking (Plass et al., 2015). In addition to the importance of play, Papert added that the use of physical objects, otherwise referred to as "objects-to think-with" serves an important role in knowledge construction. In mathematics these objects-to-think with are often referred to as manipulatives which help students explore and develop an understanding of mathematical ideas and concepts” (Kablan, 2016).

Despite play and manipulatives being incredibly important tools for learning, the medium in which students today engage with them has drastically changed from students of the past. This change can be singularly attributed to the arrival, accessibility, rapid proliferation, and advancement of digital technologies in the latter part of the 20th century. The students of today are considered to be digital natives, the first generation K-12 students that have grown up with their lives entirely immersed in using some sort of digital device - computers, videogames, music devices, email, television, cell phones, or other toys and tools of the digital era (Prensky, 2001). This century finds that the sheer accessibility and availability of technology has resulted in a fundamental shift in the way they think and process information from their predecessors. According Prensky, a digital native by the time they graduate college has spent less time reading, approximately 5,000 hours, but over 10,000 hours playing video games and 20,000 hours watching television (Prensky, 2001). Such students are accustomed to receiving information quickly which begets instant gratification, prefer parallel processes, multi-tasking, graphics over text, and games over serious work. In many cases they function best when connected via a network, because this has been the case for majority of their life. The problem however is that many schools still harken to the traditional way learning and most teachers are digital immigrants.

In the traditional classroom, learning is predicated on direct instruction from a figure of authority and a student’s ability to memorize and regurgitate facts, adhere to rules, implement procedures, and plug in formulas (Nesmith & Dean, 2008). Schools educated students by following strict curriculums, focused on teaching sets of skills in lieu of concepts, and then used these skills to measure knowledge (Nesmith & Dean,

## Game Based Learning: Literary Review

2008). Knowledge is viewed as discrete, hierarchical, sequential and fixed (Draper, 2002), where in the teacher's role was to provide clear and systematic demonstrations, reaffirm steps in response inquiry, allow practice opportunities, and offer corrective support as needed (Nesmith & Dean, 2008). Students that are digital natives, however, tend to have limited patience for this teaching format which typically emerges in the form of lectures, step-by-step logic, and "tell-test" instruction (Prensky, 2001). Additionally, most teachers grew up in traditional classrooms which shaped the way they approach learning and ultimately impart knowledge. More than often than not, these teachers tend to be digital immigrants that continue to rely on traditional methods not recognizing that modern learners are different. **Digital immigrants** are those who have adopted and adapted to the new technological environment later in life, but because of this late adoption discomfort and hesitation with regard to utilizing technology as a primary tool to positively affect and encourage learning exists. Examples of this would be printing out an email to read it or calling someone to see if they received an email instead of checking the sent folder for confirmation. This discomfort is one of the many factors that may lend itself to the skepticism and trepidation that many educators may have when it comes to utilizing digital game-based learning as a medium for instruction. Ultimately, play is important, manipulatives are powerful tools for learning, technology plays a huge role in the lives of digital natives and is a staple in today's society. Thus, in order to keep up with this new generation of students, educators must adapt. As it stands now, children despite age spend quite a significant amount of their time in school and as aforementioned, they are growing up with having access to technology from birth. With this as the case, the classroom, suggests Susan Haugland (2000) is a great place to continue getting acclimated with technology. Through early exposure, use becomes second nature. When effectively used, she argues, technology can be an excellent tool for learning, "imparting children with knowledge and skills beyond expectation" (Haugland, 2000a). To do this, as with any other learning resource, educators must focus on "the how" not "the if" technology is used. Improper integration does have the power to have

## Game Based Learning: Literary Review

negative or no affect; however, research has shown that if certain steps are taken, the technological introduction can be effective. These steps include selecting relevant developmental software and websites, incorporating these resources into the curriculum, and choosing technologies that support these learning experiences. She suggests that selecting relevant developmental software and websites can be done either by parents and educators using the Haugland Developmental Software Scale or Haugland/Gerzog Developmental Scale for Websites, which were created to evaluate the appropriateness of a software/website for learning on their own recognition or use the internet to see what software/websites are ranked (Haugland, 2000a; Haugland & Wright, 1997). It is only when educators begin to view technology as valuable and select technologies that matches their teaching objectives and goals does it become an effective teaching tool. She also stresses that access and availability to technology both in the classroom and home as well as parent collaboration are essential to maximizing the potential benefits that technology provides as a learning tool (Haugland, 2000a; Haugland & Wright, 1997). In the end, digital immigrant educators must to shift the way they educate by incorporating technology- particularly DGBL - into their curriculum or face potentially being disconnected from a new generation of students that are accustomed to technology being a part of their everyday lives.

### **Measuring Learning**

Learning is a complex cognitive process; thus, it can be increasingly difficult to observe or measure if, what, and how much of it is actually taking place (Fowler, Cusack, & Canossa, 2014). In traditional learning settings, the classroom, summative and/or formative assessments are used as measurement tools that guide teachers regarding student learning. Summative assessments evaluate what students have learned “at the end of a unit, to promote students, to ensure they have met required standards on the way to earning certification for school completion or to enter certain occupations, or as a method for selecting students for entry into further education” (“Assessment for Learning Formative Assessment,” 2008). Ministries and departments of education use them to

## Game Based Learning: Literary Review

either “hold publicly funded schools accountable for providing quality education” and/or to compare education systems on a local, national, and international level (“Assessment for Learning Formative Assessment,” 2008). However, research indicates that test anxiety becomes increasingly more common when using summative assessments. Formative assessments on the other hand are recurring, interactive tests that assess student progress and understanding to determine learning needs and modify teaching accordingly. Their main goal is to improve learning. Research indicates that formative assessment approaches and techniques allow educators to meet the need of diverse students, through differentiation and adaptation. “But there are major barriers to wider practice, including perceived tensions between classroom-based formative assessments, and high visibility summative tests that hold schools accountable for student achievement, and a lack of connection between systemic, school and classroom approaches to assessment and evaluation” (“Assessment for Learning Formative Assessment,” 2008; Kiili & Ketamo, 2018).

Given the increased prevalence of technology within society, and the growing cries for education reform, DGBL has been looked to as a solution to provide both learning and fun. This is because videogames have a compounding effect similar to learning, which for the purposes of this paper is defined as the process of acquiring knowledge, skills, or attitudes. It has been argued that existing educational measures are not appropriate measures for DGBL due to their highly invasive and disruptive nature to a player’s flow experience. However, when appropriately designed, DGBL can provide a suitable environment for summative and particularly, formative assessment integration. Thus, as researchers develop and/or choose instruments to assess learning as a result of DGBL, the purpose and context of the chosen instruments must be taken into consideration to ensure that the intended learning effect and desired inference are properly measured (Kiili & Ketamo, 2018).

Though there is no established way of measuring learning within DGBL there is an overreliance on standardized, pencil and paper, pre-posttests, which is receiving

## Game Based Learning: Literary Review

increased scrutiny due to the dynamic and interactive nature of videogames (Hebert, Jenson, & Fong, 2018). As a result, embedded assessments, which tend to be more in line with the dynamic nature of games have been gaining popularity. Additionally, eye tracking and evaluations which do not necessarily measure learning but that provide insight on learning have also been used.

**Pre-Posttests.** One of the most common ways researchers determine the effectiveness of a DGBL intervention as an instructional tool is by observing pre-post-test results. Typically, when researchers employ some version of the pre-posttest method in DGBL research, it is for the purpose of comparing groups and/or measuring change resulting from administering experimental treatment (All, Nunez Castellar, & Van Looy, 2014). When such methods are used, participants must first complete an assessment or survey to establish a baseline regarding proficiency or attitude prior to receiving a treatment, followed by another assessment or survey on the same measure after treatment occurs. Typically found in experimental and quasi-experimental research, the pre-posttest design can also include or exclude control groups (“Pretest–Posttest Design,” 2010). To give an idea of how prevalent this particular design is, a review of 54 publications between 2000 and 2012 dealing with effectiveness of DGBL and cognitive learning outcomes, showed that all employed some variation of this method; eight studies had a post-only design with a control group, 21 studies had a pre-post design without a control group, and 25 studies with a pre-post design and control group (All, Nunez Castellar, & Van Looy, 2014). For posttest only designs, an independent variable is introduced and then measured to determine its effect on the dependent variable. With such assessments, only one of the two groups receive treatment over the same period and then both groups are given the same test to determine if a difference exists. Aside from the researchers having to make sure that, both groups are equivalent, posttest only studies are limited in scope and contain threats to validity. In other words, it does a poor job guarding against bias and the researcher knows nothing about the individual differences that exist within the groups, nor the affect that this may have on the posttest outcomes; thus, the statistical

## Game Based Learning: Literary Review

significance is weak and may be due to characteristic differences or confounding variables between groups rather than the actual treatment administered. In the pre-posttest with no control group design, and assessment takes place, followed by the introduction of the treatment, and then another assessment. Though smaller samples can be used because each participant serves as their own control, they can be subject to the effects of history-events that occur outside of the experimental treatment, which affect posttest scores-and/or practice. For the pre-post with a control group, conditions remain the same for both the experimental and control groups, with the exception that the experimental group is exposed to a treatment. Participants in the control group are either specifically assigned or randomly assigned to their respective groups. The randomized control design balances groups on existing characteristics and, thus isolating the effects of the intervention. However, researchers must be mindful of internal validity issues regarding maturation-the biological or psychological progression that occurs over the passage of time, irrespective of specific external events occurring- and history, as well as the external validity factor of sensitization due to interaction with the pretest. On the flip side, nonrandomized control studies tend to be more externally valid and practical, especially if natural participant groups have already been formed, such as classrooms; however, such studies are susceptible to internal validity problems due to factors regarding selection and maturation, selection and history, and selection and pretesting (Dimitrov & Rumrill, 2003).

Outside of DGBL research, pre-posttest methods are frequently used in education. Teachers find them valuable because of the opportunity it provides to monitor student progress and educational gains in real time. Furthermore, multiple post-tests can be given throughout a student's enrollment, instruction can be fine-tuned as needed, and these tests can give powerful feedback about how to better meet students' academic needs. Aside from teachers, pre-posttests are also valuable to facilities, programs, and State and local administrators that use the aggregated results of students' academic progress to evaluate and improve educational programming. Gathering such data allows administrators to

## Game Based Learning: Literary Review

measure the effectiveness of their educational programs and make any necessary adjustments, while providing local and State administrators with information to compare results across programs and determine if they are meeting State and Federal reporting requirements (NDTAC, 2006).

In terms of actual tests used within the pre-posttest design, the two most common are criterion-referenced tests and norm-referenced tests. Criterion-referenced tests focus on observing student achievement with regard to a level of performance that has been predefined. Such scores are typically provided in relation to establishing achievement or proficiency levels, which define the skills a student has obtained. “Achievement levels can be prescriptive or descriptive. Proficiency levels are prescriptive when they specifically define what a student should and should not be able to do at a given grade. In contrast, descriptive achievement levels are not linked to specific grades or ages. Rather, they are concerned with student growth along a continuum, and provide a mechanism for monitoring how a student is progressing. Criterion-referenced tests may provide more information when tracking student progress however norm-referenced tests provide more information about how a particular student’s performance compares to that of other students who have taken the test. The test score itself does not have meaning without information describing the students in the comparison group” (NDTAC, 2006).

**Embedded Assessments.** Learning is an essential part of all games. To play, participants must at least understand the basics of a game’s mechanics, the purpose for these mechanics, and determine what the game designer wants them to do. Thus, all games regardless of whether they are intentionally developed with learning in mind, have some aspect of learning within them. These mechanics according to Plass et al. (2013) are divided into three categories- learning, assessment and game. “Learning Mechanics describe essential high-level activities, grounded in learning sciences, that have learning as the primary objective” (Plass et al., 2013). Assessment mechanics help determine what functions produce useful game metrics that allow for the measuring of variables related to learning, “including learning outcomes (cognitive, behavioral, social, affective), trait

## Game Based Learning: Literary Review

variables, general state variables, and situation-specific state variables” (V. Shute & Ventura, 2013). And finally, game mechanics are “the various actions, behaviors and control mechanisms afforded to the player within a game context” (Hunicke, LeBlanc, & Zubek, 2004; Plass et al., 2013). Simply game mechanics are the basic functions that players perform repeatedly, which can be grounded in learning mechanics, assessment mechanics, or both (Plass et al., 2013). These mechanics are developed because of the Evidence Centered Design (ECD) framework that requires designers to be intentional about the skills, knowledge, processes, goals or other characteristics they select to be developed, assessed and measured. So, designers must be careful when determining “what learners need to do, say, or create to provide evidence relating to the variables being assessed” (Plass et al., 2013).

Combined, these mechanics allow for the development of embedded assessments, which are ECD-based tests invisibly woven into the foundation of the game to “dynamically, unobtrusively, accurately, and transparently measure how players are progressing relative to targeted competencies” (V. Shute & Ventura, 2013). Such assessments are built on several assumptions and exploit the tendency humans have to construct essential knowledge through the interaction “of sensory input, transactions with the environment and causal relationship” (Reese, Tabachnick, & Kosko, 2015). The first assumption is that learning is activated by doing (predicated by gameplay) thus increasing the learning processes and outcomes. The second assumption is that it is possible for distinctive types of learning and learner attributes to be demonstrated and measured during gameplay. Third, strengths and weaknesses of the learner may be exploited and bolstered, respectively, to improve learning. Lastly, constant feedback can be used to further encourage student learning. As players interact with these games, and the game state changes, the system immediately updates the [virtually] physical game world. This can be evidenced by the study of 74 second graders to determine how Monkey Tales, a DGBL intervention would affect their accuracy, speed, anxiety, and enjoyment. Students using the DGBL intervention experienced much higher levels of

## Game Based Learning: Literary Review

accuracy, which researchers suggested may be due to the fact that students were offered specific exercises more in line with their math skills as a result of the adaptive algorithm in the game. This embedded algorithm assessment feature monitored player progression and automatically adjusted the difficulty level (Cheng, Wu, Liao, & Chan, 2009). Thus, the new state of the game world provides concrete cause-and-effect feedback to the player at the level of perceivable sensory information” (Reese, Tabachnick, & Kosko, 2015). Players then instinctively produce a rich sequence of actions while completing complex tasks. The proof necessary to assess the knowledge and skills as the products of learning is evidenced by the players’ interactions with the game (Shute & Ventura, 2013). These continuous interactions build up data logs that track behaviors as progression through the game occurs, producing a set of performance metrics such as the content accessed, time to complete tasks, and the number of “mistakes” and corrections made (Hebert, Jenson, & Fong, 2018).

In their research to evaluate the effectiveness of using a game-based intervention to teach 95 fourth graders rational numbers, Kiili, Moeller, and Ninaus (2018), observed that embedded assessments despite not being able to explain unique variance, were able to substantially predict the variance of fourth graders conceptual rational number knowledge. Furthermore, they were able to replicate findings from a study conducted a year prior, which suggests a positive correlation between in-game estimation accuracy and math grades identified (Ninaus, Kiili, McMullen, & Moeller, 2017). Replicated findings such as these suggest that teachers and educators can easily access and use embedded assessments as tools to evaluate students' current capabilities, predict future performance, thereby adjusting the difficulty level of assignments as well as the amount of explanation needed to provide clarity during math classes or specific training (Cheng et al., 2009; Kiili, Moeller, & Ninaus, 2018). Results indicate that embedded assessment scores significantly correlate with paper-based test scores, thereby suggesting that if properly integrated they provide data that is comparable to the paper-based approach. Additionally, evidence implies that embedded assessments lower test anxiety and

## Game Based Learning: Literary Review

increase engagement, which is likely to decrease assessment bias caused by test anxiety and also that earlier playing experience and gender do not affect embedded assessment scores (Kiili & Ketamo, 2018).

Currently, research, which examines DGBL usually utilizes the pre-posttest design to assess and measure knowledge, however according to Shute and Ventura (2013), such “traditional assessments do not capture and analyze the dynamic, complex performances that inform twenty-first-century competencies”. Despite research regarding embedded assessments being in its infancy, results thus far strongly suggest that they are informative tools and valid predictors of training/learning success. To strengthen this approach, Reese et al (2015) suggests a triangulation of additional ways to assess learning and increase validity. These suggestions include (a) creating a timed data log of game events which applies standard statistical procedures, such as regression and hierarchical linear models, for longitudinal data modeling, (b) observing user behavior either by video recording or observer protocols, or (c) utilizing eye tracking data. The time log if done appropriately could be undetectable, however the observations and eye tracking would not be (Reese, Tabachnick, & Kosko, 2015).

In terms of the classroom, the closest thing to embedded assessments would be “assignments, activities, or exercises that are done as part of a class, but that are used to provide assessment data about a particular learning outcome” (Maki, 2004). The teachers or course evaluators can assess the student performance directly or indirectly, utilizing a rubric. Direct methods “require a student to represent or demonstrate their learning or produce work so that observers can assess how well students’ work or responses fit institution- or program-level expectations” (Maki, 2004). These include but not limited to tests or specific questions on tests, research papers and projects, reports, the creation of a portfolio, and capstone evaluations.

**Eye Tracking.** Eye tracking research in gaming has typically been used to understand a player’s behavior and their issues regarding usability (Byun, Loh, & Zhou, 2014). Through the use of eye tracking tools, researchers are able to collect data on

## Game Based Learning: Literary Review

user's behavior through their eye movement (Mat Zain, Abdul Razak, Jaafar, & Zulkipli, 2011). However, in recent years, there has been growing interest in leveraging eye tracking tools to assess learning in videogames. Though eye tracking does not directly measure learning or at least no research as of yet has come out to refute this, when researchers are able to capture these movements and measurements these instruments provide insight into the unseen cognitive processes such as attention, memory, language, problem solving and decision making which are all factors that can reveal human learning patterns.

Eye-tracking tools are video-based software systems that document the movement of a participant's eyes while looking at a stimulus. Because a close connection exists between what a player is looking at and their thoughts (Fowler et al., 2014), eye trackers measure eye movements so that researchers know where a person is looking and the sequence with which their eyes shift from one location to another (Mat Zain et al., 2011). Typically, in order to process information, the eyes focus on things that are unexpected, significant, and/or important. Thus, the duration of time that the eyes remain fixated or unmoving for roughly 200-300 milliseconds on a particular object (Mat Zain et al., 2011), the saccades (the rapid movement from one fixation point to another), and endogenous blinks (the temporary closure of the eye due to perception, reaction or information processing) may indicate information acquisition and mental processing taking place (Fowler et al., 2014). Through the identification of all these factors, it is possible to create and place heat maps and saccade pathways against the reference image to determine and differentiate areas of interest, confusion or attention (Fowler et al., 2014).

Researchers Byun, Loh, and Zhou sought to determine if they could be a viable tool of assessment in role playing serious games. To do this they had three novice and three expert players play a military style search and rescue game. They confirmed from a previous study, "that different kinds of players perceive the game world differently and elements that grasp players' attention can vary" (Kiili, Ketamo, & Kickmeier-Rust, 2014), such as those between expert and novice players (Byun et al., 2014). The scan

## Game Based Learning: Literary Review

path of experienced players showed that they were more inclined to skip unimportant texts, whereas novice players tended to read all the text more carefully. They also discovered that experts tended to be more structured in where they looked in anticipation of upcoming events and outcomes of a particular action, whereas the novice players were sporadic and looked everywhere without specification. Additionally, they noticed that eye tracking tools had some difficulty capturing gaze points due to continuous moving game scenes and participant posture change based on emotional responses to the game. It is cautioned that additional methods should be employed while conducting eye tracking research, such as interviews, observations. Although the eye tracking does seem to provide new and important information about the learning process, relying on it only increases the risk of misinterpreting perceived data as fact (ex. making assumptions about player understanding something because they paid attention to it) (Kiili et al., 2014). Thus, current research concedes that more investigation is needed.

Aside from the lack of research that exists regarding eye tracking being used as assessment tools, eye tracking systems are quite complex. Due to the sheer speed at which eyes move, eye-tracking systems must have the ability to record the eye gazing at a very high sampling frequency. Current eye tracking systems range between the speeds of 50 to 1000 times per second, with only those measuring 500 Hz or greater being sufficient enough to measure eye fixations, saccades, and the quantity and frequency of endogenous eye blinks. Unfortunately, such systems can be intrusive because they require the use of a headset or special glasses. For those systems that are less intrusive and do not require a headset, rather they attach to the desktop or under the computer monitor, they are more expensive. Thus, though such devices provide great insight, their implementation in K-12 institutions are quite rare. The closest version of this being implemented in a classroom, is an observation done by either another teacher, researcher, or evaluator. Though it is impossible for human observes to detect eye movement the way an eye tracker does, observation over the course of time does allow for observers to

draw conclusions about behavior and level of understanding that students in the class may have (Fowler et al., 2014).

**Self-Reported Assessments.** Aside from measuring the actual changes in performance when utilizing DGBL interventions, researchers are also interested in the indirect factors such as motivation, attitude towards learning, and quality of experience. Research suggests that video games do indeed have an effect on a student's outlook towards learning math. In a case study conducted by researcher Ke to see whether this had some merit, it was found that the incorporation of games encouraged a more positive attitude to mathematics learning (Ke, 2008; Siew, 2016). Siew (2016), validated this finding, in a study to determine whether thinking and attitudes toward algebra among eighth grade students would be affected with the use of an android app, DragonBox 12+. Results indicated that students exposed to DragonBox 12+ showed increased confidence towards algebra in comparison to those learning with conventional methods. "This is evidenced when 95% of students completed their survey affirming that they either strongly agreed or agreed with the statements: 'I am comfortable to try algebra problem', 'I believe I can undertake further work in algebra', and 'I think I can solve more difficult algebra problems' "(Siew, 2016). Furthermore, "students in the experimental group tended to perceive that algebra has many uses with 88% of students either strongly agreeing or agreeing with the statements, 'I require algebra in my future task', 'Algebra become important in my daily work', and 'I will need a good mastery of algebra in my future work' "(Siew, 2016).

The incorporation of surveys such as the one used by Siew, are commonly used to capture students' feelings and experiences toward learning math, however the Fennema-Sherman Mathematics Attitude Scales (Fennema & Sherman, 1976) remains to date one of the most popular instrument used. Although many instruments such as the Thurstone Equal-Appearing Interval scales, Aiken's Mathematics Attitude scale, Semantic Differential scale existed, they illustrated "an underlying assumption that students have an overall, single dimensional attitude to mathematics which can be measured on a

## Game Based Learning: Literary Review

unitary scale” (Leder, 1985). The Fennema-Sherman, on the other hand was the first of its kind to explicitly recognize “different aspects of students' attitude to mathematics and report the effects of the different components separately” (Leder, 1985). Originally, the now modified Likert based instrument consisted of nine scales that could be used individually, collectively, or in any combination: attitude toward success in mathematics scale, confidence in learning mathematics scale, mathematics anxiety scale, effectance motivation scale in mathematics, mathematics as a male domain scale, mother scale, father scale, teacher scale, and mathematics usefulness scale available. Developed as part of a grant from the National Science Foundation, the Fennema-Sherman instrument sought to gain more insight regarding females' learning math and what variables affected the selection of math courses (Fennema & Sherman, 1976).

Despite being a commonly used tool, research conducted following its introduction called into question the validity, reliability (Suinn & Edwards, 1982), and integrity of its scores (O’Neal, Ernest, McLean, & Templeton, 1988; Tapia & Marsh II, 2006). In 1994, researchers Melancon, Thompson, and Becnel isolated eight out of the nine factors, and were not able to match their results with what the instrument proposed. Furthermore in 1998, Mulhern and Rae “identified only six factors, and suggested that the scales might not gauge what they were intending to measure” (Tapia & Marsh II, 2006). This along with the desire to have a more concise instrument prompted the creation of a shorter instrument called the Attitudes Toward Mathematics Inventory (ATMI) by Tapia and Marsh (2006). This instrument has been used successfully in recent studies with elementary, secondary and college audiences (Ke, 2008) to measure the underlying dimensions of attitudes (confidence, anxiety, value, enjoyment, motivation, and parent/teacher expectations) toward mathematics (Tapia & Marsh II, 2006). And unlike the Fennema-Sherman which contains 108 questions, the ATMI only has 49 questions.

These affective factors though not the main focus of educational interventions is often considered to be key secondary learning outcomes that potentially increase levels of

## Game Based Learning: Literary Review

enjoyment, interest, performance, higher quality of learning and a heightened self-esteem (All et al., 2014). Aside from surveys, because such factors tend to be difficult to obtain with behavioral or physiological measures, evaluating them is heavily reliant on self-reported outcomes such as observations, open-ended questions, journaling, and interviewing. In an exploratory study of 118 elementary-school students from Canada, survey questionnaires, videotaped observations and think aloud sessions, weekly journals, and interviews with teachers and students (individual, semi-directed, and group) were methods used to investigate the educational value of incorporating Minecraft into a classroom curriculum learning of computer science. From these methods of data collection, researchers noted that a few of the benefits of this included: “increased overall motivation toward school, stronger computer skills, increased feelings of academic self-efficacy, improved computer programming and computational logic skills (Minecraft’s advanced levels elicited basic programming skills), improved problem-solving skills, improved informational research competencies (to accomplish certain tasks), and development of math concepts (perimeter, volume, calculation of required resources and numbers of blocks, etc.)” (Ke, 2008). Another study which utilized such methods was by McCue (2011), who measured the lateral transfer of mathematics knowledge from the design and programming of three video game projects by 19 seventh and eighth graders. During the course of seven months, students were prompted to reflect on the plans they created and their progress in producing their own video games via notes and drawings in a journal. These self-reflections were recorded twice per each game: first, between the synthesis and construction phase, and then the completion of each game project. These reflections contained “students’ perceptions of their challenges and successes, design graphics of their video games, and comments regarding modifications or deviations from the game models that students planned and implemented” (McCue, 2011). These were done in addition to observations of students as they worked during class and talk-out loud sessions for the purpose of obtaining additional insight into whether or not students

## Game Based Learning: Literary Review

understood the math content they were implementing with the video game design and construction (McCue, 2011).

Such findings are great in providing rich context and understanding, however, self-reporting does have the potential to pose several problems which researchers must be mindful. First, researchers using these instruments are reliant on their participants to answer the questionnaires honestly and accurately, which may not be possible. Instead of being honest, there is a potential for participants to answer questions in the manner in which they think would be acceptable to the researcher. Participants may potentially misinterpret the question, thereby answering incorrectly or misinterpret the scale used, by rating question a higher or lower than they normally would. Outside of research, self-reported measures commonly extend to the classroom via course or student evaluations and observations conducted by consultants, administrative staff, or other teachers. It is a common practice on college campuses for students to be asked to rate their instructors and the quality of their learning following the completion of the semester. Though some decry this due to its subjective nature, they are still common practice within the education system. The Classroom Assessment Scoring System (CLASS) tool is an instrument used to observe and assesses the interaction between teachers and their students. CLASS is utilized for the purposes of measuring teacher professional development, monitoring and evaluating teacher performance and effectiveness, and research via three domain measures: emotional, organizational, and instructional supports. To date CLASS has been used to observe over 20,000 classrooms across the United States (Hamre, 2008).

### **When DGBL is Effective**

In psychology today, play is recognized as a very important component of learning regarding children. However, this is nothing new, as researchers have been trying to understand the role of play and development for a very long time. The earliest study regarding play can be traced back to Dutch historian Johan Huizinga's groundbreaking study *Homo Ludens* in 1938, where he established its definition. According to Huizinga, play is “a free and meaningful activity, carried out for its own

## Game Based Learning: Literary Review

sake, spatially and temporally segregated from the requirements of practical life, and bound by a self-contained system of rules that holds absolutely” (Rodriguez, 2006). In 1962, French sociologist Roger Caillois took this definition a step further by emphasizing that play, is a voluntary, removed activity that has an unknown conclusion, produces nothing, and can be governed by both rules and make-believe. He then classified play into four categories: *agôn* (competition on an artificially leveled playing field), *alea* (games of chance), *mimicry* (role-playing, or make pretend), and *Ilinx* (disorientating oneself, thrill-seeking and risk taking), which are further refined by a game's leaning towards *paidia* (chaos) or *ludus* (order) (Caillois, 2001; Robison, 2007). During this same time Piaget was developing his own definition of play, which he theorized as an being essential part of a child's stages of cognitive development. According to him, the more abstract, symbolic, and social play becomes, the more a child's cognitive development has matured. Play helps to activate a child's schemas in ways that allow for the transcendence of their immediate reality and ultimately symbolic thinking (Plass et al., 2015). Thus, the idea of using games or gamified like elements to bolster learning has always been an interest of researchers and educators alike, particularly for subjects like mathematics, which many students find to be difficult. Aside from the importance of play, Papert added that the use of physical objects serves an important role in knowledge construction. He created the term "objects-to think-with" as a depiction of how objects in the physical and digital world (such as programs, robots, and games) can transform into objects in the mind that help to design, examine, and revise connections between existing and new knowledge (Kafai & Resnick, 1996). In mathematics these objects-to-think with are often referred to as manipulatives. **Manipulatives** “are physical and concrete materials such as cubes, geometry boards, pattern blocks and other everyday objects that help students explore and develop an understanding of mathematical ideas and concepts” (Kablan, 2016). In a study conducted by Kablan (2016), to determine the effect of manipulatives on mathematics achievement across different learning styles, it was suggested that manipulatives did benefit students that possessed certain learning styles.

## Game Based Learning: Literary Review

Traditional mathematic classrooms are predicated on following strict curriculums, abstractions of concepts, dictation from the teacher, and memorization to be successful (Nesmith & Dean, 2008) thus, tend to better meet the needs of learners that are assimilators and convergers rather than accommodators and divergers (Kablan, 2016; Kolb & Kolb, 2005).

**Assimilators** tend to be rational thinkers that are more interested in concepts rather than in people, and prefer to work alone through reflective observation, avoiding what they consider to be practical activities. **Convergers** like assimilators appreciate abstract concepts, however, they prefer to learn by using active experimentation to problem solve (Bhatti & Bart, 2013; Kablan, 2016; Kolb & Kolb, 2005). Thus, it is easy to see why such learners are successful in traditional mathematics classrooms. Such environments frequently rely on the lecture format to relay information, and exercise-based teaching which through the use of word problems in textbooks and other printed material are completed by a teacher on a blackboard for students to see and in turn model (Kablan, 2016; Nesmith & Dean, 2008). The students that do not fare well in these conditions, accommodators and divergers, struggle because these environments lack concrete experience. Aside from lacking concrete material, students that are **accommodators** like convergers prefer active experiences. They use their feelings in decision-making process, and they prefer hands on engaged group work. **Divergers**, learn best when relying on their feelings and reflection, in addition to concrete, hands-on methods (Bhatti & Bart, 2013; Kablan, 2016; Kolb & Kolb, 2005). In other words, while the traditional method serves the needs of students that are abstract learners, they run the risk of losing the attention of those that require concrete examples and hands-on experimentation for comprehension (Kablan, 2016). Results of the study showed that when half of instructional time incorporated the use of manipulatives, the difference in performance across the four types of learning styles disappeared (Kablan, 2016). This may be due to the fact that manipulatives, and particularly DGBL interventions have been shown to directly support learning by giving students the opportunity to “develop

## Game Based Learning: Literary Review

knowledge and cognitive skills in an emotional way, to make decisions in critical situations by solving problems, to learn by researching and to experience situational learning” (Holzinger, Nischelwitzer, & Meisenberger, 2005). Additionally, such interventions if properly designed take components of entertainment, combine them with components that encourage knowledge transfer, and increase motivation and participation (Stege, Van Lankveld, & Spronck, 2011). Thus, learning transforms from only serving certain types learners due to the use of dictation and reliance on abstract concepts, to being more inclusive and experiential, where active contribution by the learner is encouraged (Divjak & Tomic, 2011).

Aside from students with diverse learning styles, another potential group that benefits from DGBL interventions are students that have low self-efficacy. Self-efficacy is defined by Bandura, as the belief in one’s “capabilities to produce designated levels of performance that exercise influence over events that affect their lives. Self-efficacy beliefs determine how people feel, think, motivate themselves and behave” (Bandura, 1994). This is particularly important when considering that students with low levels of self-efficacy toward mathematics tend to have their performance negatively affected. In 1989, Hackett and Betz examined the relationship between 153 female and 109 male college students’ mathematics achievement, self-efficacy, attitudes towards math, gender role socialization, and their pursuit of math related degree programs. They uncovered that a strong positive correlation between math achievement, levels of self-efficacy, mathematics attitudes, and masculine sex role orientation existed. Research suggests that girls tend to adopt a self-defeating attribution style, ascribing success in math to external factors and to effort, while their failures are considered a lack of their own ability. Boys on the other hand embraced a self-enhancing attribution pattern which attributes mathematic success to internal factors and failures to external factors (Llyod, Walsh, & Yailagh, 2005). The problem with this is that although ability and effort are both “internal attributions, it is better for an individual to attribute success to ability, rather than to effort, because ability attributions are more strongly related to motivation, self-efficacy,

## Game Based Learning: Literary Review

and skill development than are effort attributions” (Llyod et al., 2005). Furthermore, mathematics has been long attributed to be a masculine discipline; research suggests that messages from family, teachers, peers, and society at large can affect one’s self-efficacy (Hackett & Betz, 1989). Thus, though not statistically significant, these factors did provide some insight as to why Hackett and Betz (1989) had results of more males being overconfident (showing higher self-efficacy) and females being under-confident (showing lower self-efficacy) when it came to their mathematical performance. Researchers Lloyd, Walsh and Yailagh (2005) conducted a more recent study to see if findings by Hackett and Betz’s still held validity. Attribution to failure was not found to be significantly different between genders however, it did validate that despite meeting or exceeding performance expectations, female participants were still found to be less confident of their abilities in comparison their male counterparts (Llyod et al., 2005; Pajares & Valiante, 1999).

This is problematic for several reasons. Students with low-self efficacy have the tendency to feel that things are more difficult than they really are (Hung, Huang, & Hwang, 2014); they fixate on visualizing scenarios of failure scenarios and dwell on the things that can go wrong (Bandura, 1994). Whereas students who have high self-efficacy hold the belief that they are capable and tend to perform better in learning tasks, thus indirectly affecting their belief in their abilities. In other words, students perceptions of themselves and their academic aptitude, assist with determining what they do with the knowledge and skills they possess (Llyod et al., 2005; Pajares & Valiante, 1999) and influence their choice of activities, effort expended, task persistence, and task accomplishments (Llyod et al., 2005). As highlighted in a research paper by Cheng, Wu, Liao, and Chan (2009), students with higher self-efficacy tend to solve more problems successfully irrespective of their actual ability; and even when problems are incorrect, they tended to show signs of persistence much more than those with low self-efficacy. For students that have low self-efficacy, incorporating the attribute of failure has the

## Game Based Learning: Literary Review

potential to level the playing field. Several studies suggest that allowing for failure and problem solving play an important role in learning.

In 2009 Kapur and Kinzer conducted a study on a 177, randomly assigned 11th-grade science students to “solve either well-structured or ill-structured problems in a computer-supported collaborative learning (CSCL) environment without the provision of any external support structures or scaffolds” (Kapur & Kinzer, 2009). What they discovered was that students who solved well-structured problems struggled defining, analyzing, and solving the problems. In spite failing, when all students had to complete problems individually, those students in the ill-structured condition outperformed their counterparts from the well-structured condition group. Furthermore, this study confirmed that neither preexisting differences in prior knowledge nor the variation in group outcomes (quality of solutions produced) had a significant transfer effect on individual performance (Kapur & Kinzer, 2009). In other words, situations that were ill defined and where failure occurred encouraged meta-cognition and problem-solving behaviors that better prepared learners for later problem solving (Sharritt & Suthers, 2013). They dubbed this outcome productive failure (Kapur & Kinzer, 2009). In a study done to determine what activities human tutors do that result in successful tutoring for the purposes of applying them to intelligent tutoring systems, results reiterate the importance of failure. Result suggested that the “successful learning of a principle (e.g., a concept, a Physical law) was associated with events when students reached an impasse - a form of failure - during problem solving. Conversely, when students did not reach an impasse, learning was rare despite explicit tutor-explanations of the target principle” (VanLehn, Siler, Murray, Yamauchi, & Baggett, 2003).

Videogames and properly designed DGBL interventions are great environments for incorporating failure, because they allow “players to take risks and try out hypotheses that might be too costly in places where the cost of failure is higher or where no learning stems from failure” (Gee, 2008; Sharritt & Suthers, 2013). This is what Plass meant when he coined the term graceful failure. By his definition this occurs when a player instead of

## Game Based Learning: Literary Review

being discouraged by failure, becomes encouraged by it, expects it, and recognizes that in some cases it is essential in order for learning to occur (Plass et al., 2015). This allows students the ability to take time and self-regulate their learning during play, experiment with strategies and set, monitor and analyze goals for the purpose of reaching an intended outcome (Charsky, 2010; Gee, 2008; Plass et al., 2015). In such environments, each failure becomes a valuable learning situation that has the potential to result in the attainment of goals because the learner has the opportunity to practice the challenge until they get it right. In doing this, completing challenges foster the acquisition of skills that lead to more difficult challenges and opportunities to gain additional skills and knowledge (Charsky, 2010). Ultimately, for students that have low self-efficacy, the ability to fail gracefully has the potential to positively effect motivation, engagement, and adaptivity, which are all important factors that encourage learning (Plass et al., 2015).

In addition to students with diverse learning styles and those who suffer from low efficacy, DGBL has the potential to positively effect students that fall within the low literacy/low-ability spectrum according to their performance in math, through the attribute of feedback. As defined by Hattie and Timperley (2007), feedback is defined as any message from an agent (e.g., teacher, peer, book, parent, experience) that produces a response as a consequence of a learner's action. In DGBL, this suggests an interaction between the learner and the system occurs, as a result of information collection or generation by the learner being retrieved after some processing. These interactions are cumulative in nature, thus help to establish one's learning flow. Provided that the feedback is appropriate, the learner is able to address their faulty interpretations, and assess their own actions and progress in relation to goals, with the option to either modify or continue with their behavior and/or strategy accordingly (Burgos, Nimwegen, Oostendorp, & Koper, 2007; Yi, 2017). It is important to note, that without context or relation to goals, feedback can become meaningless, thus it has no effect in a vacuum (Hattie & Timperley, 2007). This is because, improper feedback does nothing to reduce the discrepancy between current learning and intended learning. This is further validated

## Game Based Learning: Literary Review

by a synthesis of 74 meta-analyses that went across 7,000 studies which determined that the most effective forms of feedback offer cues or reinforcement to learners, are in the form of video-, audio-, or computer-assisted instruction, and/or they are related to goals. On the other hand, when trying to enhance performance feedback in the form of programmed instruction, praise, punishment, and extrinsic rewards were determined to be the least effective (Hattie, 1999).

A study of 1000 elementary aged children from the Netherlands to determine the effects of different types of feedback - simple and elaborate - suggests that though both students with advanced strategies (high literacy/high-ability) and less advanced strategies (low literacy/low-ability) benefitted from feedback (simple and elaborate), students that used less advanced strategies benefitted more from a combination of the use of both types of feedback. Furthermore, having both types of feedback available thereby reduced their chances of experiencing cognitive load and the taxation of their working memory (Cheng, Wu, Liao, & Chan, 2009; Fowler, Cusack, & Canossa, 2014; Ku, Chen, Wu, Lao, & Chan, 2014). A study by Ku et al (2014) to see if DGBL interventions could be beneficial to students whose abilities specifically ranged from high to low validated these results. Despite high ability students having the best performance overall and gaining more confidence as a result of the DGBL intervention, all students that received a DGBL intervention experienced increased confidence and better mathematical performance, irrespective of their levels of ability. In a study conducted by Chang, et al (2015) to determine how proficiency level affected the performance in the game, these results were again corroborated but took it a step further. This study was particularly concerned with which sets of students, high achievers, average, low achievers benefitted the most from DGBL interventions. A total of 306 sixth, seventh and eighth grade students were divided in to two groups, where those under the experimental condition utilized the Math App to learn fractions, and those under the control condition used paper and pencil drills. Again, students from the experimental condition outperformed those in the control condition, however students that were classified as low achievers irrespective of grade

## Game Based Learning: Literary Review

benefited the most from the DGBL intervention (Chang, Evans, Kim, Norton, & Samur, 2015). Another study conducted by Li, Cheng and Liu (2013) to investigate the influence of the constructionist framework on the flow experiences and learning strategies of first year engineering students that had high, moderate and low background knowledge of computer science resulted in a similar conclusion. Students felt that learning was not as challenging as it was in traditional lectures (Li, Cheng, & Liu, 2013).

Researchers suggest that the success of students receive t fromhe DGBL intervention may in part be attributed to two factors. First, the receipt of feedback about performance and progress is in real time (Ku et al., 2014); second “the ample opportunities to apply their previous experiences -as interpreted - to similar new situations, so they can “debug” and improve their interpretations of these experiences, gradually generalizing them beyond specific contexts” (Gee, 2008). These factors particularly for students with low ability, allow for the easy manipulation and customization of individual, concrete and continuous experiences. Additionally, they provide the student with information regarding whether they are correct and/or where they made mistakes, which helps to consolidate their knowledge and strengthen their confidence (Ku et al., 2014). Unlike traditional classroom settings, videogames and properly designed DGBL interventions do not rely heavily on summative evaluation- which are tests that assess your knowledge in an abstract way after the material is learned. Rather, they utilize formative assessments, in which feedback ranges from simple confirmations of a correct response to elaborate, where errors may be highlighted, a chance to try again is provided and/or strategic prompts are given on how to proceed with the problem (V. J. Shute, 2008). Learners are placed in situated environments and are assessed in real time as they are playing. The more a learner plays and receives feedback, the more the learner learns (Hattie & Timperley, 2007). Though in most cases feedback is great, caveats exist. In a study conducted by Burgos Nimwegen, van Oostendorp, and Koper (2017) to determine the role of feedback, it was discovered that sometimes it is best not to not have feedback. This may be particularly true for high

## Game Based Learning: Literary Review

ability performing students, because having too much feedback present provides information in excess that makes the students lazier, discourages critical thinking and consequently encourages the creation of inferior strategies (Burgos et al., 2007; Ku et al., 2014). In other instances, it may unintentionally inflate the perception of skills as it did with the high background knowledge of first year students of the Li, Cheng and Liu's study (Li et al., 2013). Aside from balancing the amount of feedback received, it is also important these interventions are followed up with debriefing with peers and experts (Gee). Debriefing is another form of feedback that is external to an action, which allows "individuals who were in the experience to share, cross-fertilize, and to generalize their learnings from and between all who participated in the same experience" (Crookall, 2010). Such processes are highly valuable for learning purposes and can be used for the purposes of cooling down, data collection, external validity, reaching conclusions, testing replicability/sensitivity, and planning for future actions (van den Hoogen, Lo, & Meijer, 2016). Furthermore, "debriefing is a common, almost daily, activity, in which most people engage naturally" (Crookall, 2010).

### **When DGBL is Ineffective**

Games created for the purposes of learning have been touted as the savior of education, particularly in the areas of learning mathematics. And though research suggests that game play has positive cognitive, motivational, emotional, and social effects, research on their actual learning effectiveness remains inconclusive. Instead, research indicates that the effectiveness of digital game based learning (DGBL) interventions remain heavily dependent on the type of learning to be cultivated, the game's attributes, and how it is used in the teaching or learning process thereby affecting the students differently (Clark, Kirschner, & Sweller, 2012; Ke, 2008, 2016). In order to be utilized as potential learning tools, it is extremely important that DGBL interventions are designed with clearly defined goals and purpose. The use of lower level DGBL interventions such as edutainment, exclusion of endogenous fantasy, and careless

## Game Based Learning: Literary Review

inclusion of competition can result in reducing the potential of learning effectiveness or negatively affect learning.

Prior to the introduction of DGBL, learning mathematics was predicated on direct instruction from a figure of authority and a student's ability to memorize and regurgitate facts, adhere to rules, implement procedures, and plug in formulas (Nesmith & Dean, 2008). Schools educated students by following strict curriculums, focused on teaching sets of skills in lieu of concepts, and then used these skills to measure knowledge (Nesmith & Dean, 2008). Knowledge was viewed as discrete, hierarchical, sequential and fixed (Draper, 2002), where in the teacher's role was to provide clear and systematic demonstrations, reaffirm steps in response inquiry, allow practice opportunities, and offer corrective support as needed (Nesmith & Dean, 2008). Mathematical authority is derived from the textbook where the all the correct answers to the problems are known and found. This reliance on textbooks within schools had teachers forego their professional judgment with regard to what was suitable mathematical methodology and represent a transfer-of-information, drill-and practice approach to teaching (Nesmith & Dean, 2008). This outlook is in line with the behaviorist approach toward learning, which is founded on the idea that learning derives from the conditioning of external stimuli, either through association, which becomes instinctual or reinforced through rewards and punishments. The problem with this however is that only those adept in absorbing, accumulating, and regurgitating information in this format were the ones to excel. DGBL has often been looked to as solution to this problem. There is this assumption that combining instructional design with elements of fun enhances learning. However, if education and entertainment are to co-exist within digital learning environments the question many designers and researchers grapple with is how much 'edu' and how much 'tainment' should be included" (Okan, 2003).

Edutainment was once touted the savior of education because of the merging between entertainment and educational content, was said to effectively and efficiently teach diverse groups of students a variety of subjects. However, such games employ the

## Game Based Learning: Literary Review

“carrot and stick” instructional method. The drills are masked games where in learners complete a challenge and are then presented with an aspect of entertainment. These challenges and the game are distinctly separate. Additionally, these games tend to be linear, screen-to-screen, branching games, where the gamer takes on the role of a character “and simply moves through a single plot line—a third-person perspective similar to books, television, and movies” (Charsky, 2010). With taking on this third-party perspective, the user plays the role of the puppeteer, rather an active participant and creator of the narrative (Charsky, 2010; Gee, 2008). Furthermore, edutainment games fall short of encouraging higher level thinking and processing such as knowledge application, perception synthesizing, and evaluation. Rather their content contains predetermined curricula that lack sophistication and are heavily reliant on the lowest form of learning, drill and practice activities, thus they end up being no different from the traditional method of learning that takes place in classrooms. Ultimately, such games have resulted in some not-very-educational games and some not-very-entertaining learning activities (Charsky, 2010).

An example of is Math-City, a game in which fifth grade students were tasked to construct and maintain a city with residential, commercial, and industrial buildings, and renewable and non-renewable power sources. Similar to Sims, the main goal of the game is to create a city dwelling that keeps its residents happy. These happiness factors are based on five factors: Pollution, Police, Fire, Health, and Big Buildings. The game starts off as an empty grid to be built upon and a small amount of money to initially fund the building process (Polycarpou et al., 2010). Throughout various points of the game, players can answer different math questions with the purpose of earning more money. The amount of money earned is proportionate with the difficulty of the question correctly answered, though incorrect answers have no effect on existing funds. The math questions are based on fractions and word problems with difficulty dynamically adjusting based upon student performance on previous questions. Students are provided with instant feedback, which includes “the total number of questions attempted, the number answered

## Game Based Learning: Literary Review

correctly and incorrectly, and the percentage of correct answers” as well as a hint button which when prompted displays a “solution to a simple, related example” (Polycarpou et al., 2010). The problem with such games such as these is that they utilize extrinsic or exogenous fantasy as a way to reinforce the correct behavior or response to a challenge. The fantasy and the educational elements are separate entities, in which game designer could easily replace the educational components with any topic they choose without modifying the fantasy storyline or interrupting the flow of the game. The completion of the challenge, which in this case is to answer the question correctly results in the receipt of money to fund the building great city (Charsky, 2010; Kenny & Gunter, 2007). This is right in line with the Skinnerian behavioral approach, “where players are provided with tokens—including points, badges, play money, or publicly visible credits—contingent on exhibiting skills or completing tasks” (Slota & Young, 2014). While games such as these start out fun, “studies into and theories about cognitive load support the idea that the more immersed in the game’s fantasy context the content becomes, the more motivated the player learners will be to remain on task in order that they practice and reuse it thereby more deeply processing (i.e., learn) the material” (Charsky, 2010; Kenny & Gunter, 2007). In other words, games that utilize the concept of endogenous fantasy “have little to no disconnect between the game and the learning; the game’s fantasy aspects are not just a reward, but help develop the gamer’s knowledge (Charsky, 2010). Most players of too difficult games feel less competent and suffer from a reduced sense of challenge-skill balance and diminished enjoyment (Schmierbach, Chung, Wu, & Kim, 2014). It is important to state that despite the positive feedback received about this intervention, no students were actually evaluated using it, rather K-12 teachers were surveyed to gather feedback about the perceived functionality and game appeal.

In another study which evaluated the effect of OpenSim supported virtual environments on mathematical performance, results confirm the importance of endogenous fantasy or immersing a game’s storyline with the content being learned. In this study 132 fourth graders from five schools, were tasked with completing four

## Game Based Learning: Literary Review

fraction application tasks. Both the experimental and control groups received a digital based intervention, however only the experimental group's intervention included game characteristics of challenges, a storyline, immediate rewards, and the integration of gameplay with the learning content. The control group received web-based word problems. In other words, the experimental group's intervention was based off of an integrated fantasy. Though both groups experienced increased pre-posttest performance, students in the experimental group had higher scores than those in the control group, whose intervention did not include game characteristics (Kim & Ke, 2017). This goes back to what Kenny and Gunter (2007) discussed within their article Endogenous Fantasy – Based Serious Games: Intrinsic Motivation and Learning, which states “because the learner-player believes that the content is important to them (is relevant to them) because it is needed to solve a problem (i.e., move on to another level), he or she is ready and willing to invest in learning that content”.

Another area of contention which can negatively affect learning within DGBL is the inclusion of competition, despite inconclusive research findings. On one hand competition is seen an important component by which game developers claim positively learning through motivation. It has been found that competition increases enjoyment (Chen, Liu, & Shou, 2018), and triggers interest (Plass et al., 2013), which fosters attention, persistence, motivation, and cognitive-behavioral-emotional engagement that are important aspects in one experiencing flow (Chen et al., 2018; Csikszentmihalyi, 2008; Nebel, Schneider, & Rey, 2016). This is due to the fact that during competition, learners work harder to prove themselves, enhance their skills, and win thereby improving their knowledge. In 2009, a study conducted by researchers Cheng, Wu, Liao, and Chan (2009) suggested two things. First, that computers can create an equal learning environment for students. In a typical classroom, teachers do not have the ability to adjust to each student's individual learning style, rather they have to approach teaching from a more aggregate approach. With the continuous innovation of technology however, it is possible in DGBL environments to facilitate learning that is optimal and tailored to the

## Game Based Learning: Literary Review

individual via things like targeted feedback and adaptive curricular sequence presentation of content. An example of this was a study conducted in Ghent, Belgium where 74 second graders were tested to see how the DGBL intervention, *Monkey Tales* would affect their accuracy, speed, anxiety, and enjoyment. Students that used the DGBL intervention experienced much higher levels of accuracy, which researchers suggested may be due to the fact that students were offered specific exercises more in line with their math skills as a result of the adaptive algorithm in the game. This algorithm monitored player progression and automatically adjusted the difficulty level (but not the type of exercise) of the math exercises accordingly. Students when asked to describe the activity, significantly more often than not said it was “easy” (Cheng, Wu, Liao, & Chan, 2009). In other words, DGBL can level the playing field. Second, competition when structured appropriately and includes anonymity has the potential to provide every student with a sense of achievement, excitement, satisfaction, and flow regardless of proficiency level (Cheng et al., 2009). On the other hand, there is a lot of evidence that suggests competition potentially weakens a student’s intrinsic motivation to learn due to their focus being shifted from learning to winning. Furthermore, research suggests that competition may encourage hostility amongst students resulting in comparison negatively affecting a student’s perceived abilities, motivation to learn, and performance (Cheng et al., 2009). Additionally, competition may also constrain metacognitive skills, attention, and elaboration while creating an affective state of anxiety which is detrimental to learning” (Chen et al., 2018).

Part of the inconsistency within the debate regarding competition is attributed to the fact that competition in DGBL takes many forms; “for example, players may compete with themselves, with the game system, with other individual players, with other teams, or a combination of these to achieve game objectives” (Chen et al., 2018). In trying to solve this inconsistency Chen and colleagues conducted a study to investigate “whether competition as an element in a GBL environment affects a student’s flow experience and triggers different learning behaviors when compared to a non-competitive environment”

## Game Based Learning: Literary Review

(Chen et al., 2018). Fifty-seven junior high school students ages 13 and 14 in Taiwan participated in using the DGBL intervention SumMagic. SumMagic is a game that teaches science, “specifically, time, distance, position, and velocity. Learning objectives included: (a) to observe the timeline of an object’s movement, (b) to identify an object’s moving distance, (c) to define speed as a scalar quantity that involves a magnitude, and (d) to calculate an object’s speed from its moving distance and time data “ (Chen et al., 2018). Students were divided into two groups with only those in the competition condition having the ability to see a ranking board which showed their own ranking as well as their counterpart’s standing, score and time spent on completing the game. Results showed that students in the non-competition group, those that did not have access to the ranking board performed significantly better than those in the competition group. Researchers observed that students in the non-competition group spent majority of their time investigating the problem space and solutions, as well as utilized the support tools provided in the game. These students took time and read instructions prior to making observations, whereas students in the competition group heavily relied on surface learning that included trying different variables and observing the effects. This is because competition encourages faster and less carefully produced actions and increases the stimulation of the prefrontal brain activity (Nebel et al., 2016; Staiano, Abraham, & Calvert, 2012). Additionally, those within the competition group rarely requested help because they would have had to spend extra time reading and following the instructional supports. Essentially, students in the competition group were fixated on moving to the next step, rather than exploring other functions offered within the game environment (Chen et al., 2018). “These findings add to the existing literature that has explained how competition may harm the learning process by turning a project into a race to the finish line where understanding and internalizing concepts and knowledge becomes unimportant compared to winning” (Chen et al., 2018). Another study where 111 undergraduate students used a Minecraft based game as an intervention to learn how to program. Students were distributed into four groups: “solo play, one-versus-one (or duel)

## Game Based Learning: Literary Review

play, small group competition with the average group size of six, and classroom competition with the group size fifteen” (Nebel et al., 2016). Despite the analysis of the actual perceived challenge resulting in positive correlations with engagement, situational interest, and knowledge retention, introducing competition lowered focused attention and instructional efficiency while leaving situational interest unchanged. However, increased learning was observed by those who playing alone. This may be in part attributed to the fact that while competition has the potential to increase engagement, there can also be cases where learners may be distracted or lack engagement when witnessing the persistent winning of other students (Cheng et al., 2009).

### **Young Children**

Though young children are not a focus of this paper, it is important to consider the effect of digital based technologies on the way these little people live, play, learn, and socialize. In a 2005 survey of parents and caretakers about the use of pop culture, media and technology by young children Marsh et al. (2005) determined that young children were inundated with these from the time they are born. In 1970, regular TV viewership started at age 4 years of age, today however, children begin interacting with digital media at the tender age of 4 months old. This drastic change is due to the accessibility and prominence of technology within the household. Children of today grow up in a world that is increasingly digital which equips them with a variety of knowledge and skills such as “navigating effectively around screens, connecting and taking meanings from a myriad of interrelated images (still and moving), words and sounds” even when not exposed to computers (Wolfe & Flewitt, 2010). Between the ages of kindergarten and elementary school, these interactive digital mediums and particularly the use of computers depending on the frequency and experiences offered can have tremendous positive effect to learning. The potential gains are include “improved motor skills, enhanced mathematical thinking, increased creativity, higher scores on tests of critical thinking and problem solving, higher levels of what Nastasi and Clements (1994) term **effectance motivation** (the

## Game Based Learning: Literary Review

belief that they can change or affect their environment), and increased scores on standardized language assessments” (Haugland, 2000b).

However, this is not the same for infants and toddlers, and there is not enough empirical evidence regarding interactive media use in infants and toddlers to state otherwise. Research shows that very young children, 30 months or younger experience video deficit, which is the difficulty learning from 2-dimensional video representations. This may be attributed to the “lack of symbolic thinking, immature attentional controls, and the memory flexibility required to effectively transfer knowledge from a 2-dimensional platform to a 3-dimensional world” (Anderson & Pempek, 2005; Chassiakos et al., 2016). Before the age of two, “children are still developing cognitive, language, sensorimotor, and social-emotional skills, which require hands-on exploration and social interaction with trusted caregivers for successful maturation. Therefore, adult interaction remains crucial for toddlers to learn effectively from digital media” (Anderson & Pempek, 2005; Chassiakos et al., 2016). In other words, very young children, toddlers in particular “learn about their social world by following visual and verbal cues from adults”, and “have difficulty transferring what they see in one context to another (e.g., from a screen to real life)” (Lauricella, Barr, & Calvert, 2016). An example of this can be seen with toddlers ages 12 to 24 months of age, which begin to learn new words from videos or games that promote word learning; knowledge transfer will occur only if there is adult assistance to reteach the words, while using the digital device as a learning scaffold to build the language skills. Even in the case that recent research has shown that, under particular conditions, children between 15 and 24 months can learn sign language from repeatedly viewing video without adult help (4 times per week), a “comparison study group whose parents used a book of sign language symbols to teach the content retained more knowledge about the symbols’ meanings for a longer period of time” (Chassiakos et al., 2016).

Additionally, many games and applications that are labeled as educational are not properly designed to encourage high level knowledge transfer; rather they tend to either

## Game Based Learning: Literary Review

target rote learning skills (e.g., ABCs, colors), are not based on established educational programs, and/or include almost no input from developmental specialists or educators. Additionally, without adult involvement the inclusion of bells, whistles, rewards which are included to engage and motivate may decrease comprehension or distract children. The American Academy of Pediatrics (AAP) has recommended that pediatricians advise parents to avoid television and digital device-viewing entirely for children who are younger than 2 years and to limit the viewing time of older children to no more than 2 hours a day” (Vandewater et al., 2007). “They encourage parents to have their children engage in more interactive activities that do not require a screen which will promote proper brain development, such as talking, playing, singing, and reading together” (Vandewater et al., 2007).

### **Conclusion**

Learning is very complex; thus, educators and researchers are constantly looking for ways to improve how they can engage students, increase participation, and performance. Additionally, play is and still remains incredibly important to the early development of the way humans learn; however, as we grow, play is no longer a central part of education, thus learning becomes less fun. The introduction, proliferation, accessibility, and affordability of technology has changed the way we live our lives. Increasingly, we are living more digitally connected, which have transformed the way we connect, share, form relationships, entertain, and most importantly, learn. These factors combined have given rise to a growing field of research dedicated to understanding whether or not videogames created for educational purposes - DGBL, can affect, encourage, and foster learning (Plass et al., 2013). Though many consider DGBL as a way to transform the way students learn, especially in a society that is more technologically advanced and driven by being digitally connected, there are still those researchers and educators that deem it to be have little to no effect on learning. However, upon analyzing the learning theories of cognitivism, constructivism, and constructionism, the rise of digital natives, how learning for DGBL is measured, followed by when DGBL

## Game Based Learning: Literary Review

are effective and ineffective learning aids it is clear that when properly implemented, DGBL can and does encourage learning.

## Chapter 3: Methodology

### **Structuring DGBL Research Study**

Technology provides an enormous spectrum of possibilities by creating new and broadening existing approaches of teaching and learning. The research and professional literature suggest that technology, when properly leveraged and immersed into curriculums may enhance learning through cognitive, metacognitive and affective channels. Thus, the cognitive and metacognitive channels for improving learning by using technology are clearly strong and important to study (Barkatsas, 2005).

While there is evidence that shows digital games can be an effective tool to promote learning (Gee, 2003, 2008), research regarding its effect on developing algebraic thinking, performance and encouraging positive attitudes towards algebra over the traditional teaching methods still remain sparse (Siew, 2016). This explanatory sequential mixed methods case study sought to find out whether the implementation of DragonBox 12+ within Algebra 1 curriculum, could help promote algebraic thinking, and positively affect performance and attitudes towards algebra. The purpose of this chapter is to describe the procedures used to conduct and complete the research design. This chapter comprises of the game and research design description, research context, instruments to used measure performance and motivation, breakdown of participant sample, and how the data was analyzed to answer the proposed research questions:

**RQ<sub>1</sub>:** Is there a significant difference in the performance of students as determined by pre-post-test scores after being exposed to the gaming intervention?

**RQ<sub>1</sub> H<sub>0</sub>:** There will not be a statically significant difference in the performance of students as determined by pre-post-test scores after being exposed to the gaming intervention.

## Game Based Learning: Methodology

**RQ<sub>1</sub> H<sub>1</sub>:** There will be a statically significant difference in the performance of students as determined by pre-post-test scores after being exposed to the gaming intervention.

**RQ<sub>2</sub>:** Is there is a significant difference in the performance of students based upon age, as determined by pre-post-test scores?

**RQ<sub>2</sub> H<sub>0</sub>:** There will not be a statically significant difference in the performance of students based upon age, as determined by pre-post-test scores.

**RQ<sub>2</sub> H<sub>1</sub>:** There will be a statically significant difference in the performance of students based upon age, as determined by pre-post-test scores.

**RQ<sub>3</sub>:** Is there a significant difference in the performance of students based on their grade as determined by pre-post-test scores?

**RQ<sub>3</sub> H<sub>0</sub>:** There will not be a statically significant difference in the performance of students based on their grade as determined by pre-post-test scores.

**RQ<sub>3</sub> H<sub>1</sub>:** There will be a statically significant difference in the performance of students based on their grade as determined by pre-post-test scores.

**RQ<sub>4</sub>:** When introducing a serious game intervention, is there a correlational relationship between a student's openness to technology as determined by the Attitudes toward Math Learning Questionnaire and the amount of time students spend playing the serious game?

**RQ<sub>4</sub> H<sub>0</sub>:** The correlation coefficient for the student openness to technology as determined by the Attitudes toward Math Learning Questionnaire and the amount of time students spend playing the serious game is not significantly different from 0.

**RQ<sub>4</sub> H<sub>1</sub>:** The correlation coefficient for the student openness to technology as determined by the Attitudes toward Math Learning Questionnaire and the amount of time students spend playing the serious game is significantly different from 0.

## Game Based Learning: Methodology

Based upon prior knowledge and assumptions, it is expected that results will prove the alternative hypotheses of the first three research questions correct and there will be significant differences in terms of age, grade, and performance after the DGBL intervention. It is also assumed that the level of student openness will correlate to the amount of time spent playing the serious game.

### **Participants**

According to the Pew Research Center, 29% of Americans rated STEM K-12 education as above average or the best in the world despite most ranking math as one of the most important skills children need today (Cary Funk & Rainie, 2015). As it currently stands, the United States ranks 38th in math on the Programme for International Student Assessment (PISA), a cross-national test that measures the reading ability, math and science literacy and other key skills amongst 15-year-olds in 71 developed and developing countries (DeSilver, 2017). These statistics are alarming to researchers and educators alike, considering how important STEM related disciplines and education, and in particular the role of math is becoming in the modern world. As a result, many are seeking creative ways such as DGBL to increase student confidence, engagement, and proficiency in math.

Though there has been a lot of focus on DGBL for elementary aged students, research on those middle school and early high school aged students (depending on the district middle school can start as early as 6th grade) taking Algebra 1 still remains sparse. This is a huge problem for several reasons. Not only is “algebra is one of the few major domains of mathematics that students’ study from preschool to twelfth grade,” it is considered to be a gatekeeper to higher-level math such as Geometry, Algebra 2, Trigonometry, and Calculus and a predictor of high school graduation (GreatSchools Staff, 2018). Results of a longitudinal study that examined the high school graduation patterns of approximately 13,000 middle school students in an urban district showed that only 13% of students who failed a math course in sixth grade graduated on time. An additional 6% graduated one year late, with the remaining 81% not graduating by the

## Game Based Learning: Methodology

time the study ended (Balfanz et al., 2007; “Math Milestones: The Critical Role of Math Achievement in Student Success,” 2018).

Furthermore, when accounting for demographic traits, socioeconomic status, family and school characteristics, and overall measures of math ability (i.e., math GPA and grade 10 math test score) research shows that the higher the level of math completion, the higher the probability of college graduation and increased annual earnings. Even 10 years after high school, students who had completed a calculus course prior to graduation were found to “earn 65% more than students whose math education did not progress past a vocational math course” (“Math Milestones: The Critical Role of Math Achievement in Student Success,” 2018). In Northwest Arkansas, Algebra 1 is taken between 7th and 9th grade. Considering these factors, the sample of participants for this research were deliberately selected from the population of 7th, 8th and 9th grade students enrolled in the Algebra 1 within the Northwest Arkansas region.

The Northwest Arkansas Region consists of 15 school districts – Bentonville, Fayetteville, Rogers, Siloam Springs, and Springdale make up the big five and Decatur, Elkins, Farmington, Gentry, Gravette, Greenland, Pea Ridge, Prairie Grove, and West Fork make up the remaining ten. These districts have a total enrollment of 88,566 students, in which the per student expenditure is less than that of the state of Arkansas, \$9,563 versus \$10,005, but the graduation rate is slightly higher at 90% versus 89% (McKenzie, 2019). Participants in this study were 7th, 8th and 9th graders that came from the Bentonville school district, which is the second largest district within the Northwest Arkansas Region. Of the 17,225 students enrolled as of the 2019 school year in Northwest Arkansas, 14.2% of students were in junior high (7th - 8th grade) dispersed across three schools, and 29.27% of students were in high school (9th - 12th grade) dispersed across two schools (School Report Card, 2018). Based off the report card listed on the Arkansas Department of Education Data Center website, 7th- 9th grade students classified as ready or exceeding performance in math in comparison to the state and are significantly higher within the Bentonville school district; 74.42% of 7th graders in

## Game Based Learning: Methodology

Bentonville versus 47.38% in Arkansas are classified as ready or exceeding performance, 66.53% of 8th graders in Bentonville versus 47.49% in Arkansas are classified as ready or exceeding performance, and 57.14% of 9th graders versus 35.64% in Arkansas are classified as ready or exceeding performance (School Report Card, 2018). The average class size in the Bentonville School District is 20 students, with 13 years as the average years of teaching experience held by the teachers. As of 2019, 23% of students were on reduced/free lunch, and 10% were eligible to receive special education.

In December of 2015, the Arkansas Department of Education passed the Every Student Succeeds Act (ESSA) as a way to “provide all children significant opportunity to receive a fair, equitable, and high-quality education, as a way to close educational the achievement gaps” (Division of Elementary and Secondary Education, 2020). The ESSA is made up of five indicators - achievement, growth, English learner progress toward English proficiency, graduation rate, and school quality and student success. Of the five indicators, three factors - achievement (35% of the overall score), growth (50% of the overall score), and school quality and student success (15% of overall score) make up the score. The achievement score measures how well students perform on the state’s annual exams. Growth scores measure the increase of individual student achievement scores from year to year (McKenzie, 2019). School quality and student success scores, though relatively “new includes measures like student attendance, reading at grade level, science achievement, and science growth” (McKenzie, 2019). In terms of Bentonville ESSA scores, both middle school and high school ratings are significantly higher than that of the state.

In addition to ESSA, schools are given a National Assessment of Educational Progress (NAEP) rating “which assesses student performance in mathematics at grades 4, 8, and 12 in both public and private schools across the nation. NAEP achievement levels define what students should know and be able to do. A rating of Basic indicates partial mastery of fundamental skills, Proficient indicates solid academic performance and competency over challenging subject matter, and Advanced indicates superior

## Game Based Learning: Methodology

performance beyond proficient” (NAEP, 2019). Though eighth graders within the Bentonville school district are slightly below the national average there has been a steady increase from 2015 (NAEP, 2019; School Report Card, 2018).

### **Research Design**

This research employed an explanatory sequential mixed methods case study design of both students and teachers. This methodology was chosen to examine the effects of the DGBL intervention DragonBox 12+, with a focus on confidence toward mathematics and learning performance. In selecting this method, along with the procedures of the study, the following factors regarding the appropriateness of a case study method, the DragonBox 12+ intervention, and three hours as the time allotment were analyzed.

**A Case for Case Studies.** A case study is a detailed exploration of multiple perspectives ranging in complexity and uniqueness of a particular project, policy, institution, program, or system in a real-life context. “It is research-based, inclusive of different methods and is evidence led. Its primary purpose is to generate an in-depth understanding of a specific topic” (Cook & Kamalodeen, 2019). Cases are constrained by time and activity, and researchers collect detailed information using various data collection procedures over a sustained period of time” (Crestwall & Plano Clark, 2017, p. 14). A mixed methods case study design takes this approach a step further by collecting both quantitative and qualitative data and results, to provide in-depth evidence or develop cases for comparative analysis (Crestwall & Plano Clark, 2017, p. 116). The strengths of employing this method, are that it allows multiple complex questions to be answered with a certain level of depth and clarification, due to it being a multidisciplinary approach. Additionally, this method allows for the exploration of contradictions that may appear between quantitative results and qualitative findings,” while also providing a great range of flexibility which can be “adaptable to many study designs, such as observational studies and randomized trials, to elucidate more information than can be obtained in only quantitative research” (Wisdom & Creswell, 2013). Lastly, mixed methods give a voice

## Game Based Learning: Methodology

to study participants and ensure that study findings are rooted in their experiences while adding breadth and depth to richness of the data collected (Wisdom & Creswell, 2013). Though utilizing such a method has many great benefits, challenges however, can emerge regarding the level of research expertise required to gather and collect data, length of time it takes to complete the research, and effort required to design a study that integrates both approaches appropriately. These challenges are significant enough to present major roadblocks to leveraging this method.

**A Case for DragonBox 12+.** To determine the appropriate intervention, a criteria of four rules were established. The intervention must be easy to obtain, requires little to no experience, created for the purposes of teaching Algebra, and had been used in previous research regarding gaming and learning. After researching various games and conducting an analysis based upon the aforementioned criteria, DragonBox 12+ was selected. Outside of the cost of the game, which would be covered by the researcher, it could be easily downloaded on a smartphone, required no background knowledge for play, and was created specifically for the purposes of helping students learn the foundations of Algebra 1. Additionally, there were two recent studies uncovered where DragonBox 12+ was used as the DGBL intervention. The first study uncovered comprised of 33 middle school mathematics teachers “enrolled in a course designed to prepare preservice middle childhood educators to teach mathematics in urban, suburban or culturally diverse middle school classrooms,” DragonBox 12+ was the DGBL tool that was utilized. The purpose of the study was to understand if incorporating simulation games would increase mathematics teaching efficacy and prepare as well as encourage teachers to incorporate technology and innovative teaching tools in their classrooms (Cates, 2018). The second study uncovered wanted to understand the effects of introducing and using a specific mathematical video game on “cognitive, affective, and content-retentive learning outcomes of eighth graders studying elementary algebra for the first time” (Galarza, 2019). Considering that DragonBox 12+ was able to meet all the predetermined criteria, in addition to the fact that both studies were using a portion of the

selected population that were going to be used in this particular study, it was selected as the intervention of choice.

**A Case for Time Allotment.** The time allotment given to complete the study was three hours. It can be argued that three hours is not enough time to determine whether actual learning has taken place, however this condensed time allotment was selected primarily for three reasons: (a) the inability to control for confounding variables, (b) the role of behavioral observation, and (c) the sensitivity of the population. “Confounding variables or confounders are often defined as the variables that correlate (positively or negatively) with both the dependent variable and the independent variable. A confounder is an extraneous variable whose presence affects the variables being studied so that the results do not reflect the actual relationship between the variables under study” (Pourhoseingholi et al., 2012). In other words, without having a controlled environment there would be no way for me to determine and ensure that outside variables such as time of day the student played, length of play or additional play were equivalent for every student. There would be no way to ensure that all students followed the same procedure in the exact same way, thereby making it incredibly difficult to ascertain that whether the intervention exposure effected performance, and thereby reducing internal validity of the relationships established by the results. Additionally, the predetermined time allowed for behavioral observation to be possible. As it currently stands, this method is one of the most widely used assessment strategies in schools to date. “Given its flexibility and ease of use, behavioral observation procedures can be used to collect a range of data that provide helpful information and are useful for making a variety of psychoeducational decisions. Because of its direct nature, behavioral observation is particularly well suited for everyday life settings and can provide a systematic record of behavior that can be used in preliminary evaluation, intervention planning and design, the documentation of changes over time, and as part of a multimethod–multisource evaluation that integrates other forms of assessment (e.g., interviews and rating scales) and sources (e.g., teachers, parents, and children)” (Hintze, 2004). Lastly, the subjects being researched, children are

## Game Based Learning: Methodology

considered a protected class. There are certain protocols that researchers must follow when interacting with such subjects. Choosing a preselected time, with a clearly defined start and stop was done to circumvent any potential concerns that may arise by parents allowing their children to participate.

Keeping these factors in mind, the study was designed, and all student participants were to complete the study in the exact order as follows:

1. Download DragonBox 12+ and have it purchased by the researcher;
2. Complete the demographic study;
3. Complete the pretest to establish a baseline of student's algebraic thinking and performance;
4. Be exposed to the intervention (playing DragonBox 12+) with think out loud interview conducted simultaneously;
5. Complete the posttest to assess algebraic thinking and performance;
6. Complete the Attitudes to Technology in Mathematics Learning questionnaire to capture attitudes; and
7. Participate in an in-depth interview to gain uncover perspectives (Ku et al., 2014).

Upon the completion of these tasks during the allocated time, students would be provided a \$25 Walmart gift card as remuneration. Due to each student serving as their own control group, the potential for history effects due to exposure of the pretest and having to take the post-test after the intervention exists.

The teacher participants were given a week to download, play and familiarize themselves with the DragonBox 12+ game. To accommodate schedules, teachers were given 2 weeks within playing the game to create the pre-posttest assessments and respective answer keys. In depth interviews were scheduled and conducted, within a week of this familiarization. Immediately following the interview, teachers were sent both the demographic and teacher survey to complete via Survey Monkey. For their

## Game Based Learning: Methodology

participation, each teacher was given a \$108 Walmart gift card as remuneration, which included the \$7.99 purchase of the DragonBox 12+ game.

### Setting

Northwest Arkansas is the moniker given to the rapidly growing cities within Benton, Madison, and Washington counties with a population of 549,128 residents as of July 1, 2018, according to the Northwest Arkansas Council and U.S. Census Bureau. Aside from this, it is the home to three Fortune 500 companies, Walmart (No. 1), Tysons (No. 8), and J.B. Hunt Transport Services Inc (No. 354) as well as suppliers and vendors that services these corporations (*Our Region By the Numbers*, n.d.). As a result of these companies, the region has experienced rapid population growth over the last decade, “increasing by more than 20% since 2010. U.S. Census estimates show the region’s population experiences a net gain of 30 people per day, with the expectation that the population to grow an additional 10% by 2024” (Peacock & Lemaster, 2020). In terms of demographics, the region’s racial and ethnic populations have increased from “less than 5% in 1990 to nearly 24% in 2010. As of 2019, the region was nearly 28% diverse and is expected to grow to almost 31% by 2024.” The breakdown is as follows, Whites (72.0%), Black/African America (2.4%), Asian (3.3%), Hispanic/Latino (16.7%), Two or more races (2.7%), American Indian/Alaskan (1.4%), and Hawaiian/Pacific Islander (1.5%) (Peacock & Lemaster, 2020).

Bentonville’s 50,061 residential population closely mirrors the Northwest Arkansas region population percentages: Whites (70.4%), Black/African America (3.8%), Asian (11.6%), Hispanic/Latino (9.9%), Two or more races (2.8%), American Indian/Alaskan (1.1%), and Hawaiian/Pacific Islander (.04%) (Peacock & Lemaster, 2020). In terms of economy, as of December 2019, the unemployment in the region was incredibly low at a rate of 2.5% with the median household income being \$79,259. The most common employment sectors are retail trade, professional, scientific and technical services, and health care and social assistance (*Bentonville, AR | Data USA*, 2020).

## Game Based Learning: Methodology

To accommodate parents and participants, the study settings ranged from the local Starbucks, Bentonville Public Library and one participant's home office within the city of Bentonville.

### **Sampling Procedure**

The sample consisted of 11 students (between the ages of 13 and 15 years old) selected through random sampling. Random sampling is simple and allows for an unbiased approach to garner the responses from a larger group. In this particular research, students in grades 7-9<sup>th</sup> were selected as the population, due to the fact that in Arkansas, these are the grades that the enrollment in Algebra I occurs. The primary goal for this sampling procedure is to get a representative sample from a small number of individuals that are not only representative of the bigger population, but can produce accurate generalizations about the population being targeted (Mohd Ishak & Abu Bakar, 2014). Furthermore, removal of statistical analysis allows for "more creative in dealing with sampling issue, because the results cannot be generalized to a bigger population, and only analytical generalization can be conducted where a particular set of results is generalized to a broader theory" (Mohd Ishak & Abu Bakar, 2014). Utilizing this method, however, does increase the likelihood of the sampling error and inevitably bias, due to the small size. Second, to ensure that a true random sample is selected, the characteristics of the whole population should be known, which is not necessarily possible with qualitative studies. Additionally, "random sampling of a population is likely to produce a representative sample only if the research characteristics are normally distributed within the population. There is no evidence that the values, beliefs and attitudes that form the core of qualitative investigation are normally distributed, making the probability approach inappropriate" (Marshall, 1996). Last but not least, not all participants are the same in terms of how they express themselves, thus some participants provide richer context, understanding and answers than others, which can affect the quality of data collected (Marshall, 1996).

## Game Based Learning: Methodology

Due to previous research regarding the characteristics of this sample population, their attitudes toward learning and utilizing technology, as well as gaming and learning in general this method was deemed as appropriate. This research was focused less on a sample's representativeness or on detailed techniques for drawing a probability sample (Mohd Ishak & Abu Bakar, 2014; Neuman, 2009). Rather it was done to illuminate the social life or the phenomenon being studied and “collect specific cases, events, or actions that can clarify or deepen the understanding about” DGBL interventions for middle school students taking Algebra 1 (Mohd Ishak & Abu Bakar, 2014).

### **Recruiting Participants**

To gather participants for this research, initially, the head of research for Bentonville Public Schools was contacted. The goal was to be given permission to market the study within various schools within the Bentonville School District. Unfortunately, after several weeks of back and forth and then silence, this effort was abandoned. The next attempt was with the office of the superintendent of Fayetteville Public Schools. The goal remained the same – get permission to market the study within the Fayetteville School District. After having a promising meeting, followed by multiple attempts over three months to follow up, this effort was abandoned. The next option to recruit students was to reach out to individual school principals within Bentonville. Due to the small number of schools to contact - three junior high and two high schools within Bentonville – this seemed promising. After calling three of the five schools multiple times and sending multiple emails, this effort was abandoned. The last resort was to reach out to coworkers and turn to social media (Facebook). Coworkers were provided detailed information regarding the study, as well as a flyer to share amongst their networks. In addition to this, a post was made on two closed Facebook Groups: Multicultural Mommas of NWA and NWA Moms in the KNOW to recruit participants. From both of these avenues, participants - students and teachers joined the study.

### **Intervention: The DragonBox 12+ application**

After noticing that many of his students struggled with algebra, despite their intelligence and eagerness to learn, Jean-Baptiste Huynh a high-school math and economics teacher in Norway decided to turn to games as a way to remedy this situation. To his dismay existing games fell short and he became increasingly frustrated with their quality and ability to create a bigger picture in terms of math (Huynh & Marchal, 2018). He decided to take matters into his own hands and collaborated with designer, Dr. Patrick Marchal, a professor in cognitive science to create the DragonBox game series. The DragonBox series consists of several games, two of which focus on algebra – DragonBox 5+, for children five and up and DragonBox 12+, which specifically targets students ages 12 and up. The apps were created to assist students in the learning the basics of algebra incorporating math concepts such as the “property of addition and subtraction, expansion, operations of variables, and factorization or substitution” (Siew, 2016). In DragonBox 12+ in particular, the game contains many representations of concepts central to the algebraic equation-solving process although it does not initially utilize notations and representations found in equation solving. According to Dolonen and Kluge’s (2015) description of the game, “[each stage] consists of two large fields corresponding to the two sides of an equation, along with a storage located underneath consisting of objects that can be pulled out and placed within the two fields.... A level ends when the main symbol—the dragon box (and later an “x”)—stands alone in one field” (Dolonen & Kluge, 2015; Galarza, 2019). In other words rather than have algebra always shown explicitly as players advance, it progressively moves their gameplay towards stages that appear to mimic the same concepts that would be found in equations implicitly (Galarza, 2019).

Aside from the algebraic concepts, DragonBox 12+ along with the other games within the DragonBox franchise were designed with the RETAIN Model in mind. The RETAIN Model is an evaluation tool for educational games to determine how well pedagogy is endogenously woven within the game’s fantasy and story, as well as the

## Game Based Learning: Methodology

extent to which the game promotes the transfer of knowledge, and encourages repetitive usage until the actions of players become automatic (Gunter, Kenny, & Vick, 2008). Developed by researchers Gunter, Kenny & Vick, the RETAIN Model stands for the dimensions of Relevance, Embedding, Translation, Adaptation, Immersion and Naturalisation.

**Relevance.** The first dimension Relevance deals with presenting content to players in a way that is relevant to the learner and applicable not just to their needs but the other elements that are present within the game. To do this, DragonBox 12+ game is structured in a progressive unit by unit method, which is age appropriate, targeted, clearly defined, related to and builds upon the content being learned in an Algebra 1 class as well as the game (Gunter et al., 2008; Siew, 2016). Very early on in the game, players are able to establish mathematical rules so that they can learn how to play the game. The instructions clearly define the structure of the game, passing along the understanding to the player that there are two fields on the screen, which are expressed via two rectangles (Nordahl, 2017). Players are unable to advance through game without having a firm understanding the rules or the significance of the shapes (Cates, 2018).

**Embedding.** The second dimension Embedding refers to how well pedagogy is endogenously woven within the game's fantasy, story, and game structure. DragonBox 12+. An example of this is in order to win or progress to the next level the player has to get a box alone on either side (Nordahl, 2017). Players are provided drag, drop and tap to disappear capabilities, which allow them to establish patterns within the game, isolate the box on one side, while building their dragon and creating balanced equations without realizing it (Gorrell, 2014). Players must decide which of these actions will lead to the isolation of the box on one side of the board. These decisions mimic what an actual Algebra student would have to do when solving for a variable, putting emphasis "on the relationship of solving equations over varying interacting inputs and targeted outcomes" (Cates, 2018). As the player continues to engage and move throughout the game, they are presented with opportunities to solve problems that are similar but get progressively

## Game Based Learning: Methodology

harder and within the different scenarios. “The player is introduced to the different tiles and told that each tile has a ‘dark side’ which represents ‘negative numbers’” (Nordahl, 2017). As they continue to progress through the five game levels, which each level has 20 sublevels within it, new actions are intermittently introduced with an interval of every four to eight sublevels. The actions can vary in activity from adding extra tiles to multiplying the factors. Each of these actions teach the player an algebraic rule according to the developers thereby reinforcing pre-existing knowledge and using those schemas to create new knowledge while watching how their actions affect their dragon.

**Translation and Adaptation.** The ability to apply and create knowledge in different ways coupled with the progression from easy to complex in an interactive environment, are examples of both Translation and Adaptation, which are the third and fourth dimension within the model. The instant feedback provided by the interactive nature of the game and dragon transformation which is a direct result of the player encourages experimentation and a vested interest in what happens to the dragon.

**Immersion.** The investment of time playing the game and emotional response or reaction to the game are examples of Immersion, the fifth dimension within the model.

**Naturalization.** The last element, Naturalization occurs when the actions become habitual, automatic even when they are spontaneous which is evidenced as the player progress throughout out the game (Gunter et al., 2008; Siew, 2016).

### **Data Collection Instruments**

In order to collect data for this study, the following instruments were utilized: Attitudes to Technology in Mathematics Learning Questionnaire (ATMLQ), pre-posttests, and interviews.

**Attitudes to Technology in Mathematics Learning Questionnaire (ATMLQ)** - see Appendix B. Though the Fennema-Sherman which was created in the 1970’s, has been often used as a standard tool for measuring student attitudes towards math, especially when these attitudes are not the primary focus of the study but rather viewed as one factor to be possibly considered when evaluating the success of a curriculum or

## Game Based Learning: Methodology

teaching innovation. It is lengthy, with 108 items, which over time has proven to become somewhat outdated (Barkatsas, 2005). In 2001, Fogarty et al. (2001) validated the Attitude to Technology in Mathematics Learning Questionnaire (ATMLQ), which is a 37 item measurement “developed to assess students’ mathematics confidence, their computer confidence, and their attitudes to the use of technology,” (Fogarty et al., 2001). Unlike the Fennema-Sherman scales which contains “separate measures of attitudes to computers and attitude to mathematics learning, the ATMLQ targets the tertiary population and includes a scale that is designed to capture attitudes to situations wherein students are expected to use computers to learn mathematics” (Cretchley et al., 2000). Each statement is measured by a five-point Likert-hierarchy, with options ranging from 1 (Strongly Agree), 2 (Agree), 3 (Neutral), 4 (Disagree), to 5 (Strongly Disagree). The three scales utilize a mixture of positive and negative worded statements, where in most of the statements are negatively worded. This is intentionally done to provide educators with information regarding student views towards the use of technology, particularly digital games and mathematics. For the purposes of this research, 35 items were chosen. The 11 of the 12 items chosen to measure mathematics confidence, particularly Algebra, came from a scale developed by Fogarty and Taylor (1997) as part of their research on the effect of learning styles on achievement in mathematics, and the 12<sup>th</sup> item was developed as a part of the Mathematics and Technology Attitudes Scale. Items for the computer confidence scale used the similar statements as the ones included in the mathematics confidence scale, with the word “digital games” substituted for “mathematics”. For example, “It takes me longer to understand mathematics than the average person” (Mathematics Confidence) became “It takes me longer to understand digital games than the average person” (Computer Confidence). To address the need for a scale that focused particularly on attitudes toward mathematics/technology interaction, Cretchley, Harman, Ellerton, and Fogarty (2000) created 15 items scale that focused on the students’ feelings about situations that involved the use of technology as a medium to learn mathematics of which 11 items were used. For this research purposes, the term

“technology” was interchanged with “digital games,” due to it being the technological device used.

In order to get more distinctive answers, for the purposes of this research the ATMQL 5-point Likert scale was modified to be a 7-point Likert scale. In 1956, George Miller argued that the human mind has a span of absolute judgment that can distinguish about seven distinct categories, a span of immediate memory for about seven items, and a span of attention that can encompass about six objects at a time (Colman et al., 1997). Furthermore, research has shown that several indices of reliability, validity, and discriminating power are significantly higher for scales with more response categories, up to about 7. Additionally, when considerations of face validity rather than time are paramount, it may be important for the respondents to perceive the scales as allowing them to express their feelings adequately thereby having larger scales may be most appropriate (Preston & Colman, 2000).

**Pre-Post Test.** To measure understanding of the algebraic thinking and performance, students were required to complete a pretest and posttest. The pre-test was given to all students prior to the treatment to determine their prior knowledge of algebra and also establish initial equivalence amongst the different groups. The post-test was given to measure treatment effects. The format for both pre-test and post-test were similar – two multiple choice questions in the beginning, followed by six open equations, and closing with a word problem. These instruments were created through participatory design by two Algebra 1 teachers at Thaden School, a private combined middle and high school located in Bentonville. The math teachers were utilized to determine the appropriate number of the test items (nine problems), content range, and approximate time allocation for completion, which was designed to be no more than 15 minutes (Kim & Ke, 2017).

**Interviews.** To gain an in-depth understanding of student participant experiences, interviews were conducted. These interviews allowed for the identification of unique patterns and categorization of similarities and differences across participant responses

## Game Based Learning: Methodology

and activities, with the goal of finding the recurring themes and organizing the data systematically. Furthermore, interviews were conducted to “encourage students to express a range of significant reactions, facilitate better understanding of these reactions, check and validate trends identified by the surveys and questionnaires, identify different learning styles and preferences, and enable valid comparisons” (Cretchley et al., 2000). Lastly, interviews provide an explanation for the data and interpretations of findings because they are experiences had by real people, rather than abstract theories or principles (Cates, 2018). This allows for the capture of rich context, that though subjective is still important to take into consideration (Ke, 2008).

There were two types of interviews conducted. The first was a think out loud interview where only student participants were asked to think out loud while playing the game. According to Vygotsky,

A speaker often takes several minutes to disclose one thought. In his mind the whole thought is present at once, but in speech it has to be developed successively.... Precisely because thought does not have its automatic counterpart in words, the transition from thought to words leads through meaning... and then through words. (Vygotsky, 1962, p. 150)

Thus, the think-aloud method encourages participants speak aloud any words in their mind as they complete a task. The goal is to gather insight into the processes of working memory, due to the fact that the information captured within it is held briefly and can disappear as soon as new thought patterns emerge (Charters, 2003). “For this reason, only verbal reports which follow very rapidly after a thought process can be supposed to accurately reflect conscious thought” (Charters, 2003; Olson et al., 1984, pp. 253–286). For this reason, researchers must focus on the participants’ “immediate awareness,” not delayed explanations for their actions (Charters, 2003; Olson et al., 1984, pp. 253–286). The questions remained in the same line of prodding for each participant:

- Tell me your thoughts so far...how do you feel?

## Game Based Learning: Methodology

- Why did you make that face/reaction/sound?
- You are still playing, why?

The second set of interviews, which both students and teachers participated in were semi-structured, with the presence of a guide to ensure everyone was asked the same questions. To ensure reliability and validity, all interviews were audio recorded, transcribed, and the data was codified and triangulated with the other data collected (Cates, 2018). These interviews ranged between ten and fifteen minutes for students and roughly an hour for teachers. Clarifying questions were asked when it was deemed necessary. Advantages of the interview method include direct access to research phenomena, high levels of flexibility in data gathering, and the ability to capture of expressions, comments, reactions, and clarification of interpretations regarding their experience with the game in real time. At the same time, the disadvantages of these interviews are longer time requirements, increased levels of observer bias, and the effect of the observer on primary data, in a way that presence of researcher may influence participant behavior (Dudovskiy, 2018).

### **Validity Check**

There is a widespread agreement among scholars that the “interaction of pretesting and treatment comes into play when the pretest sensitizes participants so that they respond to the treatment differently than they would with no pretest” (Dimitrov & Rumrill, 2003, p. 160). As Bellini and Rumrill (2009) mention there are several threats to the external validity of the study. These threats include interaction effects of selection biases and treatment, reactive interaction effect of pretesting, reactive effect of experimental procedures, and multiple treatment interferences. In an experiment design where subjects are assigned randomly, a testing threat arises when the pretest and posttest are the same. The potential for testing threat can affect the internal validity of the study. This is because the pretest may prime the subjects toward the posttest, which may result in a better posttest score where the improvement in the scores is not due to intervention (Shadish, Cook & Campbell, 2002, Trochim, 2000). Additionally, there is the risk of

## Game Based Learning: Methodology

instrumentation threat, by having the pre-posttest being completely different from one another. In order to avoid sensitization, priming, and instrumentation threat the pre-posttest materials were created with the same question format, but different items for each instrument.

Another consideration to be accounted for is the time difference between instrument exposure. When the time difference between taking the pretest and taking the posttest is short in duration, students might be even more sensitized because of the exposure to pretest. For this reason, there was time built in within the procedures to separate the time of exposure to the pretest and posttest. On average the duration between the exposure to the pretest and exposure to the posttest assessments was about 25-30 minutes.

### **Researcher's Position**

In preparation for the study, the game DragonBox was played by the researcher in order to ensure familiarity and an understanding of the game. Due to concerns regarding bias and researcher effects, students were not provided with any instructions or assistance while playing the game or completing the pre-posttests. Additionally, students were made aware that they could stop at any time.

### **Research Plan Analysis**

This study utilized both quantitative and qualitative measures as forms to measure the results. The demographics questionnaire, was used to gather participant identity data, that would allow for the further grouping of results based on factors such as race, gender, math proficiency, etc. The Attitudes to Technology in Mathematics Learning Questionnaire and Teacher Survey and were administered to gather student towards learning math and teacher attitudes towards utilizing technology while teaching math. These instruments provided additional background on the participants and aided in the explanation of possible results of pre-posttest exams for students, and interview for teachers. The in-depth interviews served to further explore the thoughts and viewpoints of all participants. The overall hypothesis of the study was that if the more comfortable

## Game Based Learning: Methodology

with technology students are, and the more they use it in their everyday life, the more likely they would be to see the videogame intervention as an asset thereby performing better after being exposed to the intervention.

## Chapter 4: Results

### **Results of DGBL Study**

When leveraged and correctly immersed into education, research shows serious games have the potential to enhance learning through cognitive, metacognitive and affective channels. However, research regarding the effect of serious games on developing algebraic thinking, increasing performance and encouraging positive attitudes towards algebra over the traditional teaching methods still remains sparse (Siew, 2016). Thus, this pre-posttest quasi-experiment case study, sought to find out whether utilizing the serious game, DragonBox 12+ as an intervention could help promote algebraic thinking, and positively effect performance and attitudes towards algebra. The purpose of this chapter is to discuss in detail the process used to analyze the data and the results of the study as they relate to answering the proposed research questions:

1. When introducing a serious game intervention, is there a significant difference in the performance of students as determined by pre-post-test scores?
2. When introducing a serious game intervention, is there a significant difference in the performance of students based on their grade as determined by pre-post-test scores?
3. When introducing a serious game intervention, is there a significant difference in the performance of students based on gender?
4. When introducing a serious game intervention, is there a correlational relationship between a student's openness to technology as determined by the Attitudes toward Math Learning Questionnaire and the amount of time students spend playing the serious game?

### **Sample Analysis**

There were two distinct groups of participants that were a part of the study, over the course of three months from January 2020 to March 2020. One set of participants consisted of eleven students, whereas the other set consisted of three teachers. Each

## Game Based Learning: Results

group had their own distinct tasks flows that they were required to complete. For students, their task flows were broken into four sections – a. part one: demographic survey, b. part two: assessments and intervention, c. part three: attitude towards math survey, and d. part four: in-depth interview. Part one, or the demographic survey was used to gather information regarding race, gender, expertise, and digital game playing preferences. Part two, was used to set the baseline and measure the effects of the intervention. Part three, gathered student perceptions, and part four, allowed for the exploration of these perceptions and ideas students had regarding DGBL. For teachers, their task flows consisted of three sections - a. pretest-posttest instrument creation and answer key creation via participatory design, b. part two: teacher survey, and c. part three: in-depth interview. Part one, the creation of the pre-posttest instruments and answer key were used to assess student performance. Part two, was used to gather both teacher demographics and perception towards technology data. Lastly, part three allowed for the exploration of these perceptions and ideas teachers had regarding DGBL.

### **Student Demographics**

To understand the demographics of the sample population, a student survey was conducted (**Refer to Appendix E**). In terms of age, 14-year old's made up the majority of the sample at 55%, followed by 13-year old's at 36%, and lastly 15-year old's at 9%. To determine whether the ages within the sample were normal, a Shapiro Wilks test was conducted.

Created in 1965 by Samuel Shapiro and Martin Wilk, the Shapiro Wilks test is a correlation-based analysis. It is based upon the amalgamated null hypothesis that the data is independent, identically distributed, and normal (*NIST/SEMATECH e-Handbook of Statistical Methods: 7.2.1.3. Anderson-Darling and Shapiro-Wilk Tests*, 2012; *The Shapiro-Wilk and Related Tests for Normality*, n.d.). It uses an ordered sample to get the W statistic, which determines the normality of the data. The smaller the values of W, the more evidence of departure from normality. When conducted for age, the Shapiro-Wilks  $p\text{-value}_{\text{age}} = .0108 < .05 = \alpha$ . This result indicates a rejection of the null hypothesis,

## Game Based Learning: Results

thereby suggesting that data lacks a normal distribution. Similar to age, the sample was highly concentrated around a particular grade - 8<sup>th</sup> grade. Eighth graders comprised of 64% of the sample population, with 9<sup>th</sup> graders following behind at 27% and 7<sup>th</sup> graders coming in last at 9%. When conducted for grade, the Shapiro-Wilks  $p\text{-value}_{\text{grade}} = .0069 < .05 = \alpha$ . This result as did with age, indicates a rejection of the null hypothesis, thereby suggesting that data lacks a normal distribution.

Table 1

Student Age Descriptive Statistics t-Test

<i>Student Age Descriptive Statistics</i>	
Mean	13.727
Standard Error	0.195
Median	14
Mode	14
Standard Deviation	0.6467
Sample Variance	0.4182
Kurtosis	-0.208
Skewness	0.2913
Range	2
Minimum	13
Maximum	15
Sum	151
Count	11

## Game Based Learning: Results

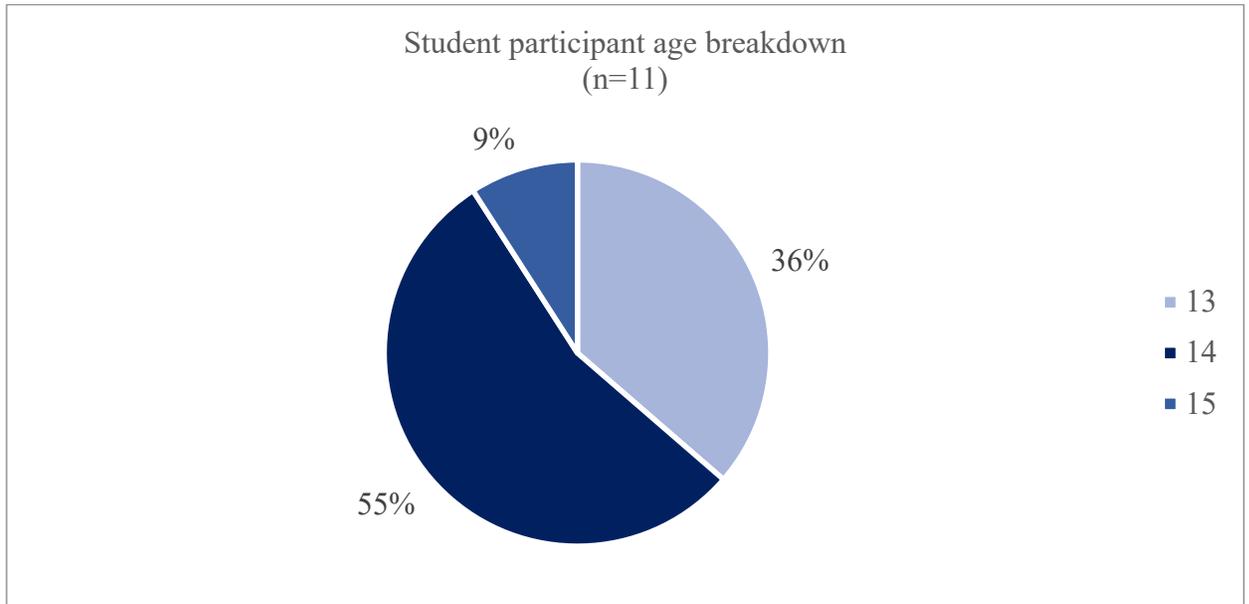


Figure 1. Graph: Student participant age breakdown.

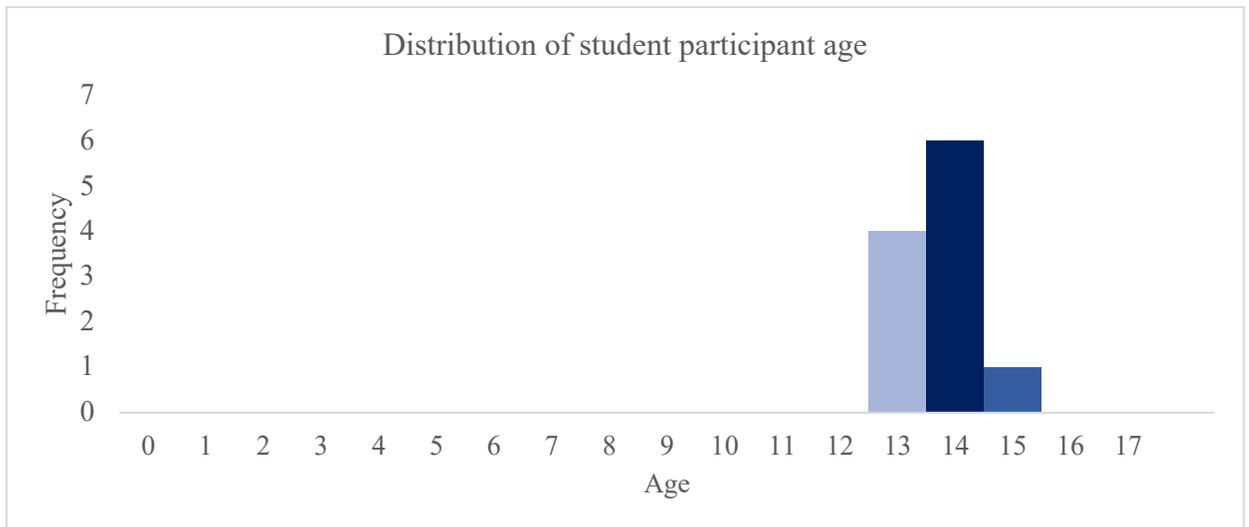


Figure 2. Graph: Distribution of student participant age.

## Game Based Learning: Results

Table 2

Student Grade Descriptive Statistics t-Test

<i>Student Grade Descriptive Statistics</i>	
Mean	8.181818182
Standard Error	0.181818182
Median	8
Mode	8
Standard Deviation	0.603022689
Sample Variance	0.363636364
Kurtosis	0.4125
Skewness	-0.02763854
Range	2
Minimum	7
Maximum	9
Sum	90
Count	11

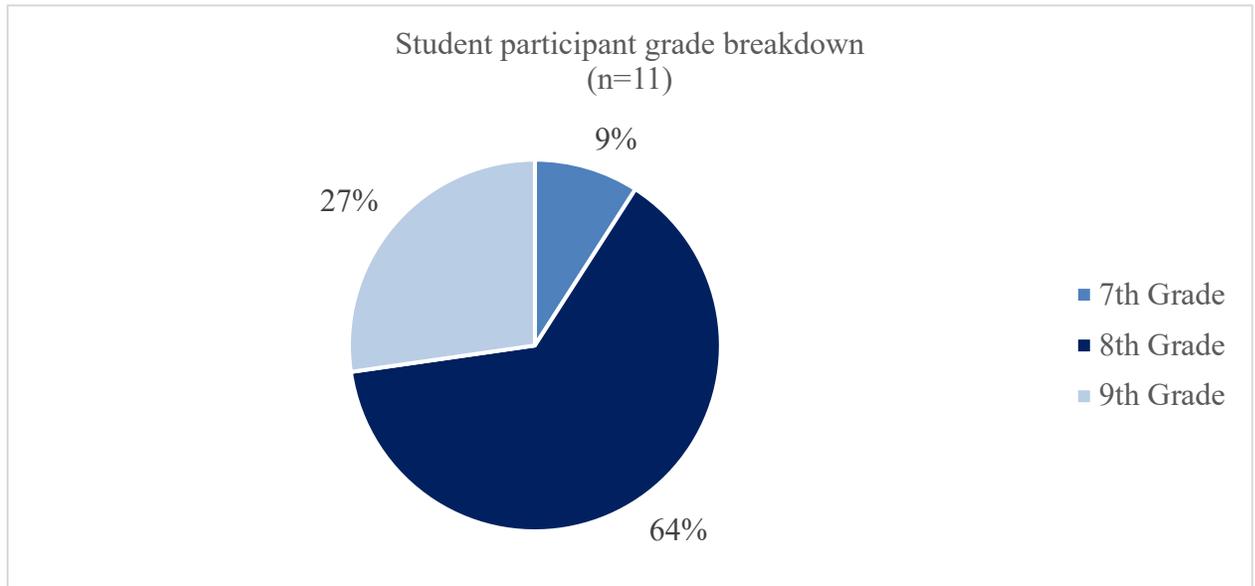


Figure 3. Graph: Student participant grade breakdown.

## Game Based Learning: Results

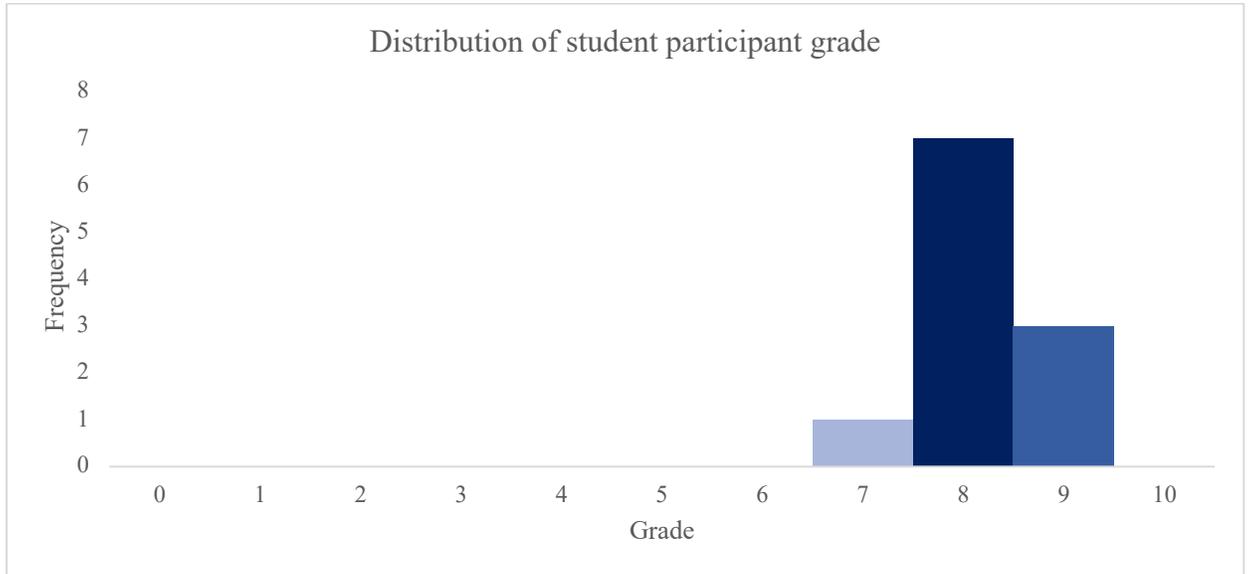


Figure 4. Graph: Distribution of student participant grade.

Due to the sample size being small and not normally distributed across age and grade, drawing conclusions to answer the following questions below, would not be representative, and therefore not recommended.

**RQ<sub>2</sub>:** Is there is a significant difference in the performance of students based upon age, as determined by pre-post-test scores?

**RQ<sub>3</sub>:** Is there a significant difference in the performance of students based on their grade as determined by pre-post-test scores?

As far as racial demographics, though there was no participation by those whom self-identified as Asian, the sample population was rather diverse with 45% of students self-identifying as Caucasian, 27% as Latin X, 18% as African American, 9% as Native American, and 9% Pacific Islander/Hawaiian. One student, however, did self-identify as both Caucasian and Native American. Additionally, the sample population's gender was heavily skewed in one direction with nine out of the eleven student participants self-identifying as male (73%) and the remaining two participants self-identifying as female

## Game Based Learning: Results

(27%). Race and gender were not a focus of this study; therefore, no measurements or conclusions were drawn upon them.

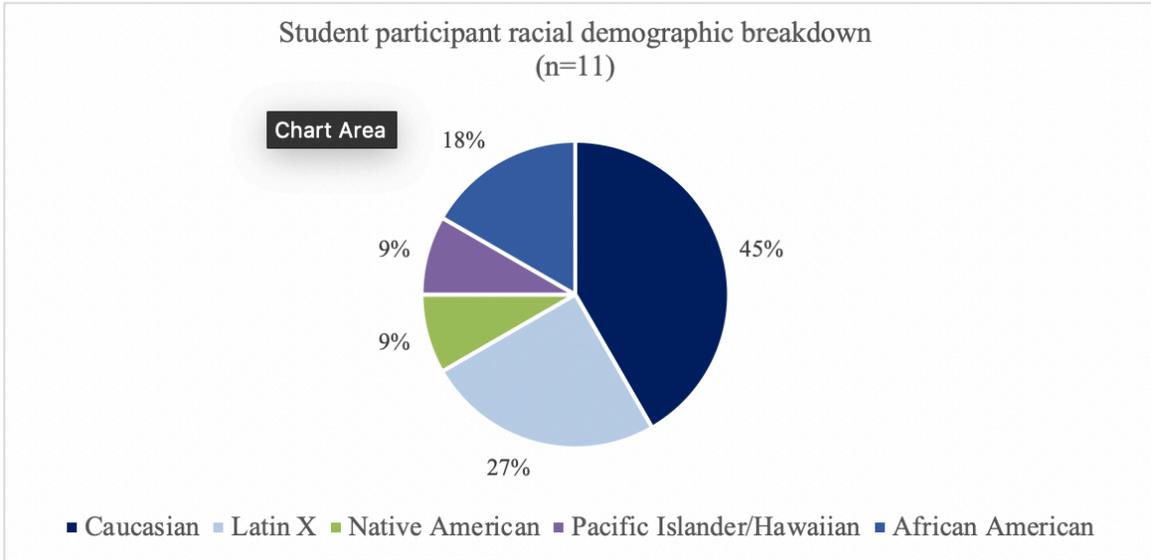


Figure 5. Graph: Student participant racial demographic breakdown.

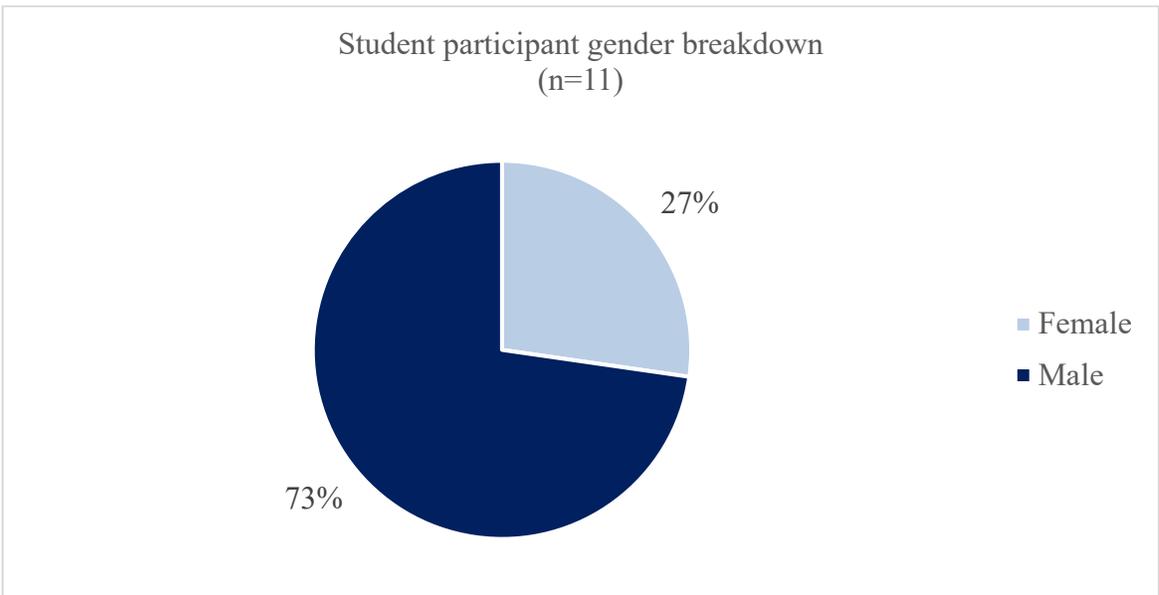


Figure 6. Graph: Student participant gender breakdown.

## Game Based Learning: Results

On average, majority of students (64%) spent one to two hours per day playing videogames, with 18% spending no time playing, and 9% spending either 2-3 hours or 3-4 hours equally. Those who played longer, tended to self-identify as male. There was one participant that selected other and mentioned that they did not play games much at all, so this option may have been chosen due to lack of understanding the answer options available.

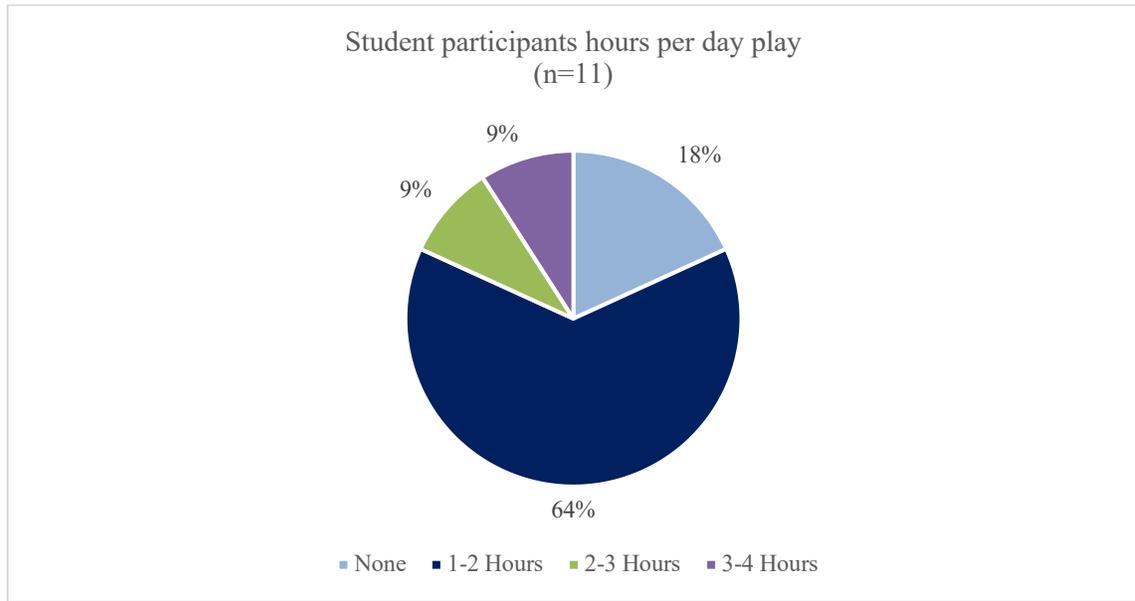


Figure 7. Graph: Student participants hours per day play.

Additionally, most participants rate of play was heavily concentrated and roughly even between daily (37%) and weekly (36%), with monthly (18%) being the next biggest percentage, followed by never (9%) coming in last.

## Game Based Learning: Results

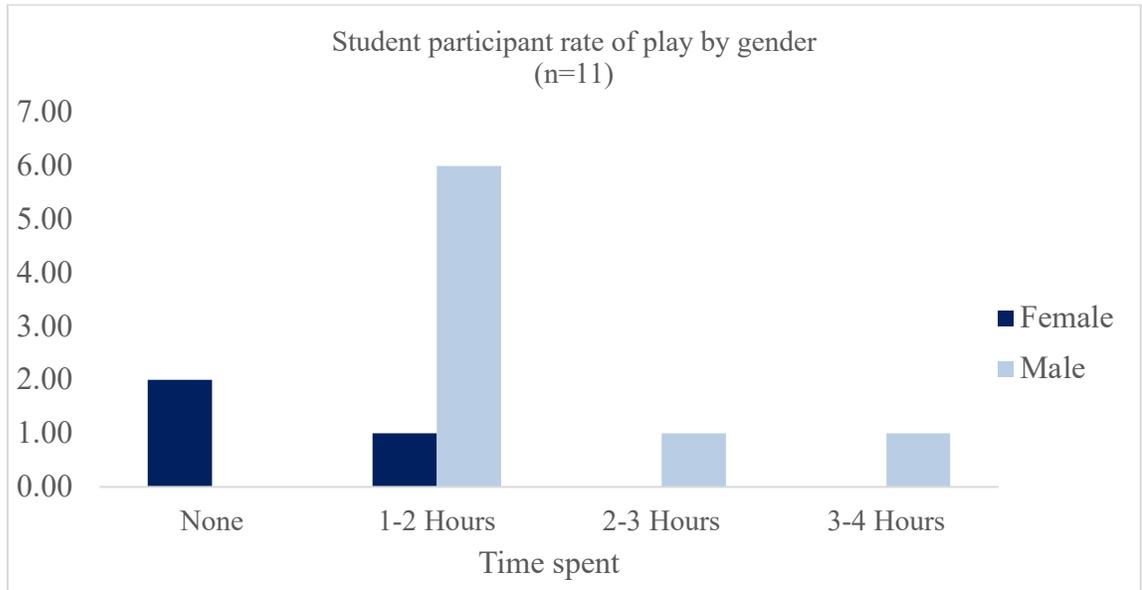


Figure 8. Graph: Student participant rate of play by gender.

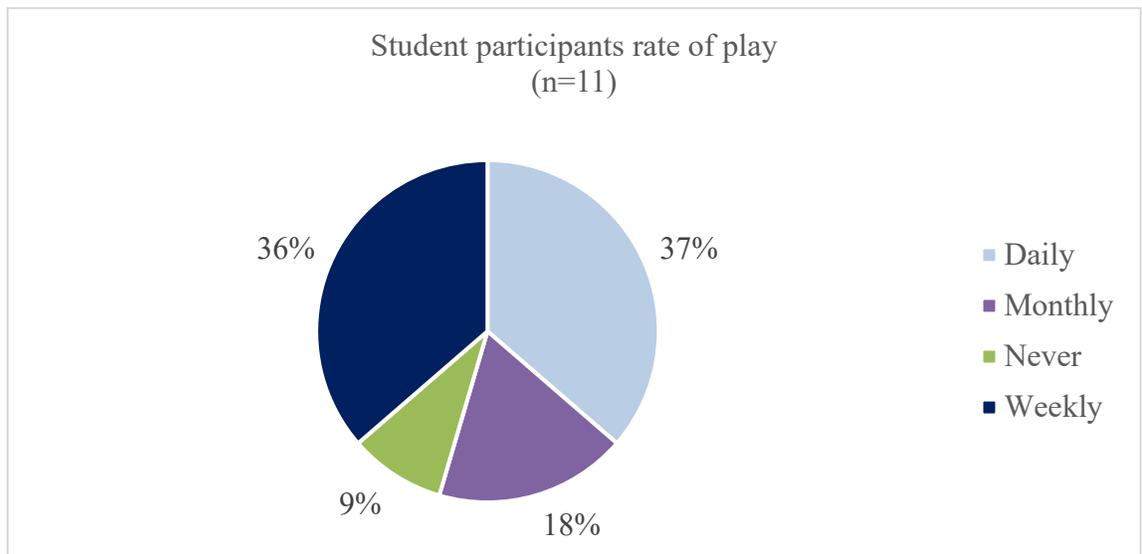


Figure 9. Graph: Student participants rate of play.

When asked '*Have you ever spent money to purchase a game?*', roughly 73% of participants said yes. Majority were evenly split between those that spent \$21.00 - \$50.00 per game and those that spent \$51.00 - \$80.00 per game. Students were asked to give list

## Game Based Learning: Results

the top five games they played. Only one student did not provide any games. Roughly 90% of students were able to provide at least three games. In total, 31 games were mentioned. Students were asked to provide up to three platforms they used; out of a possible 33 responses, gaming consoles were the most utilized platform followed by mobile phones. When data was categorized, 46% mentioned gaming consoles, 18% mentioned mobile phones, 33% left options blank, and 5% responded other. The top gaming consoles were Xbox, Nintendo and PlayStation.

Table 3  
Average Cost of Student Games

Code	Cost
N/A	N/A
4.00	\$81 - and up
4.00	\$81 - and up
3.00	\$51.00-\$80.02
3.00	\$51.00-\$80.01
3.00	\$51.00-\$80.00
2.00	\$21.00-\$50.02
2.00	\$21.00-\$50.01
2.00	\$21.00-\$50.00
1.00	\$20.00 and below
1.00	\$20.00 and below

## Game Based Learning: Results

Table 4

List of Games Played by Students

Games	# of Times Mentioned	Video Game Genre
Dauntless	1.00	Action role playing game
Assassins Creed	1.00	Action/Adventure
Destroy 2	1.00	Action/Adventure
Black Ops	1.00	First person shooter
Call of Duty	5.00	First person shooter
Battle Cats	1.00	Mobile game
Big Win	1.00	Mobile game
Brain Teasers	1.00	Mobile game
Helix Jump	1.00	Mobile game
Brawlhala	1.00	Multiplayer
Clash Royale	2.00	Multiplayer
Gang Beasts	1.00	Multiplayer
Mario Brothers Wii	1.00	Multiplayer
Minesweeper	1.00	Puzzle
Asphalt	1.00	Racing
Mario Kart	1.00	Racing
Grand Theft Auto	2.00	Role playing
Pokémon Alpha Sapphire	1.00	Role playing
Roblox	1.00	Sandbox
Fortnite	4.00	Sandbox
Minecraft	4.00	Sandbox
Jurassic World	1.00	Simulation business
Kabal Space Program	1.00	Simulation flight
Forza	1.00	Simulation racing
Wii Sports	1.00	Simulation racing
Madden	1.00	Simulation sports
NBA 2k	3.00	Simulation sports
Rainbow Six Siege	1.00	Tactical shooter
Uncharted Series	1.00	Third person shooter

## Game Based Learning: Results

Table 5

Platforms Used to Play Videogames

Game Platform	% Breakdown	Type of Platform
Xbox 360	18%	Console
Xbox One	45%	Console
PlayStation 3	0%	Console
PlayStation 4	9%	Console
Nintendo Wii	18%	Console
Nintendo Wii U	0%	Console
Nintendo Switch	36%	Console
PC	0%	Computer
Mobile device	55%	Mobile
Other	9%	Other

### Student Performance

To answer the following research question below, students took a pretest to first establish the baseline of their algebraic knowledge and proficiency, immediately followed by exposure to the DragonBox 12 + intervention, and finally a posttest to measure the exposure of that intervention on their performance.

**RQ<sub>1</sub>:** Is there a significant difference in the performance of students as determined by pre-post-test scores after being exposed to the gaming intervention?

After being exposed to the intervention, 45% of students increased their scores by an average of 22%, 27% experienced no change, and 27% each had scores that decreased by exactly 11%. The lowest scores on the pretests were 44% and 67% respectively, however, the participant with the lowest score had an increase of 33% on the posttest assessment after being exposed to the intervention. This also served as the largest performance improvement by participants that took the assessment. The second lowest score, 67%, resulted in the participant's score increasing by 22% post intervention exposure.

## Game Based Learning: Results

The lowest posttest assessment score was 67%, whereas the highest score was 100%. All in all, for the posttest performance 55% of students scored an 89% or better, and 45% scored 78% or lower. On average, students were exposed to the intervention for roughly 35 minutes, with the most exposure time being an hour and 15 minutes and the least being 5 minutes. In spite of the participants primarily self-identifying as male, if play duration was to be broken down by gender, male participants played significantly longer; approximately 26 minutes longer on average than their female counterparts. To analyze the data, both a paired t-test and a Wilcoxon Signed Rank Test were conducted.

Table 6  
Student Pre-Posttest Assessment Scores

<b>Participant</b>	<b>Pre-test assessment score</b>	<b>Post-test assessment score</b>	<b>Change in pre-post score</b>
DBASP01	89%	78%	-11%
DBASP02	78%	67%	-11%
DBASP05	78%	67%	-11%
DBASP09	89%	89%	0%
DBASP03	89%	89%	0%
DBASP11	67%	67%	0%
DBASP04	78%	100%	22%
DBASP08	78%	100%	22%
DBASP07	78%	89%	11%
DBASP10	67%	89%	22%
DBASP06	44%	78%	33%

## Game Based Learning: Results

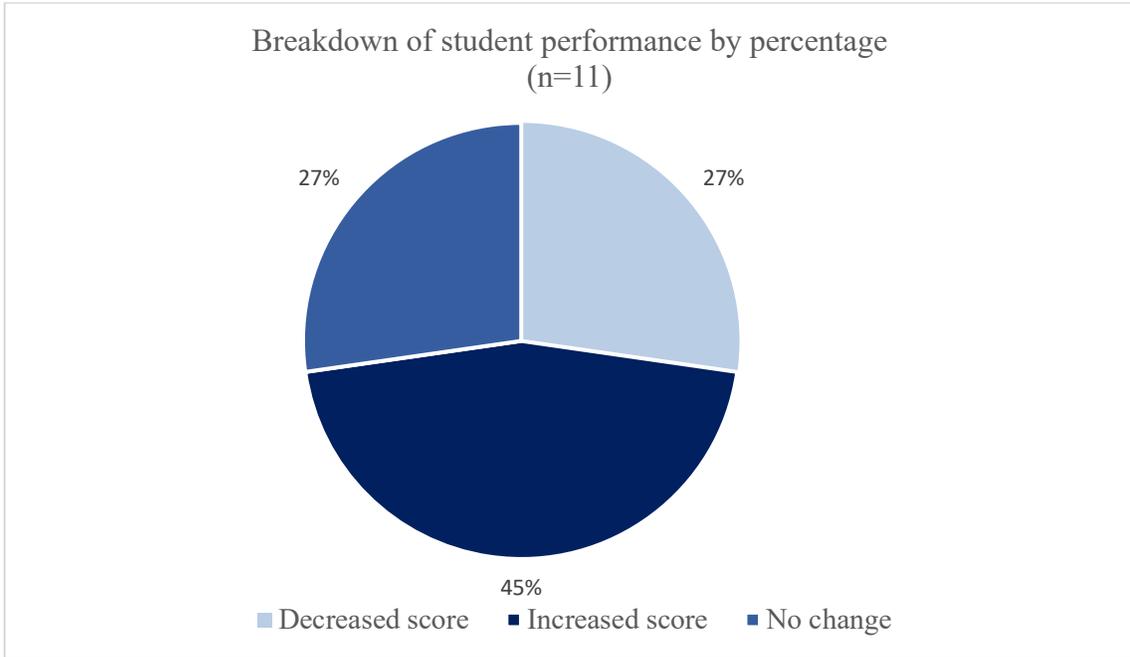


Figure 10. Graph: Breakdown of student performance by percentage.

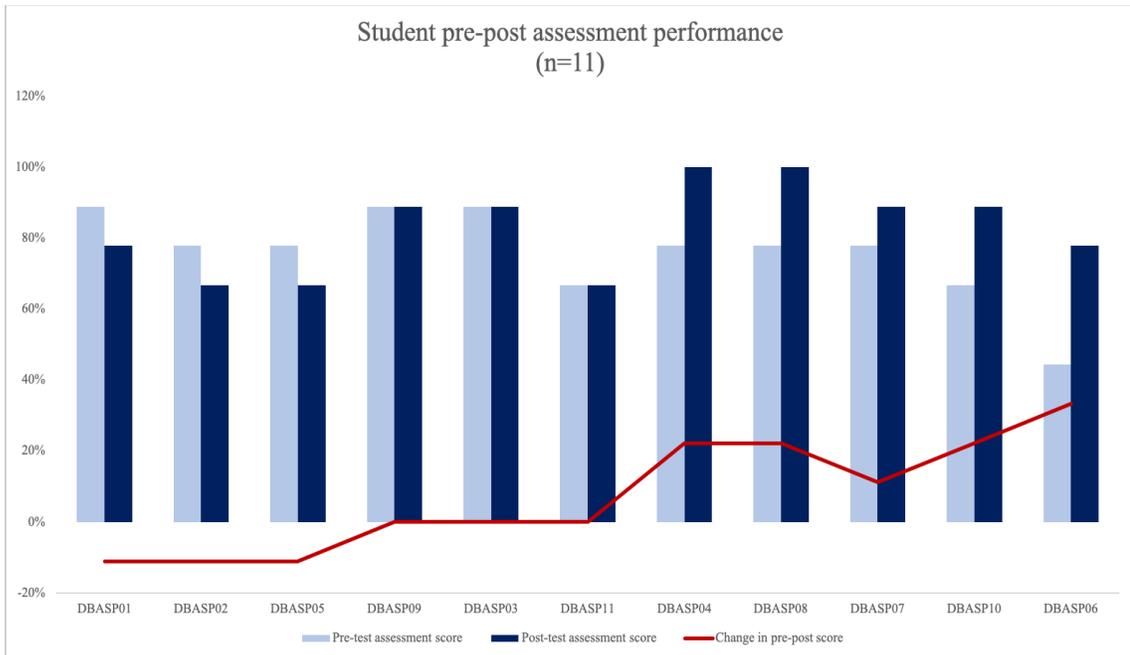


Figure 11. Graph: Student pre-post assessment performance.

## Game Based Learning: Results

Paired t-tests are designed to compare the means of the same group under two separate scenarios while using the same participants. This allows for the removal of potential variance that may emerge as a result of outside factors (Gleichmann, 2020).

Paired t-tests are based upon four major assumptions:

- The dependent variable is normally distributed.
- The observations are sampled independently.
- The dependent variable is measured on an incremental level, such as ratios or intervals.
- The independent variables must consist of two related groups or matched pairs (Gleichmann, 2020).

Based upon this analysis, the main effects of the game intervention as determined by posttest assessment scores ( $M_{post} = .83$ ,  $SD_{post} = .12$ ) and pretest assessment scores ( $M_{pre} = .76$ ,  $SD_{pre} = .13$ ) were found to not be statistically significant ( $t(11) = 1.48$ ,  $p > .05$ ), therefore failing to reject the null hypothesis of research question 1,  $H_0: M_{pre} = M_{post} = 0$ .

Table 7

t-Test: Paired Two Sample for Means: Pre-Post Test Assessment

	<i>Variable 1</i>	<i>Variable 2</i>
Mean	0.75838384	0.82949495
Variance	0.01712231	0.01553021
Standard deviation	0.13085225	0.12462028
Observations	11	11
Pearson Correlation	0.22213446	
Hypothesized Mean Difference	0	
df	10	
t Stat	1.47961734	
P(T<=t) one-tail	0.08488721	
t Critical one-tail	1.81246112	
P(T<=t) two-tail	0.16977442	
t Critical two-tail	2.22813885	

## Game Based Learning: Results

The sample size, however, was previously noted as not being normally distributed, which violates one of the main assumptions for conducting a paired t-test. To rectify this violation an additional analysis, the Wilcoxon Signed Rank Test, was also conducted. This non-parametric analysis, an alternative to the paired t-test, allows for the comparison of repeated measurements on a single sample to determine if the population mean ranks differ. It assumes the following:

1. The differences are continuous (not discrete).
2. The distribution of each difference is symmetric.
3. The differences are mutually independent.
4. The differences all have the same median.
5. The measurement scale is at least interval

One limitation of the Wilcoxon test is that it discards observations where there is a zero difference between the two groups, which in this sample, two scores were excluded for that very reason. This can particularly be an issue concern if samples are taken from a discrete distribution, however that was not the case with this population (“Paired Wilcoxon Signed-Rank Tests,” n.d.). The Wilcoxon Signed-Ranks Test results confirmed the paired T-test results, by indicating that the exposure to the DragonBox 12+ intervention, as determined by posttest assessment scores ( $M_{post} = .83$ ,  $SD_{post} = .12$ ) were not statistically significantly higher than pretest assessment scores ( $M_{pre} = .76$ ,  $SD_{pre} = .13$ ), ( $W(9) = 17$   $p > .05$ , two tailed test) thereby failing to reject the null hypothesis of research question 1,  $H_0: M_{pre} = M_{post} = 0$  (**Refer to Appendix O, Appendix P**) (“Wilcoxon Signed-Ranks Table,” 2020).

### **Attitudes to Technology in Mathematics Learning Questionnaire (ATMLQ)**

For the third task, students had to complete the Attitudes to Technology in Mathematics Learning questionnaire (ATMLQ). The questionnaire consisted of 36 questions, which are broken down to measure three distinct dimensions - student’s confidence when learning math, student’s confidence when using digital games and

## Game Based Learning: Results

technology, and students use of DGBL and applications as a medium to learn and understand mathematics (**Refer to Appendix J**).

**Dimension 1.** Dimension 1 sought to measure the student's confidence when learning math and in particular, Algebra and consisted of twelve questions (Refer to Appendix D). On average students expressed some degree of agreement and confidence with being able to learn math and overcome difficulty, despite not necessarily finding math particularly interesting (**Refer to Appendix N**).

**Dimension 2.** Dimension 2 sought to measure student's confidence when using digital games and technology. It consisted of thirteen questions (Refer to Appendix D). Despite not necessarily agreeing or disagreeing that gaming prompts better learning of math, on average students expressed some agreement and confidence with being able to try new things in a gaming environment, tackle challenges, and the ability to adapt to new technology (**Refer to Appendix N**).

**Dimension 3.** Dimension 3 sought to measure the way students feel about the use of DGBL and applications as a medium to learn and understand mathematics. It consisted of eleven questions (Refer to Appendix D). On average students expressed some agreement and confidence with being able to utilize DGBL as a tool for practice and exploration, while disagreeing with statements that either made reference to DGBL being too strange, a waste of time, or not being properly suited for learning (**Refer to Appendix N**).

To answer the following research question below, and better understand if a relationship between time spent on the DGBL intervention and student attitudes toward math learning exists, a Pearson's R test was conducted.

**RQ4:** When introducing a serious game intervention, is there a correlational relationship between a student's openness to technology as determined by the Attitudes toward Math Learning Questionnaire and the amount of time students spend playing the serious game?

## Game Based Learning: Results

This method was chosen because a correlation analysis measures the strength of a linear association between two variables, typically denoted as “r” either  $-1 < r < +1$ . Linear correlations either indicate a strong, inverse, or weak relationship. If the relationship is positive, the correlation is strong resulting in the increase of both variables. If the relationship is negative or inverse, then one value increases while the other decreases. If there is no correlation, then the r is closer to 0, which denotes that there is a random, nonlinear relationship between the two variables.

The analysis showed weak positive effects,  $r = .2044$  for both attitudes toward math and attitudes toward gaming, and an even weaker positive effect for attitudes toward math DGBL,  $r = .1029$ . Despite anticipating a strong correlating relationship, results indicate a weak positive correlation between time spent on the game and average student attitudes thereby failing to reject the null hypothesis. However, a strong correlation was found between attitudes toward math, attitudes toward gaming, and attitudes toward math DGBL; suggesting that students open to math and/or gaming, would also be open to learning math with DGBL tools.

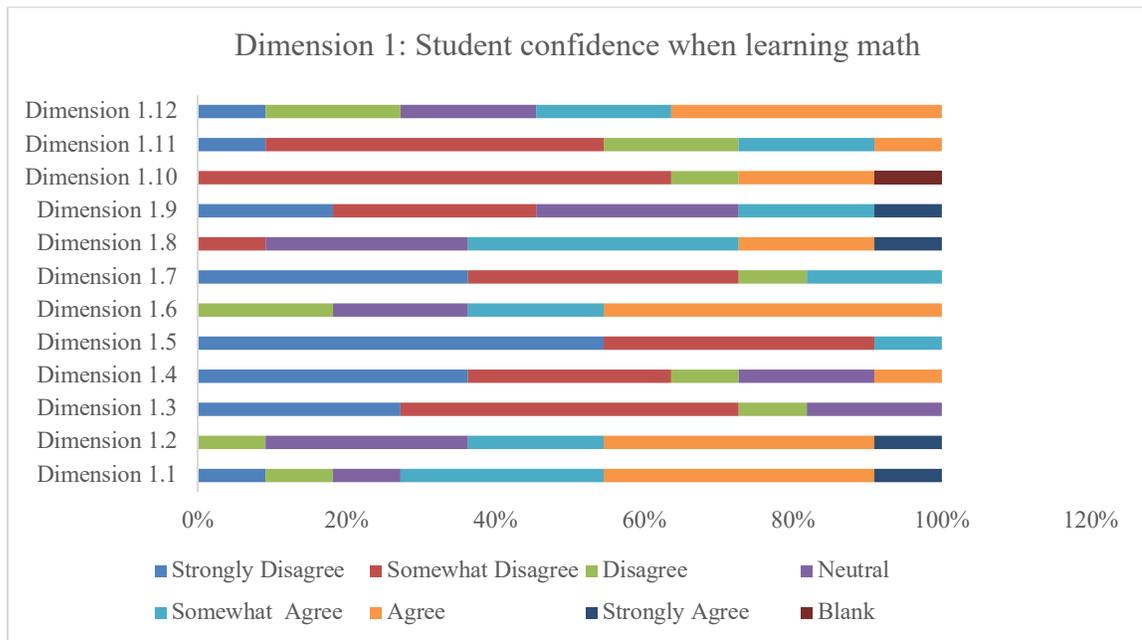


Figure 12. Graph: Dimension 1 - Student confidence when learning math.

## Game Based Learning: Results

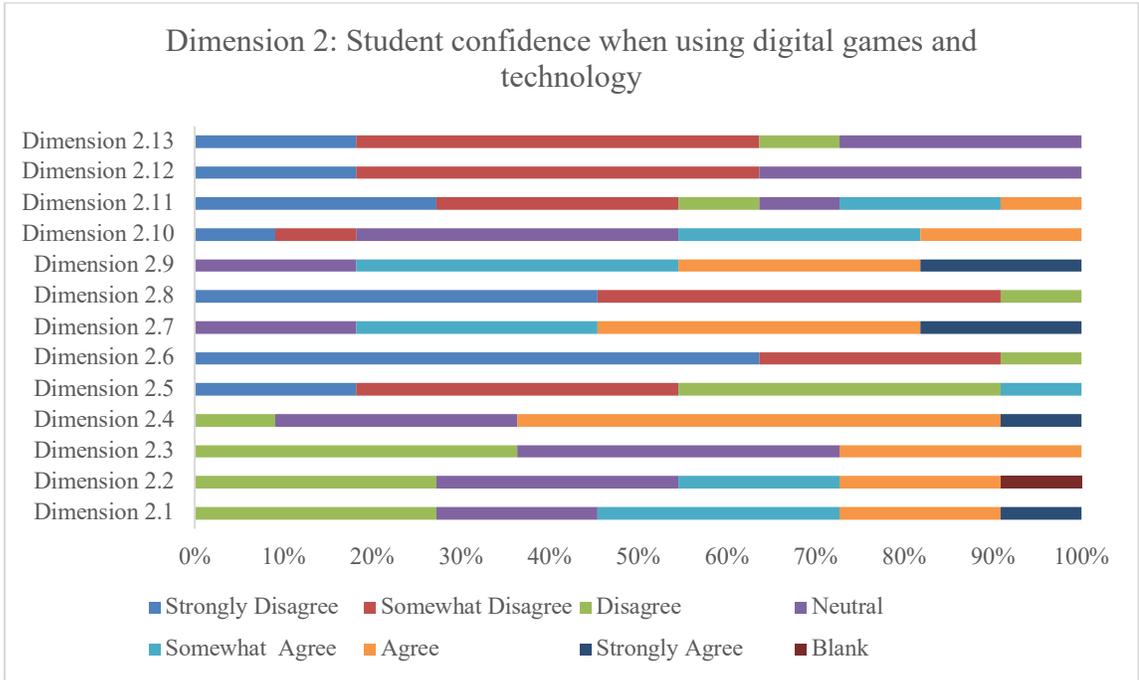


Figure 13. Graph: Dimension 2 - Student confidence when using digital games and technology.

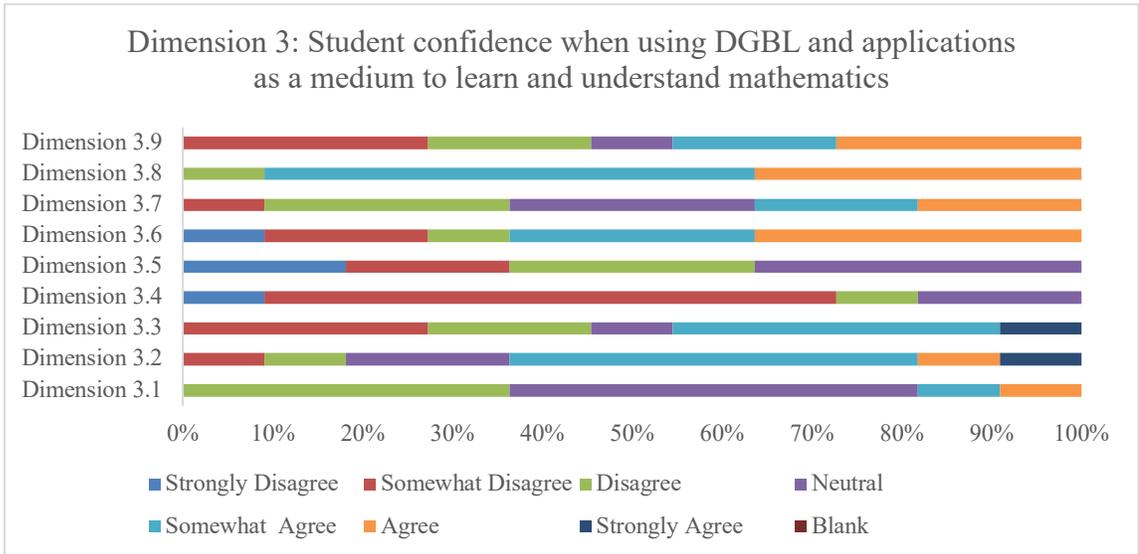


Figure 14. Graph: Dimension 2 - Student confidence when using DGBL and applications as a medium to learn and understand mathematics.

## Game Based Learning: Results

Table 8

Correlation Analysis: ATMLQ and Time Spent Playing Intervention

	<i>Math Attitudes</i>	<i>Game Attitudes</i>	<i>DGBL Math Attitudes</i>	<i>Time</i>
Math Attitudes	1			
Game Attitudes	1	1		
DGBL Math Attitudes	0.932213725	0.932213725	1	
Time	0.204459344	0.204459344	0.102942841	1

### Student In-Depth Interviews

For the final task, students had to complete an in-depth interview, which consisted of questions that explored the gaming experiences, dug deeper into their ideas about using digital gaming for the purposes of learning, and finally their experience with playing Dragon Box 12+ (**Refer to Appendix K**). The questions and corresponding answers are as follows:

**Question 1. At what age did you start playing digital games?** The age that students mentioned when they started to play games, ranged from as young as four years old, to twelve. Forty-five percent of the students gave a specific age (age 5, age 6, age 7, age 10, age 12), 45% provided two ages (ages 4/5, ages 6/7, ages 9/10), and one participant or 10% of students did not mention an age.

**Question 2. How were you introduced to playing digital games?** In terms of how students were introduced to gaming, 64% mentioned family. Interestingly enough, older brothers played a tremendous role in this introduction, with 45% of students mentioning them as the reason, followed by 18% mentioning their father, and 9% mentioning their mother. It must be noted however, that the 9% that mentioned their mother did not play digital games - it was a game of Sudoku using pencil and paper.

## Game Based Learning: Results

**Participant 1:** *“The reason why I started was because my brother got the new device or the new game- Nintendo 2 DS- we played that a lot.”*

**Summary Participant 1:** **The student expressed being introduced to videogames by brother.**

**Participant 8:** *“I did Sudoku with my mom - ever since I was younger, I just liked working with numbers, so I started playing it.”*

**Summary Participant 8:** **The student expressed that being introduced to games by mother.**

**Participant 9:** *“My dad introduced me - all the guys in our house play. They play basketball games- 2K, Minecraft, Call of Duty. My little brother plays- I watched him all the time and finally I just like tried it out.”*

**Summary Participant 9:** **The student expressed being introduced to videogames by father.**

**Participant 11:** *“Dad would play Nintendo – my older brother would play Xbox or PS4 - so pretty much me watching older brothers made me interested.”*

**Summary Participant 11:** **The student expressed being introduced to videogames by parent and siblings.**

Forty-five percent specifically mentioned friends as the introductory factor to gaming, and 9% mentioned both family and friends.

**Participant 2:** *“The first game I played was at my friend’s house - Mario Kart. It brings back fond memories because that was all we would play all the time.”*

**Summary Participant 2:** **The student expressed being introduced to videogames by a friend.**

**Participant 5:** *“I saw someone at a birthday party playing it [Minecraft]. Then my friends [at school] were talking about it, so I wanted to learn about it [Minecraft].”*

**Summary Participant 5:** **The student expressed being introduced to videogames by friends.**

## Game Based Learning: Results

Additionally, during the interview, it was uncovered that 45% of the participants had younger siblings who they introduced to gaming. This usually started with the younger siblings watching them play and evolved into them playing with their younger siblings which follows the exact pattern of those who had older brothers.

**Participant 7:** *“I would watch him play [older brother]. I then played with my friends and my little brother and sisters. They [younger siblings] came into gaming like I did - they started watching me - they ask to play and then sometimes just play on their own.”*

**Summary Participant 7:** **The student expressed that they would watch their older brother play, and their younger siblings replicate this same behavior.**

Thus, based off of this, it is clear that family and friends play a major role introductory role into how students within this study were exposed to gaming.

**Question 3. Why and when do you play digital games?** Students had a variety of reasons that prompted them to play games, ranging from doing it as a past time with friends and family to serving as entertainment during a period of down time, especially when in transit to school, after school or when there was nothing to do.

**Participant 1:** *“Mostly to play with my friends - its....I also play it to take away time, like when you are waiting inside of a bus to go to school - I usually play games to wake myself up in the morning - going to school.”*

**Summary Participant 1:** **The student expressed they played videogames with their friends or in transit to school.**

**Participant 2:** *“I play games when bored, done my homework and it’s too cold to go outside to play basketball.”*

**Summary Participant 2:** **The student expressed they played videogames for entertainment.**

**Participant 3:** *“I honestly don't play them that much unless I am having a sleep over or friends over.”*

## Game Based Learning: Results

**Summary Participant 3: The student expressed they did not play games unless with friends.**

**Participant 7:** *“I play after school probably like an hour - because I have a lot of homework a couple times a week [three to four times]. I also play with friends online.”*

**Summary Participant 7: The student mentioned playing after school.**

**Participant 11:** *“Either swim in the pool or play [video]games - I usually play because it is fun - it entertains me a lot - when I have nothing to do... free time after school.”*

**Summary Participant 11: The student mentioned using gaming for entertainment.**

**Question 4. How do you feel about playing digital games created specifically for learning?** For the most part, students did find value in games created for learning even if they did not particularly care for the games themselves. The ability to use technology was specifically called out by 36% of respondents, particularly because it allowed them to visualize what they were doing and presented a new way to learn.

**Participant 1:** *“I feel like these types [of games] are designed for the basics or foundations of algebra, because I noticed the negative and positive. If you are struggling in the subject it will help you a lot to understand. if you are not, I guess it could be boring.”*

**Summary Participant 1: The student expressed that DGBL was created to learn the foundations, and that it has the potential to help people learn.**

**Participant 2:** *“Um I mean it’s not as fun obviously [playing for learning], but I have a lot of brain teaser games in my phone to get my mind working - [I play them] every once on a while but not as much as 2k.”*

**Summary Participant 2: The student expressed that DGBL was not as fun as commercial gaming.**

## Game Based Learning: Results

**Participant 4:** *“Um I definitely think it would be good, depending on like the audience - like there are a lot of kids that don't really enjoy playing videogames that much - and then you definitely...the game has to be interesting enough to keep playing - there is an objective you are trying to get towards other than just playing levels.”*

**Summary Participant 4:** **The student believed that DGBL would be good but depended on the audience.**

**Participant 5:** *“I think it will be...ugh I can learn better with that - I just pay more attention to electronic devices than I do paper and pencil.”*

**Summary Participant 5:** **The student mentioned that they prefer to learn using electronic devices.**

**Participant 6:** *“I think it helps, because it's like...opening up to new ideas rather than just the basics. Personally, they all have a very good purpose, but for me it doesn't pique my interest, because it feels like school on a phone. It doesn't change the fact that they are useful so... [Why school on a phone?] Because it will have like an animal or something that acts as a teacher - it's basically school in virtual reality. It's [the game] the same way they teach in school, but it ss a little more fun and colorful.”*

**Summary Participant 6:** **The student believed that DGBL are helpful when learning.**

**Participant 7:** *“I mean it's fine - it's a different way to learn and people learn differently so if that works for them that's fine, but I don't really like technology that much....the more that it comes into our world.”*

**Summary Participant 7:** **The student stated that they do not care for technology but acknowledged that for some people DGBL may work.**

**Participant 11:** *“I like playing on the phone, I am a big visual learner. It's a lot harder to pay attention when I see teacher doing it [teaching the lesson]- it [playing the game] helps me remember.”*

**Summary Participant 11: The student mentions enjoying playing games on the phone, and that games help with retention.**

**Question 5. Have you ever played a digital game created specifically for learning?** Every student that participated within study answered yes to this question. The reason for this yes, was due to them being required to play a game as a part of their math curriculum.

**Question 5a. If yes, then what was the name of the game?** Forty-five percent of participants mentioned playing both Prodigy and Dream Box as the games that they played, 18% mentioned Dream Box only, 27% mentioned Prodigy only, and 9% mentioned Khan academy.

**Participant 2:** *“When I was a kid, I played a lot of Khan Academy. It has some games you can play on there, I guess. But I don't know.... it's more like a brain test.”*

**Summary Participant 2: The student mentioned Khan Academy.**

**Participant 6:** *“Prodigy and DreamBox. They are required. They help a lot with strategies on how the teacher teaches you and it is less boring.”*

**Summary Participant 6: The student mentions being exposed to Prodigy and DreamBox in school.**

**Question 6. Why did you play this game?** As mentioned in the answer to question 5, every participant mentioned school was the place that they were introduced to gaming that pertained to learning. However, one participant in particular had a parent that was a math teacher, hence they were exposed at home.

**Participant 9:** *“I learned about Prodigy was school and DreamBox was with my dad. He has like a whole chart with DreamBox.”*

**Summary Participant 9: The student learned about Prodigy in school and DreamBox with parent.**

**Question 7. Did you like playing this game?** The general consensus for most students was that the games were ok, potentially interesting in the beginning, however

## Game Based Learning: Results

they soon got repetitive and boring. Twenty-seven percent however, specifically mentioned that they did not like playing the game(s) at all.

**Participant 1:** *“[DreamBox] it’s more like a homework now. It’s not like a game like this [DragonBox 12+], teachers make sure you have to do a certain amount of lessons and they call it lessons so you feel like it’s more homework. It’s more equations, step by step, type in the formula. It’s kind of boring...more like a learning program but they say it’s a game. You can see it in school also. Every time you mention DreamBox, they sigh. The teachers love it because it keeps you busy, but the children don’t learn from it. It doesn’t teach you anything it just lets you fail, I guess.”*

**Summary Participant 1:** **The student states that the game [DreamBox] is like homework, tends to be boring, and disliked by students but loved by teachers.**

**Participant 3:** *“I enjoy it, but after a while it can get a little boring. Different equations, the same stuff over and over again. It doesn’t change. It’s like different equations. It can get a little too repetitive.”*

**Summary Participant 3:** **The student expressed that they enjoy the game at first, but it soon becomes repetitive.**

**Participant 5:** *“[Prodigy] I liked how you can make your own characters and buy stuff with the coins, the different worlds and you could switch over to different worlds like the lava world, where you could change who you were depending on the world. I liked the ability to level up and get coins.”*

**Summary Participant 5:** **The student expressed that they enjoy specific parts of the game [Prodigy], particularly the ability to personalize characters and buy things with coins.**

**Participant 7:** *“A game where you had a character, you can go around the map and you have to do a certain math problem. It was required. It actually seemed interesting at the time because you could put on armor. But I got bored because*

## Game Based Learning: Results

*every once on a while, monsters would constantly attack you, so you would have to do math problems. Each corner you travel around there was a monster you had to fight and depending on the complexity of the attack was dependent on how complex the math equation was. In 7th grade I started with new problems, new math, new ways to solve them. The way the game was set up, it was different from what was being done in school. Me getting the stuff right in the game didn't mean I would get it right in school."*

**Summary Participant 7: The student explained how the game works but expressed that what was learned in the game did not translate to what was required in the classroom.**

**Participant 8:** *"I just do it to get done."*

**Summary Participant 8: The student did not care for the game.**

**Participant 9:** *"Like whenever I play games it's just like I don't really like them. They are not like really terrible, but it just wouldn't be my first choice. [Why would it not be your first choice?] The fact that they like force us to do it is not fun. The games are fine...if it wasn't as mathy...if it wasn't like a homework assignment. [Would you ever play it on your own?] Probably not. My brother enjoys it. He plays it for fun. [Why] I think it's just a challenge. He wants to beat the game and be best. [But for you?] It's just another assignment on the table."*

**Summary Participant 9: The student expressed disdain for game [Prodigy] and mentioned that sibling loves the game.**

**Participant 10:** *"It was pretty fun a game [Prodigy] where you just fought things. I just liked it, but I did not like that it cost money to do certain things...like better stuff like the armor. I also liked that you could play with your friends, and other people."*

**Summary Participant 10: The student expressed their enjoyment of the game [Prodigy], and the ability to play with friends.**

## Game Based Learning: Results

**Participant 11:** *“DreamBox, it gives you a bunch of questions. When you get it right you get a scale bar, it says complete. It makes your count stronger. With three stars, there is a gold level. You are just getting stars, that’s it. It’s not really that fun. If I don’t do the lessons, I have to get detention. For Prodigy, they should change the graphics and you have to pay to be a member. You can buy you outfits and what you want.”*

**Summary Participant 11:** The student focused on the aspects of both DreamBox and Prodigy that they found to be appealing – leveling, getting rewards and the ability to personalize their avatar.

**Question 8. How do you feel about playing digital games created specifically for math?** Students expressed that there was value in creating games for learning that specifically taught math depending on the audience, irrespective of if they found them to be personally interesting.

**Participant 1:** *“If it was with the lesson plan the teacher is teaching it would be definitely beneficial to some.”*

**Summary Participant 1:** The student expressed the desire to have DGBL match curriculum.

**Participant 4:** *“I think games for learning definitely could be good depending on the audience- there are kids that don’t enjoy playing video game that much. The game definitely has to be interesting. There has to be an objective that you are trying to get towards, instead of just completing levels.”*

**Summary Participant 4:** The student expressed that DGBL could be beneficial depending on audience.

**Participant 5:** *“I think it would be helpful. In modern times a lot of people are on their phones.”*

**Summary Participant 5:** The student expressed that DGBL would be helpful depending on audience.

## Game Based Learning: Results

**Participant 7:** *“I would say it wouldn't really interest me. I am ok where I am with math. I wouldn't say it is a waste of time, but it is something I would rarely think about.”*

**Summary Participant 7:** The student expressed disinterest with DGBL.

**Participant 8:** *“I like that it was math related.”*

**Summary Participant 8:** The student expressed appreciation for math DGBL.

**Question 9. What were your thoughts about playing DragonBox 12+?** During the observation of students playing DragonBox 12+, every student mentioned some variation of the adjective's fun, interesting or both. Over 50% mentioned that they did not want to stop because they wanted to beat the game. Those that particularly said this were male, however this may be due to the low participation rate of female participants within the study. Several also spoke of their surprise that the game got progressively harder, or more confusing.

**Participant 1:** *“I think it could be used in everyday school if it gets harder, that means that you can solve bigger problems, because algebra is the foundations of foundations. That means you can solve bigger math like geometry, trigonometry, pre-calculus - so I guess it would be beneficial. When I was learning algebra, would a game like this be helpful. When I was in 5th grade my dad would teach me the foundations, I would struggle with dividing, and keeping both sides equal, so I think this game would help.”*

**Summary Participant 1:** The student expressed that DGBL has the potential to help learn more difficult/advanced math topics such as geometry, trigonometry, calculus.

**Participant 2:** *“I think [if it was a part of school] it would be fun but after a while it would be ‘oh we have to do this again’. If they can make 3 different things inside of the game, or if you could compete with others in the class...you get a lot of math and get to beat your best friend, that would be fun.”*

**Summary Participant 2:** The student expressed that DragonBox 12+ would be fun at first but quickly become boring.

**Participant 3:** *“At first I was kind of confused because of the little animals, I didn't know what to do with them, but once I learned how to put them together I kinda saw the math part of it”*

**Summary Participant 3:** The student expressed that DragonBox 12+ was initially confusing, became clear as they play continued, and that they were able to detect math concepts as they played.

**Participant 4:** *“I thought it was interesting for the first little bit, but then it got kind of boring, but I think most games get boring after an hour - most electronic games. If I were to be playing and I had my friends over, I would probably play longer.”*

**Summary Participant 4:** The student expressed that DragonBox 12+ was initially fun, but soon became boring and mentioned that playing with friends would increase play time.

**Participant 5:** *“It was simple in the beginning - if you are learning to use it - but as you went on to the next couple levels it got to be the same thing.”*

**Summary Participant 5:** The student expressed that DragonBox 12+ became repetitive.

**Participant 6:** *“Um, it's interesting because I have never played a game like that before- as you got into more levels, it got more difficult it wasn't all bad I just think it was made for younger kids.”*

**Summary Participant 6:** The student expressed that DragonBox 12+ got progressively difficult, but it was made for younger children.

**Participant 7:** *“I went into it, thinking ok this is going to be like a normal game, because of the cover of it, it might not be as interesting as I thought. But then as you play it and get through the levels it really starts to pull your attention in. You really have to be strategic about it. [why did you mention it would not*

## Game Based Learning: Results

*interesting?] Because of the cover I thought this was a kid's game...because most kids games will have numbers like 1,2,3 and all the addition and subtraction symbols on the cover."*

**Summary Participant 7: The student mentions that the way DragonBox 12+ was marketed was misleading, which warped their perception.**

**Participant 10:** *"It's hard...it's hard."*

**Summary Participant 10: The student expressed the DragonBox was hard.**

**Participant 11:** *"It was pretty cool - it was kind of easy in the start then it got more confusing than I was expecting to be."*

**Summary Participant 11: The student expressed that DragonBox got progressively difficult.**

**Question 10. What did you like about playing DragonBox 12+?** Students continued to express that the game was interesting, particularly for younger children. There was also a reoccurring theme of wanting to continue playing to beat the game or figure it out in the statements below, as well as confusion in trying to figure out the game. This theme also emerged during game play observations, where students would express delight, utter sighs of relief, smile and or nod, when they completed a particular task. Several times when asked to express what they were feeling, students would mention the feeling of satisfaction after completing a task that they were experiencing trouble with.

**Participant 1:** *"I think that they have the right idea of first starting off without the plus or minus, because when I was younger, I struggled with that. I liked that it wasn't so easy, it was more of a puzzle - it got progressively harder."*

**Summary Participant 1: The student expressed that DragonBox 12+ would have been helpful when they were younger.**

**Participant 4:** *"I thought it probably good for younger kids for sure- like 10- if they had it with class, that would be a lot more interesting...on Chromebooks. [Fun?] Yea, I think the cartoon aspect, could be fun for younger kids."*

**Summary Participant 4:** The student expressed that DragonBox 12+ would be good for younger children.

**Participant 6:** *“Getting past the levels, because it made me feel a little more accomplished.”*

**Summary Participant 6:** The student expressed they enjoyed progressing through DragonBox 12+.

**Participant 7:** *“I would have kept going until someone stopped me - because it was one of those games, like it doesn't have infinite levels, but it makes you want to keep going -the interestingness and the satisfying-ness is what made me want to keep going. Knowing that each level was going to come up with a new challenge.”*

**Summary Participant 7:** The student expressed that they would have continued playing DragonBox 12+ because they wanted to see what was next.

**Participant 8:** *“I mean the patterns that it had - I could easily match them and it made it fun, but it got more difficult. I didn't want to stop because I wanted to figure it out, but I knew I would be sitting here for a really long time.”*

**Summary Participant 8:** The student expressed that they wanted to continue playing DragonBox 12+ for a long time.

**Question 11. What did you not like about playing DragonBox 12+?** The things that students did not like ranged greatly; from the way the hints were set up within the game, the lack of different challenges they could encounter which prompted repetition, to the not using real numbers or math equations and the scale up factor with regard to difficulty.

**Participant 1:** *“How they set the hints. It showed you exactly how to do it. I feel like if this was used at school people using the hints all the time. The hints are basically giving you the answer. I feel like the math equation symbols made it more like homework - made it more important like for school for a grade, but without the symbols it was more like a game.”*

## Game Based Learning: Results

**Summary Participant 1: The student expressed that the hints DragonBox 12+ could potentially be an issue.**

**Participant 2:** *“It could have been a little better on the prizes and like mini games. Different types of games to help you learn inside the game. Also, probably if it had some directions...or better instructions on certain parts it would have been more helpful.”*

**Summary Participant 2: The student expressed the desire for better prizes and better instructions within DragonBox 12+.**

**Participant 3:** *“You know its math, but it’s not an actual equation - it’s all over the place. I would arrange it in order [characters at the bottom of the screen].”*

**Summary Participant 3: The student expressed that they preferred the math to be more explicit in DragonBox 12+.**

**Participant 5:** *“I did not like it being repetitive. In the beginning when you picked your name and character, you could not use your character, it was just there.”*

**Summary Participant 5: The student expressed that DragonBox 12+ was repetitive and did not like being able to leverage of their avatar.**

**Participant 8:** *“I dunno...I guess just when it got more difficult, I couldn't figure it out.”*

**Summary Participant 8: The student expressed that DragonBox 12+ got progressively difficult.**

**Participant 10:** *“How hard it got after a little bit of time.”*

**Summary Participant 10: The student expressed that DragonBox 12+ got difficult quickly.**

Overall the interviews were able to provide a deeper understanding of the observations that took place while students were playing and were in line with the survey responses provided on the ATMLQ. One statement that stood out in particular, due to the correlation the student was able to draw between lack of interest and the effect on math

## Game Based Learning: Results

performance. This was particularly important to highlight, because it is in line with what many researchers believe as one of the major benefits of creating games for learning.

**Participant 1:** *“There are a lot of people in my class that don't really get the concepts well - they really don't have a math mind - and this combines games with the foundations of math. So, I think that this could be beneficial for them because it's a game. And since they think it is a game, and it plays like a game, they may find it more interesting. There are a lot of variables that determine how well you do in math...like what happens at homes and what interest you, so I guess that what interests you is one of the variables that helps you in math. So, if you are interested in games you may pay attention.”*

**Summary Participant 10:** **The student expressed that there are a lot of factors that determine one's interest in math, and that gaming might help encourage this interest.**

One thing this study made clear was that creating a learning game is not enough. There were several instances students mentioned the necessity of not having repetitive tasks, the game having the ability to scale accordingly to their skill level and emulating more of recreational game features. Though not mentioned by many, particularly for those that gamed more often, adding additional complexities, the ability to compete surprises imbedded within the game, the ability to buy things or win things, the ability to manipulate and use their avatar were factors that were particularly important.

### **Teacher Survey Results**

The second participant group was made up of three teachers. The teacher population was not the primary focus of the study; thus, the sample population was much smaller than that of the student population. In terms of demographics, all teacher participants were female, with two of the three falling within the age range of 25-29 and having between 6-10 years of teaching experience, and one in the 24 and under range having less than 5 years of experience. Two of the three teachers use technology daily, with one responding that their frequency was on a weekly basis. To better understand

## Game Based Learning: Results

their attitudes towards the utilization of technology and math, teachers took a modified version of the Attitudes to Technology in Mathematics Learning questionnaire, that was based upon various 5-point Likert scales based upon the question. The questions and their associated analysis are as follows:

**I use \_\_\_\_\_ in the classroom.** The Likert scale used consisted of the following options: never, yearly, monthly, weekly, daily. Of the options listed, the most commonly used technologies either on a daily or weekly basis were the internet for developing lesson plans/ideas, digital manipulatives, management programs for student data, and active boards. The least utilized technologies, which were rated as never or yearly were digital video cameras, mobile devices, apps, and tablets. Though computers were not used as often, they tended to be used on either a monthly or yearly basis.

**I use technology in my classroom to...** The Likert scale used consisted of the following options: never, rarely, sometimes, usually, always. Teachers commonly used technology to perform drill and practice, provide tutorials or remediation, perform calculations, explore relationships, graph data. To a lesser extent technology was used to develop math models and solve applications problems. Technology was rarely or never used to technology develop programs. They were also given the option to write in additional ways they utilized technology that were not mentioned; however, no additional ways were mentioned (**Refer to Appendix L**).

**I would use technology in the classroom more if...** The Likert scale used consisted of the following options: strongly disagree, disagree, neither disagree nor agree, somewhat agree, strongly agree. Teachers agreed that additional training and time to get acclimated to the technology as well as the ability to take different ideas to integrate with technology would affect how much they used technology within the classroom. Having technology accessible at home and at school had little to no effect. They were also given the option to write in additional factors that were not mentioned, however no additional factors were given.

## Game Based Learning: Results

**To be good at mathematics, it is for important for students to...** The Likert scale used consisted of the following options: strongly disagree, disagree, neither disagree nor agree, somewhat agree, strongly agree. Remembering formulas was not considered as important by teachers for a student to be good at math. However, understanding concepts, thinking creatively, real world applications, and the ability to explain solutions were all factors that the teachers believed help someone become good at math.

**When using technology...** The Likert scale used consisted of the following options: strongly disagree, disagree, neither disagree nor agree, somewhat agree, strongly agree. Teachers remained impartial by neither agreeing nor disagreeing with the statements that incorporating technology would increase motivation, more encourage collaboration, ease problem solving, prompt willingness to work longer at complex problems, and help explain how students arrived at their answers. They also remained impartial to the statement that the sources on the internet were unreliable. For the statements such as less student collaboration, going to inappropriate sites, the answers were equally divided between the agree, neither, nor disagree options. Overall, based upon the way teachers within this study answered this section, they are impartial to utilizing technology as a learning medium.

**I think...** The Likert scale used consisted of the following options: strongly disagree, disagree, neither disagree nor agree, somewhat agree, strongly agree. Two of the three teachers, agreed to some extent that technology changed the way they approached teaching, their students were more adept with technology than they were, and schools had expectations of learning technology without implementing training. Additionally, two of the three teachers disagreed that technology would improve their ability to teach.

**I need...** The Likert scale used consisted of the following options: strongly disagree, disagree, neither disagree nor agree, somewhat agree, strongly agree. At least two of the three teachers, agreed to some extent that they wanted more technological

## Game Based Learning: Results

training and professional development, increased access to tech tools that can be integrated in their classroom, and additional opportunities to collaborate with colleagues on using technology. All teachers agreed that more time to integrate technology into their curriculum was important, however two teachers disagreed that they needed additional tech support to keep computers and applications running.

Ultimately, due to the small sample size teachers within this study cannot serve as a representative sample from which generalizations about teacher attitudes towards technology could be drawn. However, this data could be used to further explore the major and reoccurring themes that though teachers are open to utilizing technology, the lack of adequate time, technological training and technological professional development affect their views of how useful technology is within the classroom.

### **Teacher In-Depth Interview**

For the final task, teachers had to complete an in-depth interview, which consisted of questions that explored their experiences with technology, dug deeper into their ideas about using digital gaming for the purposes of learning, and finally their thoughts about Dragon Box 12+ (**Refer to Appendix M**).

All teachers taught Algebra 1, with at least one high level math class, whether that be geometry, Algebra 2, statistics, calculus or combination of a few. One teacher in particular mentioned teaching 6<sup>th</sup> grade math which focused on patterns and problem solving. When asked about the idea of using manipulatives to aid in teaching, all teachers were open to them though their use of them differed drastically based upon their personalized teaching styles.

**Participant T01MF:** *“I am a big fan of getting messy, visualizing concepts – I will teach with 3 dimensional solids such as vegetables. I have found anytime kids can get up and move around, it is oddly helpful, at any age- that could be Legos, base 10 blocks that snap together, strings, straws.”*

**Summary Participant T01MF:** **The teacher expressed their desire for children to learn through exploration.**

## Game Based Learning: Results

**Participant T02HB:** *“The biggest manipulative that I use...that I think is so beautiful and a great connection for students learning math is Desmos. What seems to be an online grapher, once you dig deeper, it allows you to explore a number of different relationships and a great way to get students to interact with something so abstract. It takes a non-tangible concept and makes it visible, and tactile. I use it [Desmos] nearly every day.”*

**Summary Participant T02HB:** **The teacher expressed their appreciation for the use of Desmos [a graphing digital tool], which helps with concept visualization.**

**Participant T03CG:** *“I love it [manipulatives]. I try to use them as much as possible to model things. And I especially have students draw what’s happening in the problem...to draw their thinking to make it more concrete. I think it’s important to show that math is hands on and its real, not just numbers floating around in the clouds. That they actually mean something, and what we are doing with those numbers happens in real life. [Aside from drawing] yes, we have used centimeter cubes, blocks, popsicle sticks, cubes, physical number lines, money to talk about decimals, tangrams in geometry and or talking about values.”*

**Summary Participant T03CG:** **The teacher expressed their appreciation for using manipulatives for learning.**

When asked about their thoughts regarding the necessity of using technology to teach and learn mathematics, teachers were seemingly open to the idea, especially because of the prevalence of technology within society and the differing learning styles of their students. However, there was a discomfort with totally relying on technology as a primary source for learning, and also the need to vet the technology prior to implementation.

**Participant T01MF:** *“There has to be a healthy mixture, but the time that it takes, it is not feasible in a school year to fit that in. When we find technology that is healthy or a benefit to the curriculum, then I incorporate it in. But every*

## Game Based Learning: Results

*teacher has their own style. In a classroom of students, there is going to be students who learn differently, absorb material differently, who resonate with material differently.”*

**Summary Participant T01MF: The teacher expressed the need for balance with using technology and learning.**

**Participant T02HB:** *“There are some great lessons that can be done without any technology, but I think there are a lot of lessons that are enhanced and bettered by technology. And it is important to take a balanced approach, though it is hard to define what is a balance. I do think it would be a mistake for someone to say we can do this all by hand because at the end of the day we are trying to teach them critical thinking skills where they can use their resources, and computers are going to be a resource they are going to need for the rest of their lives. I believe you can learn mathematical concepts without - but it would be a shame to avoid it.”*

**Summary Participant T02HB: The teacher expressed the need for balance between technology and traditional learning methods, while recognizing the important role technology plays in society.**

**Participant T03CG:** *“I honestly have not had much experience using technology as a tool for learning, but I have used it as a tool for teaching math. I do know of an app on an iPad that is good for geometry and then a website for balancing equations. But I really have not. I feel like I don’t know what kind of technology to use in the classroom, so I just sticking to what I know of paper and manipulatives. [ So, it’s not that you are not open to it, it’s more that you don’t know what you don’t know?} Yes, exactly. [What would make you feel comfortable if you had to use something?] I think maybe watching someone else use it [technology] and seeing that it’s successful and engaging. Also having some go to technological resources that have been maybe been vetted, that I know I can use for a for specific concept. I feel like a lot of it is me trying to search and find, and I don’t*

## Game Based Learning: Results

*necessarily know which one is best. So, I choose to use what I know and don't really branch out."*

**Summary Participant T03CG: The teacher expressed their openness to technology, but not knowing what tech to choose from is challenging and expressed the need for help.**

When asked if they had ever used a game to teach, and how they feel about using a game specifically for learning, two of the three had utilized games, though one of the games mentioned did not involve technology. This on technological game was not used to teach math, but rather the concept of collaboration. One teacher expressed that though she did not have personal experience using games in her classroom, she was able to observe a game being used, which did not convince her of its value.

**Participant T01MF:** *"I tutor, and I used a game to practice solving equations. Like a free throw basketball game, I found online. I do think it has to be something that I have vetted, or instead of using it to teach it, use it at the end of the year and solicit feedback from students...then implement it into class the following year. Or get feedback from older students."*

**Summary Participant T01MF: The teacher expressed that DGBL has to be vetted and would require student feedback prior to it being implemented in the classroom.**

**Participant T02HB:** *"Yes, sometimes we use games to get at skills that are might not necessarily be an objective for the math class. Recently I used a game to demonstrate collaborative thinking. I don't know what the definition of a game would be, but I use a lot of things that have goals. Not necessarily that there is a winner and a loser, but I do things like telephone where a student write an equation of a line, then they will pass it to someone else who will graph it, then they will pass it on to someone else who writes the equation and so forth to see if the message can get passed throughout. At my previous school I would do jeopardy and do things for points, but at the end of the day, it would have*

## Game Based Learning: Results

*negative impact, even though the students never showed that. They seemed to get excited about the game, but I noticed it added unnecessary pressure.”*

**Summary Participant T02HB: The teacher expressed concern with leveraging games for learning, particularly ones that encouraged competition.**

**Participant T03CG:** *“I have not. I know last year when I was an intern, students played Prodigy, an online game. But I noticed it was more of customizing their characters and walking around, playing more of the videogame than doing the math problems for practice.”*

**Summary Participant T03CG: The teacher expressed concerns about DGBL not actually being a tool for learning.**

When asked about introducing digital games created specifically for learning within their classrooms, teachers, all teachers expressed similar apprehension regarding the amount of vetting needed to take place prior to implementation, despite them being open to the possibility. The major reoccurring theme was with regard to the time spent to ensure appropriateness.

**Participant T01MF:** *“In order to introduce a game into the classroom, I would want to see how a game works. I would be worried, if my willingness to try it [game] will help it or not – I would prefer speaking to older students because older students are more vocal- they are able to explain their feelings. The implementation of learning objectives is incredibly important. The games have to effectively practice a skill - should incorporate modelling, coaching, scaffolding - should be able to tie it into the classroom either by the teachers doing reflection or have an assessment piece within the game. {Students} should be able to understand WHY, and the game should present questions of varying types that assess the WHY. They also need to adjust to their [student] learning styles and to their math ability.”*

## Game Based Learning: Results

**Summary Participant T01MF:** The teacher expressed desire to have vetting prior to integration in the classroom, and also shared what factors would inspire confidence in DGBL.

**Participant T02HB:** *“Time is very precious, making sure that I fully understand the game and the outcome that they are trying to achieve is important. I think that this takes a lot of work on my part, and it could be worth it but there are a lot of games out there. And some of them cost money. So, I want to make sure whatever I am introducing is worth it, and make sure that it is also supported by my colleagues and our department as a whole. This means I have to put a lot of time and research into it. I think that they can be really powerful [DGBL]. A class without technology, would be strange.”*

**Summary Participant T02HB:** The teacher expressed concerns with DGBL, while understanding that technology is important.

**Participant T03CG:** *“I would definitely like to incorporate more games. Especially now with students this age. They are so motivated by technology and so I feel like this is one extra foot in the door to begin learning because of their buy in with technology.”*

**Summary Participant T03CG:** The teacher expressed openness to DGBL.

Lastly, only two of the three teachers were asked to provide their critique of DragonBox 12+, because they were involved in the assessment creation process, therefore had exposure to the game. Both teachers expressed their appreciation for the effort the game made to teaching the concept of balancing equations. However, there was a concern about student ability to translate their game experience outside of the gaming environment. Additionally, they expressed the need for showcasing math concepts more explicitly, to prompt identification and processing of material.

**Participant T02HB:** *“I appreciated it as math teacher, the connections I could see between balancing equations and what they were doing in the game. I am really interested to see what your research shows because I wonder how much of*

## Game Based Learning: Results

*that will resonate with the students depending on their familiarity with that concept...because I could see it [referring to the math concept of balancing equations]. But I am not sure if I passed it to one of my peers who hasn't done that work in a while, if they would know. I think its intent is good, but I am not sure how visible those connections are or how they can be translated. [What did it do well] It prompts the user in a good way to recognize that one action has to be matched. I think once you get used to it, the idea of signed avatars was good. [What did it not do well] It did not do a good job of framing the exercise. Why were we doing this? What was the narrative? I didn't understand what the motivating factor was. It didn't stop and translate that this is what we have done and how can it be relevant to something outside of the game."*

**Summary Participant T02HB: The teacher expressed thoughts about DragonBox 12+; liked the idea of the game but did not feel the game was explicit in what it was trying to achieve.**

**Participant T03CG:** *"I wish there had been kind of the math concepts behind what we are doing interwoven in between every few levels. I think it was good to show relationships, as far as balancing both sides. Overall good concepts were in there. I just wish it had been a little more explicit to math concepts."*

**Summary Participant T03CG: The teacher expressed thoughts about DragonBox 12+; liked the way the game showcased relationships but did not feel the math within the game was explicit.**

## Conclusion

This study investigated whether a DGBL intervention, DragonBox 12+ could help promote algebraic thinking, and positively affect performance and attitudes of students enrolled in Algebra 1. Results indicated that the DragonBox 12+ intervention did not influence student performance despite there being some participants that did experience an increase in scores post exposure. This result was unanticipated, as it was expected that the intervention would have a positive effect upon student performance. The

## Game Based Learning: Results

rejected hypothesis was in part cultivated by existing research which has shown that DGBL can affect performance in a positive way. Conclusions regarding gender and grade could not be drawn, due to the small size of the ample population, which were not normally distributed and heavily skewed toward males and eight graders. It must be noted however that having a larger normally distributed sample, may have yielded different results which potentially could fall in line with existing research. Interestingly enough, irrespective of whether students liked to play videogames and the intervention itself, all stated that they saw the benefit of utilizing such tools to enhance learning. Words such as interesting, cool, fun were often used to describe the intervention. Overall, students were open to technology, often expressed its huge effect in their everyday lives and the desire to have alternative ways to practice concepts, which gaming was often mentioned as a way to achieve this.

In addition to students' teachers also took part of this study for the purposes of creating the assessment instruments, and also to provide clarity into their attitudes towards technology. Though the sample population was very small, participating teachers shared that they were open to utilizing DGBL tools because of the role technology plays in the lives of their students and the desire to stay relevant with the times. They also expressed the need for adequate training, support from administration and parents, and the need to have such interventions properly vetted to ensure that they met certain learning requirements.

Currently, majority of the research with regard to DGBL focuses on small children. Considering technology has become more accessible and prevalent within our society, which has contributed to the popularity of gaming, more research in DGBL particularly for older children is necessary.

## Chapter 5: Conclusion

### **Reforming Math for the Future**

Over the past few years, the push for educational reform has become louder and louder due to student performance. In 2018, 79 countries administered The Programme for International Student Assessment (PISA exam), to more than 600,000 students in their public and private schools. Developed by the Organization for Economic Cooperation and Development (OECD), an intergovernmental agency made up of 37 members of which most are industrialized nations, the PISA exam is given every three years to measure what 15-year-old students have learned in math, reading and science. Results regarding U.S. student performance were troubling because scores were slightly above average in reading and science, and slightly below average in mathematics, with no significant improvement or decline since 2000 in reading, 2003 in math and 2006 in science. Additionally, 30 countries scored higher than U.S. students in math, with that performance gap between top-performing and lower-performing students continuing to widen especially in reading (Camera, 2019). Additionally, when test results were broken out by achievement level and citizenship status, accounting for socioeconomic status and school, immigrant students not only outperformed their non-immigrant peers, they were also more than 25% less likely than non-immigrant peers to be low performers (Camera, 2019).

Some researchers believe that this maybe partly linked to the way math is taught within the United States, which differs from the way it is taught in other countries (Richards, 2020). The heavy emphasis that is placed upon memorizing formulas and procedures, rather than critical thinking and creativity to solve complex problems has prompted researchers and educators over the past few years to seek alternative measures and methods for learning (Richards, 2020). As a result, the interest and calls for utilizing play as a medium for learning, which has long been researched and looked to as a viable option, has increased. Not only is it seen as a way to encourage and engage, utilizing play

## Game Based Learning: Conclusion

to learn has in some cases has proven to be very effective in prompting understanding, aptitude and performance of students. With steady advancement of technology, accessibility and affordability of ubiquitous devices, play has not only gone digital, but has skyrocketed in popularity, user adoption – and, importantly, discontinuously – changed the way people raised in this time period think, learn, and process information (Prensky, 2001).

According to the Entertainment Software Association (ESA), the trade organization of the video game industry, three-quarters of all Americans have at least one gamer in their household. Furthermore, 70% of families have a child that plays videogames, with 21% of those gamers being under 18 (*2019 Essential Facts About the Computer and Video Game Industry*, 2019). This further corroborates the survey findings of the Pew Research Center, in which more than eight-in-ten teens between the ages of 13 and 17 (84%) either owned a game console at home or had access to one (Perrin, Andrew et al., 2018). Additionally, 90% of these teens stated they played video games on a computer, game console or cellphone. An exploratory study trying to understand parental perception of digital games found that 50% of the participating parents (N=1087) allowed their children to spend 1-2 hours at computer games every day, while 28.54% allowed 3-4 hours (and more) of computer games every day. What this indicates is that digital gaming is becoming more acceptable in our society. Thus when we take into consideration the statistics regarding user adoption, the change in parental attitudes, and the fact learning through game play “is an essential part of childhood and healthy brain development, because it contributes to the cognitive, physical, social, and emotional well-being of children” (Ginsburg et al., 2007), the growing calls to incorporate digital game play into education are growing seemingly louder. Frequently-cited arguments held by researchers for using digital games in education are: “(a) computer games can invoke intense engagement in learners (Malone, 1981; Rieber, 1996) (b) computer games can encourage active learning or learning by doing (Garris, Ahlers, & Driskell, 2002) (c) empirical evidence exists that games can be effective tools for enhancing learning and

## Game Based Learning: Conclusion

understanding of complex subject matter (Ricci, Salas, & Cannon-Bowers, 1996), and (d) computer games can foster collaboration among learners (Kaptelin & Cole, 2002)” (Ke, 2008). With this as the case, along with the desire to contribute to the overall body of work regarding gaming and learning, the research sought to examine the effect of incorporating digital gaming, such as DragonBox12+ on learning Algebra.

### **Outcomes of Research**

The central phenomena explored in this study was whether there is a need to modify the way learning math is carried out, to match the social and societal changes that exist outside of the classroom. The following four hypotheses stated in the study were:

**RQ<sub>1</sub> H<sub>1</sub>:** There will be a statically significant difference in the performance of students as determined by pre-post-test scores after being exposed to the gaming intervention.

**RQ<sub>2</sub> H<sub>1</sub>:** There will be a statically significant difference in the performance of students based upon age, as determined by pre-post-test scores.

**RQ<sub>3</sub> H<sub>1</sub>:** There will be a statically significant difference in the performance of students based on their grade as determined by pre-post-test scores.

**RQ<sub>4</sub> H<sub>1</sub>:** The correlation coefficient for the student openness to technology as determined by the Attitudes toward Math Learning Questionnaire and the amount of time students spend playing the serious game is significantly different from 0.

Overall, exposure to the intervention DragonBox 12+, was not found to be statically significant in affecting participant performance. Additionally, conclusions on the factors of age and grade were inconclusive due to the lack of normal distribution and small size of the sample population. Additionally, there was no relationship found

## Game Based Learning: Conclusion

between the amount time students spent playing the DGBL and their attitudes toward math as determined by the ATMLQ. It is important to note however, that after being exposed to the intervention, 45% of students increased their scores by an average of 22%. The lowest scores on the pretests were 44% and 67% respectively, however, the participant with the lowest score had an increase of 33% on the posttest assessment after being exposed to the intervention. Additionally, a strong correlation was found between attitudes toward math, attitudes toward gaming, and attitudes toward math DGBL; suggesting that students that are open to math and/or gaming, would also be open to learning math with DGBL tools. Despite all of the anticipated hypotheses being disproven, these results are enough to give pause about the potential positive effect of digital games for learning, and warrant additional exploration with a larger sample size, from which broader generalizations can be drawn. Additionally upon conducting this study, the four major themes uncovered, were (a) friends and family play a significant role in game adoption, (b) students understand that games can be useful but may not necessarily see them as fun nor required to learn, (c) teachers are open to leverage digital games, but often times do not get adequate training or support, and (d) utilizing a mixed methods methodology to understand gaming was beneficial to uncovering the major themes uncovered.

**Friends and family affect adoption.** All student participants were introduced to digital gameplay prior to starting middle school, even for the student that opted to use paper and pencil. This age ranged from as early as five to as late as twelve. Typically, the introduction to gaming was done through outside influencers close to the participant, and outside of school. Typically, this introduction took place in their homes, or at the homes of their friends. These influencers were either family, friends, or both that they watched play videogames, and/or from whom they received encouragement to start playing. Sixty-four percent specifically highlighted family as the primary introductory factor. Of this percentage majority of the familial influencers tended to be male, with 45% participants specifically mentioning older brothers and 18% mentioning their father.

## Game Based Learning: Conclusion

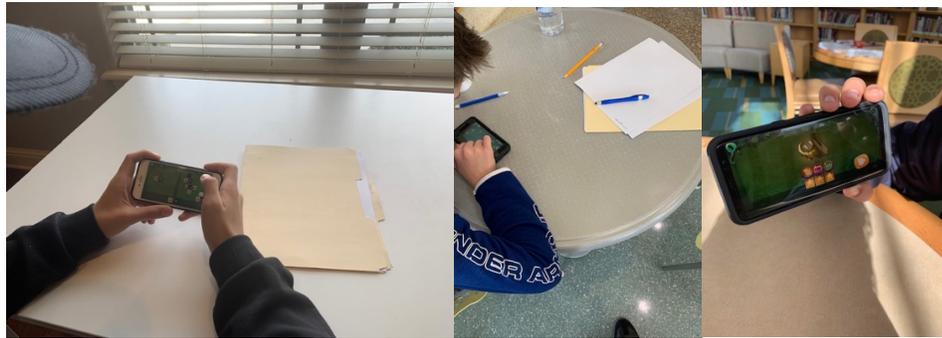
Forty-five percent specifically mentioned friends influencing their decision to start playing, and 9% mentioned both. When asked why and when they would play digital games, 90% mentioned for the purpose of entertainment. When this entertainment was broken down the two major specific factors that stood out were reducing boredom and playing friends.

This further corroborates findings of the Teens, Technology, and Friendship study conducted by the Pew Research Institute (2015), which determined that 72% of teens ages 13 to 17 play video games on a computer, game console or portable device and use these games as a way to establish relationships, spend time and engage in day to-day interactions with their peers and friends (Lenhart, Smith, Anderson, Duggan, & Perrin, 2015). Thus, these findings potentially indicate that though family plays a significant role in introduction of gaming to children, being entertained and playing with friends become the main reasons for their continued use. Therefore, creators of digital games for learning should consider ways balance the involvement of parents and peers of the gamer in their design.

**Learning games are useful but not fun.** Overall, student attitudes were favorable to utilizing games for the exploration, practice and learning of new themes. Ninety-one percent of participants considered digital games for learning to be beneficial, with slightly more than half believing that such games provided an alternative form of learning. This, however, did not translate to such games being considered fun, nor necessary to establish learning. Again, they were seen as tools to provide additional practice and alternative learning methods. All students mentioned they had played a learning game that was specifically created for math, and that this was done in school. Overwhelmingly, the games played were either Prodigy, DreamBox, or both. Seventy-three percent stated these games were not fun, and slightly over half made referred to them as a forced assignment or homework. When asked about DragonBox 12 in particular, though 63% considered it to be interesting and expressed an existence of progressive difficulty resulting in the feeling of accomplishment by completing levels,

## Game Based Learning: Conclusion

45% stated that it was rather simple, repetitive, and may be better suited for younger audiences. When asked about what changes they would make, often suggestions provided would lend themselves to characteristics found within specific commercial games that they played for fun. Suggestions ranged from having more explicit math being showcased, wanting more complexity or variety regarding challenges they had to complete, the desire to compete with their friends, to the ability to modify avatars, have more robust features and opportunities to receive better rewards.



These suggestions, fall in line with what Charsky described in his article From Edutainment to Serious Games, that in order for learning games to be effective, there is a need to understand how game characteristics such as competition and goals, rules, challenges, choices, and fantasy can influence motivation and facilitate learning (Charsky, 2010). They also lend themselves to the idea that player styles may have been a factor that affected their experience, thereby influencing their suggestions. This is not surprising considering when asked what types of games students played, in total 31 were mentioned, with only 19% of those games being mentioned more than once. Similar to the concept of there being different types of learners - assimilators, convergers, accommodators and divergers, according to Bartle's Test of Psychology there are four types of players – killers, achievers, socializers, and explorers - of which each category has a specific way they approach and are motivated to play and thereby learn while playing. For **killers**, the primary focus and motivation is this desire to win, climb ranks quickly or rank highly, and directly compete with their peers. For them, winning is

## Game Based Learning: Conclusion

ultimate thereby DGBL for these players must include elements that allow them to see their scores or ranking in comparison to others, and they must be allowed to either compete against others or the game itself. Similar to killers, **achievers** want to win, but win DGBL to be effective, it must allow for elements that show players how they are progressing through the game from beginner to expert, of which each level gets progressively harder and require more sophisticated expertise. Additionally, badges or rewards should not be easily obtained, because collecting these badges and/or rewards requires advanced skills. Unlike the previous two **socializers** focus on socialising and are driven to develop a network of friends. For DGBL to be effective in this case, there must be elements of that encourage collaboration and teamwork to achieve the bigger or ultimate goal. Ultimately, these types of players are open and excited as long as they do it with friends or others. The last category, **explorers** focuses on seeking to understand the unknown. They are fine with repetitive tasks as long as it leads to the uncovering of something great. For DGBL to be effective in this case, players must be able to go where one else has gone and know what no one else knows. Important elements for this group should include being able to try new things, a sandbox if you will, where they are free to create and not inhibited by too many rules.

It is important to note however that a game cannot be all things to everyone. Despite having suggestions and ideas about what would make the game better which are valid and do have the potential to do just that, the central purpose of the DGBL is to encourage learning – and that must be at the forefront. With this as the case, potentially for older children despite our (researchers, game designers) best intentions and the fact that DGBL has been shown to provide new ways to learn, practice concepts, and bring the abstract to life, they may be exactly what students of this study ultimately concluded - not fun but useful.

**Training and support are imperative for teacher adoption.** Teachers within this study, like students did not believe that technology is necessary to learn math, however they did see it as a tool that if properly leveraged, can be incredibly beneficial.

## Game Based Learning: Conclusion

They acknowledged that technology plays a significant role in the lives of their students, thus ignoring this fact would be futile. All stated interest in exploring digital games as a medium for enhancing curriculum and leveraging its capabilities as an additional method to encourage learning. However the teachers interviewed did express concerns that introducing such technologies into the classroom may not be effective for all students, serve as a distraction, and ultimately may not create the learning intended due to the fact that they are created for the purposes of fun and not for the purposes of learning, by which learning happens as a byproduct and not as a requirement (Ke, 2008). In other words, they were concerned about not having games properly vetted by the teaching community at large to ensure that upon its implementation into the classroom curriculum learning objectives would still be met.

Lastly, but most important was the concern around the lack of support and/or training that exists for implementing such tools into their curriculum. For such to be deemed effective, the interviewed teachers mentioned these games must practice a skill, while incorporating modelling, coaching, and scaffolding. They expressed the need to be able to tie them back to the classroom by either a reflection activity which explores the why, and/or an imbedded assessment within the game. More often than not however, teachers do not find this to be the case. Moreover, the additional tasks of researching the game, learning its nuances, finding parallels within the curriculum for integration, getting school and parental approvals, ensuring that it's versatile enough to incorporate a diverse group of skills and caters to varied learning styles, on top of implementation is not only incredibly taxing, but requires a lot of heavy lifting from teachers. These factors in addition to meeting the demands of their job, while trying to come up with tried and true creative methods, demotivates teachers from exploring digital games in spite of their interest. Ultimately teachers in the study were not against leveraging gaming as tool, if the games are properly vetted, balanced with regard to learning and time spent in preparation for its use, and that they have support upon its implementation into curriculum.

**The desire for commercial games characteristics may be counterintuitive.**

The balance of fun and learning is crucial for students; however, this is not an easy feat to achieve. While certain characteristics typically found in commercial games such as competition and more robust feedback were often expressed to by the students as elements that would add a layer of desired fun and complexity to the DragonBox 12+ intervention, it is important to note that such elements have the potential to not translate to the learning that serious games aim to achieve but can also be detrimental to the learning process. In terms of competition a 2018, researchers Chen, Liu, and Shou, sought to understand its effect on learning science. What they and previous studies found was that the incorporation of such characteristics into DGBL interventions potentially inhibit metacognitive skills, attention, and elaboration as well as create an affective state of anxiety that may be detrimental to learning. Students in the non-competition group performed significantly better than those in the competition group (Chen et al., 2018).

In terms of the desire for robust feedback, one of the things that makes commercial games fun is the little to no explicit feedback they contain. Despite students requesting more of it, research shows that too much detail reduces fun and spontaneity. Thereby, commercial games rely heavily on by automation (e.g., gaining quick reflexes) and chunking (e.g., developing a relatively small number of strategies or procedures that can be rapidly called upon), which are fostered through repetition rather than true scaffolding, and the transference or utilization of what was learned in novel situations or settings (Wainess et al., 2011).

**Employing a mixed methods methodology helped uncover themes.** There has been an increased interest in understanding the effects of DGBL, thus this has fueled the rise of research in this particular area. In most cases, students are exposed to the intervention, and their performance is measured, or students are provided a survey to measure attitudes. Though such methods have provided a wealth of knowledge about the effects of and attitudes toward DGBL, there are some aspects that are not possible to be uncovered by solely employing these methods. Irrespective of failing to reject the null,

## Game Based Learning: Conclusion

pursuing the explanatory sequential mixed methods case study design of both students and teachers does provide much value to future researchers studying DGBL. Not only was the method rigorous and serve as a multi-layered detailed exploration of divergent perspectives ranging in complexity, it also provided the measurement of learning outcomes based upon DGBL exposure, while generating an in-depth understanding of this topic (Cook & Kamalodeen, 2019). This method allowed for the exploration of contradictions that did appear between quantitative results and qualitative findings, while also providing a great range of flexibility which was adaptable to multiple methods of data capture: (a) participatory design of instruments, (b) student/teacher surveys, (c) observations and think aloud sessions, and (d) in depth interviews. Moreover, this method gave a voice to study participants and ensured that the study findings were rooted in their experiences while adding breadth and depth to richness of the data collected (Wisdom & Creswell, 2013). Lastly, the successful implementation of this research design showed that employing such a rigorous method could be done and needs to be done on a larger scale for future DGBL research.

### **Limitations and Considerations**

Working with a protected class of subjects, children posed to be very difficult due to three main barriers, ability to obtain school system approval and access children to participate, moving cross country, and the country shutting down due to the coronavirus (COVID 19) pandemic. There were three attempts to conduct the study within the classroom, at three separate school systems - Howard County Public School System (HCPSS) in Maryland, Fayetteville Public Schools (FPS), and Bentonville School District (BSD) in Arkansas. Unlike the FPS and BSD, HPSS had a formal submission process by which researchers are able to request conducting research within schools. It consists of submitting a form for approval which is reviewed by a committee, similar to the Institutional Review Board (IRB) process done by University of Baltimore. This information was discovered after calling the HPSS headquarters. Unfortunately, the decision was unfavorable, thereby conducting research with HCPSS schools was not

## Game Based Learning: Conclusion

pursued. Soon following, the researcher, who had been working full time relocated to Bentonville, AR for work. The attempt to pursue research in BSD and neighboring FPS were abandoned after multiple months of unsuccessful attempts to connect with the superintendent, school principals, and other school administrators.

Additionally, because of the children are a protected class, rightfully so, getting access to them was difficult. Upon relocating to Arkansas and not having a community that could be leveraged, the researcher had to rely on word of mouth with coworkers, and ultimately two social media groups to get participants. As a result of all of these factors, invisible confounding variable of parental involvement may have played a role in who participated within the study. Unlike conducting this study in a school where parental involvement would consist of only requiring the signing of a consent form, parents in this case had to carve out time out of their schedule and transport their children outside of school hours to participate. As a result of this not all parents who agreed for their children to participate actually followed through. This added dependency on parents, despite word of mouth and social media mommy networks being successful mediums to recruit participants, added a layer of difficult to get participants. Thus, there is a potential that only students whose parents were particularly invested in their child's education and/or had high achieving children, were the students that participated thereby influencing results. Lastly, the COVID 19 pandemic which shut down the United States, started as data collection was underway. As a result of that, including how difficult it was to get participant's, it was decided that the study would conclude early.

### **Final Thoughts and Discussion**

As of the 2019 ESA report, 75% of Americans have at least one gamer in their household, 65% of American adults play video games, 21% of gamers are under 18, 57% of parents play games with their child at least weekly, and 74% of parents believe video games are educational. Additionally, spending on videogames and related accessories went from 25B in 2016 to \$43.4B in 2019 (*2019 Essential Facts About the Computer and Video Game Industry*, 2019). These daunting statistics make it glaringly clear, that

## Game Based Learning: Conclusion

gaming is rapidly becoming a part of mainstream society, and therefore cannot be ignored.

In this study, irrespective of whether students liked to play videogames and/or the intervention itself, all stated that they saw the benefit of utilizing such tools to enhance learning. Additionally, the ATMLQ showed that on average students were open to technology. This was also confirmed in both the demographic survey and in-depth interviews. Though not specifically called out, it was clear that technology played a huge role in their everyday. Students also expressed a desire and interest in having alternative ways to practice concepts, in which gaming was often mentioned as a way to achieve this. Additionally, this study also briefly touched on the important role that teachers play, and why they should be targeted by DGBL designers, developers, and researchers, rather than be considered as an afterthought.

Though students are the primary target of whom the game is created for, teachers are responsible for imparting knowledge, and thereby play a major role in introducing DGBL via the classroom. Repeatedly, teachers made mention of the competing priorities they had to face, which reduced how much time they were willing to spend exploring new techniques. All in all, they are keenly aware and acknowledge that technological advancements which have put the power of the computer in the palm of our hands, reducing barriers of distance and time have transformed every aspect of modern-day society. As a result, the way in which we live our lives, consume products and services, and ultimately learn has irrevocably changed. No longer do the tenets of the past hold true, especially when it comes to education. Teachers recognize that the traditional educational and training theory of the past, regarding how people think and learn may no longer be relevant today, and are therefore open to exploring alternatives such as DGBL (Prensky, 2001). Competing priorities and requirements, time constraints, no formalized vetting process, and lack of training and/or support however, often lend them to revert to trusted and historical methods and approaches rather than exploring new alternatives such as DGBL. Thus, for there to be more adoption of DGBL in the

## Game Based Learning: Conclusion

classroom, these games must be easy enough for teachers to understand and assess, while balancing educational requirements without necessitating large investments of time.

These factors – explosive adoption and acceptance of videogames by society at large, openness of students to DGBL as a tool, and openness of teachers to leverage DGBL to enhance their curriculum – in addition to the fact that majority of DGBL research focuses on small children and not older children, decries the need for more studies such as these to be conducted.

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**Appendix A: Student Participant Letter****MONTH, DATE, 2020**

Dear Parent/Guardian,

My name is Pamela Gibbs, and I am an Information and Interaction doctoral student at University of Baltimore. I am kindly requesting your child's participation in a doctoral research study that I am conducting titled: Game Based Learning: The Effects of DragonBox 12+ on Algebraic Performance of Middle School Students. The intention is to assess the effect of digital games on the way students learn algebra. The study involves completing a demographic questionnaire, two assessments, a survey, and an interview about their experience. Participation is completely **VOLUNTARY** and your or your child may withdraw from the study at any time. All personal and identifying information will be scrubbed and replaced with a serial code, thereby protecting the identity of all participants. If you give your child permission to participate in this study, please read and sign the Informed Consent.

This research study aims to explore whether there is a need to modify the way learning for math - in particular - is carried out, to match the social and societal changes that exist outside of the classroom. Your child's participation in the research will be of help add more evidence to the growing body of research regarding children, learning, and digital games.

This study will be scheduled for **WEEKDAY, MONTH, DATE 2020, from TIME**, at the following address, **ADDRESS**. To participate, your child **MUST** be enrolled in Algebra 1, (b) have mobile phone that can download Dragon Box 12+ (which will be paid for by Pamela Gibbs) and (c) not have played or downloaded DragonBox 12+ prior to the start of the study. If you have any questions or concerns, please contact Pamela Gibbs, by either phone: (301) 807-3744 or email: [pamela.gibbs@ubalt.edu](mailto:pamela.gibbs@ubalt.edu).

Thank you for your time.

Sincerely,

Pamela Gibbs  
M.B.A, Doctoral Student  
University of Baltimore

### Appendix B: Student Participant Flyer



**Participants Must:**

- 7th/8th grade student enrolled in Algebra 1
- Have a cellphone & be able to download mobile games
- Have not played DragonBox 12

**Research Study**

**Contact for participation:**

Pamela Gibbs

Phone: 301-807-3744

Email: [pamela.gibbs@walmart.com](mailto:pamela.gibbs@walmart.com)

**Location**

Local Library

**\$25 Walmart Gift Card for Participation**

**Appendix C: University of Baltimore Student Consent Form****Whom to Contact about this study:**

Principal Investigator: Pamela Gibbs  
Department: University of Baltimore  
Telephone number: (301) 807-3744

**CONSENT FORM FOR PARTICIPATION IN RESEARCH ACTIVITIES**

Game Based Learning: The Effects of DragonBox 12+ on Algebraic Performance of Middle School Students

**I. INTRODUCTION/PURPOSE:**

My child is being asked to participate in a research study. The purpose of this study is to determine whether or not the DragonBox 12+ affects Algebra 1 performance. My child is being asked to volunteer because they are currently a student enrolled in Algebra 1. Their involvement in this study will begin and end on **Friday, March 6, 2020**, from **4:30pm to 7:30pm** when I agree to their participation. In total 10 middle school students will be invited to participate, and this will be open to the public.

**II. PROCEDURES:**

As a participant in this study, my child will be asked to complete all activities and assessments as requested and administered by the researcher.

To participate, my child MUST:

1. Be enrolled in Algebra 1
2. Have mobile phone that can download Dragon Box 12+
3. Not have played or downloaded DragonBox 12+ prior to the start of the study

My child will be asked to download the game DragonBox 12+ on their mobile device at the start of the study, upon the researcher's instruction. My child will complete two surveys regarding their demographics and experience, take two assessments, as well as participate in an audio recorded interview about their experience, strictly for the purposes of allowing the researcher to capture their answers and reactions to questions accurately. These recordings will not be released.

Their participation in this study will last for three hours on **WEEKDAY,**  
**MONTH, DATE 2020,** from **TIME** at the predetermined address,  
**ADDRESS.**

### **III. RISKS AND BENEFITS:**

My child's participation in this study does not involve any significant risks and I have been informed that their participation in this research may not benefit them directly, but will provide more evidence and validation to the growing research regarding the positive effect of digital games as a medium for learning, and ultimately serve as proof of the benefits that can be gleaned when properly integrated within the classroom.

### **IV. CONFIDENTIALITY:**

Any information learned and collected from this study in which my child might be identified will remain confidential and will be disclosed ONLY if I give permission. In order to protect my child's privacy, they will be assigned an identifying serial code that will take place of their name on all materials collected. This code will be generated and understood by only the researcher and members of the research team. All information collected in this study will be placed in an excel workbook on the researcher's encrypted hard drive. The data will also be kept in a secure external device maintained by dissertation advisor. Only the investigator and members of the research team will have access to these records. If information learned from this study is published, my child will not be identified by name. By signing this form, however, I allow the research study investigator to make my records available to the University of Baltimore Institutional Review Board (IRB) and regulatory agencies as required to do so by law.

Consenting to participate in this research also indicates my agreement that all information collected from my child may be used by current and future researchers in such a fashion that their personal identity will be protected. Such use will include sharing anonymous information with other researchers for checking the accuracy of study findings and for future approved research that has the potential for improving human knowledge.

Please select one:

Yes, I do give permission to have audio recordings taken of my child **SOLELY** for the purposes of capturing information. This information will not be used outside of analyzing data.

No, I do not give permission to have audio recordings taken of my child **SOLELY** for the purposes of capturing information.

**V. SPONSOR OF THE RESEARCH:**

Research is funded by a University of Baltimore grant to support student research. This research study is a dissertation to fulfill the doctoral program requirements at the University of Baltimore.

**VI. COMPENSATION/COSTS:**

My child’s participation in this study will involve no cost to me. A remuneration of \$25 in the form of a Walmart gift card will be provided as a result of my child’s participation.

**VII. CONTACTS AND QUESTIONS**

The principal investigator, Pamela Gibbs, and research advisor, Dr. Deborah Kohl have offered to answer any and all questions regarding my participation in this research study. If I have any further questions, I can contact Pamela Gibbs at 301-807-3744, [pamela.gibbs@ubalt.edu](mailto:pamela.gibbs@ubalt.edu) or Dr. Deborah Kohl at [dkohl@ubalt.edu](mailto:dkohl@ubalt.edu).

For questions about rights as a participant in this research study, contact the UB IRB Coordinator: 410-837-6199, [irb@ubalt.edu](mailto:irb@ubalt.edu).

**VIII. SIGNATURE FOR ASSENT**

The above-named investigator has answered my questions and I agree to be a research participant in this study.

Minor Participant’s Name: \_\_\_\_\_ Date: \_\_\_\_\_

Minor Participant’s Signature: \_\_\_\_\_ Date: \_\_\_\_\_

**IX. VOLUNTARY PARTICIPATION**

I have been informed that my child’s participation in this research study is voluntary and that I on my child’s behalf or my child at his/her own choice am/is free to withdraw or discontinue participation at any time.

*I will be given a copy of this consent form to keep.*

**X. SIGNATURE FOR CONSENT**

The above-named investigator has answered my questions and I agree to allow my child/person under my guardianship to be a research participant in this study.

Minor Participant’s Name: \_\_\_\_\_ Date: \_\_\_\_\_

Minor Participant’s Signature: \_\_\_\_\_ Date: \_\_\_\_\_

Parent/Legal Guardian’s Signature: \_\_\_\_\_ Date: \_\_\_\_\_

Investigator's Signature: \_\_\_\_\_ Date: \_\_\_\_\_

**Appendix D: University of Baltimore Teacher Consent Form****Whom to Contact about this study:**

Principal Investigator: Pamela Gibbs  
Department: University of Baltimore  
Telephone number: (301) 807-3744

**CONSENT FORM FOR PARTICIPATION IN RESEARCH ACTIVITIES**

Game Based Learning: The Effects of DragonBox 12+ on Algebraic Performance of Middle School Students

**I. INTRODUCTION/PURPOSE:**

I am being asked to participate in a research study. The purpose of this study is to determine if integrating DragonBox 12+ within the Algebra 1 classroom curriculum will affect performance. My involvement in this study will begin when I agree to participate and will continue for a few hours, during Spring 2020.

**II. PROCEDURES:**

As a participant in this study, I am being asked to complete a survey as well as participate in a video/audio recorded interview about my experience strictly for the purposes of allowing the researcher to capture my answers and reactions to questions accurately. These recordings will not be released. My participation in this study will last for over the course of a few hours during the Spring of 2020.

**III. RISKS AND BENEFITS:**

My participation in this study does not involve any significant risks and I have been informed that my participation in this research may not benefit me directly, but will provide more evidence and validation to the growing research regarding the positive effect of digital games as a medium for learning, and ultimately serve as proof of the benefits that can be gleaned when properly integrated within the classroom.

#### IV. CONFIDENTIALITY:

Any information learned and collected from this study in which I might be identified will remain confidential and will be disclosed **ONLY** if I give permission. All information collected in this study will be kept in an encrypted file on researchers hard-drive and a locked file cabinet in a locked room. In order to protect the privacy of myself and the participating students, an identifying serial code will be assigned and take place of our names on all materials collected. This code will be generated and understood by only the researcher and members of the research team. The data will also be kept in a secure external device maintained by dissertation advisor. Only the investigator and members of the research team will have access to these records. If information learned from this study is published, I nor the participating students will be identified by name. By signing this form, however, I allow the research study investigator to make my records available to the University of Baltimore Institutional Review Board (IRB) and regulatory agencies as required to do so by law. Consenting to participate in this research also indicates my agreement that all information collected from me individually may be used by current and future researchers in such fashion that my personal identity will be protected. Such use will include sharing anonymous information with other researchers for checking the accuracy of study findings and for future approved research that has the potential for improving human knowledge.

Please select one:

- Yes, I do give permission to have video and audio recordings taken of me **SOLELY** for the purposes of capturing information. This information will not be used outside of analyzing data.
- No, I do not give permission to have video and audio recordings taken of me **SOLELY** for the purposes of capturing information.

#### V. SPONSOR OF THE RESEARCH:

Research is funded by a University of Baltimore grant to support student research. This research study is a dissertation to fulfill the doctoral program requirements at the University of Baltimore.

**VI. COMPENSATION/COSTS:**

My participation in this study will involve no cost to me. A remuneration of \$108 in the form of an Amazon gift card will be provided as a result of my participation.

**VII. CONTACTS AND QUESTIONS:**

The principal investigator, Pamela Gibbs, has offered to and has answered any and all questions regarding my participation in this research study. If I have any further questions, I can contact Pamela Gibbs at 301-807-3744, [pamela.gibbs@ubalt.edu](mailto:pamela.gibbs@ubalt.edu).

For questions about rights as a participant in this research study, contact the UB IRB Coordinator: 410-837-6199, [irb@ubalt.edu](mailto:irb@ubalt.edu).

**VIII. VOLUNTARY PARTICIPATION**

I have been informed that my participation in this research study is completely voluntary and that I am **FREE** to withdraw or discontinue participation at any time.

*I will be given a copy of this consent form to keep.*

**IX. SIGNATURE FOR CONSENT**

The above-named investigator has answered my questions and I agree to allow to be a research participant in this study.

Participant's Name: \_\_\_\_\_ Date \_\_\_\_\_

Participant's Signature: \_\_\_\_\_ Date: \_\_\_\_\_

Investigator's Signature: \_\_\_\_\_ Date: \_\_\_\_\_

### Appendix E: Student Demographic Questionnaire

Q: Age \_\_\_\_\_

Q: Gender

- Male
- Female
- Binary

Q: Ethnic group (please check all that apply):

- African American
- Asian
- Caucasian
- Latin X
- Native American
- Pacific Islander/Hawaiian
- Not listed

Q: Name of middle school:

Q: Grade

- a. 7<sup>th</sup> grade
- b. 8<sup>th</sup> grade
- c. 9<sup>th</sup> grade

Q: How many hours on average do you play a day?

- a. None
- b. 1-2 hours
- c. 2-3 hours
- d. 3-4 hours
- e. Other (please specify) \_\_\_\_\_

Q: How often do you do you play computer/videogames?

- a. Daily
- b. Weekly
- c. Monthly
- d. Never

Q: The number of players one regularly plays with online-

- a. Zero

- b. One,
- c. Two
- d. Three
- e. Other (please specify) \_\_\_\_\_

Q: What level do you consider yourself to be on in regard to video games?

- a. Novice
- b. Intermediate
- c. Expert

Q: List the top five games that you play:

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Q: Which platform do you play on?

- Xbox 360
- Xbox One,
- PlayStation 3
- PlayStation 4
- Nintendo Wii
- Nintendo Wii U,
- Nintendo Switch
- PC
- Mobile device
- other (please specify)

Q: Which is your favorite genre of game?

- a. Role Playing Game- Role Playing Game (RPG)
- b. First Person Shooter (FPS)
- c. Adventure, Action
- d. Casual, Sandbox
- e. Indie
- f. Massively Multiplayer Online (MMO)
- g. Massively Multiplayer Online Role-Playing Game (MMO RPG)
- h. Simulation, Strategy, Platformer
- i. Other (please specify)

Q: Have you ever spent money to purchase a game?

- a. Yes
- b. No

Q: If yes, on average how much do your games cost?

- a. \$20 and under
- b. \$21- \$40, \$41
- c. \$60, \$61 – \$80
- d. \$81 – \$100, \$101+

**Appendix F: Student Assessment Pretest**

**Complete the problems below.**

1. Mary says that equations A and B have the same solution.

Equation A:  $-3(x+7) = 24$

Equation B:  $x+7 = -8$

Which statement explains why this is true?

- A. Adding 3 to both sides of Equation A gives  $x + 7 = -8$ .
- B. Applying the distributive property to Equation A gives  $x + 7 = -8$ .
- C. Subtracting 3 from both sides of Equation A gives  $x + 7 = -8$ .
- D. Dividing both sides of Equation, A by -3 gives  $x + 7 = -8$ .

2. Circle all of the expressions that are equivalent to  $(x + 3) + (x + 3) + (x + 3)$ .

- A.  $3x + 9$
- B.  $x^3 + 33$
- C.  $3(x + 3)$
- D.  $3x + 3$

3. Find the value of x for the following equations.

- A.  $x+9=14$
- B.  $20=2x$
- C.  $2+2x=7$
- D.  $\frac{x}{3}+7=10$
- E.  $9x-x-1=15$
- F.  $7=2x+3+x-6$

4. Write an equation for the following scenario, then solve:  
After eating pizza, Joe, John, and Jill decided to divide the bill evenly. If each person paid \$38, how much was the bill?

**Appendix G: Student Assessment Posttest**

Complete the problems below.

1. Which equation is equivalent to the equation  $5x + 30 = 45$ ?

- A.  $35x = 45$
- B.  $5x = 75$
- C.  $5(x+30) = 45$
- D.  $5(x+6) = 45$

2. Circle all of the expressions that are equivalent to  $9(g+2)$ .

- A.  $11g$
- B.  $9g+18$
- C.  $9(g) + 9(9)$
- D.  $18g$
- E.  $18g + 9$

3. Find the value of x for the following equations.

G.  $x+7=21$

H.  $10=5x$

I.  $3+2m=-1$

J.  $\frac{x}{3} - 3 = 5$

K.  $3x+x-1=11$

L.  $7 = -3x+3+x-6$

4. Write an equation for the following scenario, then solve:

The cost of a pizza is \$19.99 plus \$1.50 per topping. How many toppings can you get on your pizza if you have \$25.49 to spend?

**Appendix H: Student Assessment Pretest Answer Key**

**Complete the problems below.**

1. Mary says that equations A and B have the same solution.

Equation A:  $-3(x+7) = 24$

Equation B:  $x+7 = -8$

Which statement explains why this is true?

- A. Adding 3 to both sides of Equation A gives  $x + 7 = -8$ .
- B. Applying the distributive property to Equation A gives  $x + 7 = -8$ .
- C. Subtracting 3 from both sides of Equation A gives  $x + 7 = -8$ .
- D. Dividing both sides of Equation, A by -3 gives  $x + 7 = -8$ . **Answer**

2. Circle all of the expressions that are equivalent to  $(x + 3) + (x + 3) + (x + 3)$ .

- A.  $3x + 9$  **Answer**
- B.  $x^3 + 33$
- C.  $3(x + 3)$  **Answer**
- D.  $3x + 3$

3. Find the value of x for the following equations.

- A.  $x+9=14$  **Answer:**  $X = 5$
- B.  $20=2x$  **Answer:**  $X = 10$
- C.  $2+2x=7$  **Answer:**  $X = 2.5$  or  $5/2$  or  $2 \frac{1}{2}$
- D.  $\frac{x}{3} + 7 = 10$  **Answer:**  $X = 9$
- E.  $9x - x - 1 = 15$  **Answer:**  $X = 2$
- F.  $7 = 2x + 3 + x - 6$  **Answer:**  $X = 3.3$  or  $10/3$  or  $3 \frac{1}{3}$

4. Write an equation for the following scenario, then solve:  
After eating pizza, Joe, John, and Jill decided to divide the bill evenly. If each person paid \$38, how much was the bill?

**Answer** =  $b = \$418$

**Appendix I: Student Assessment Posttest Answer Key**

Complete the problems below.

1. Which equation is equivalent to the equation  $5x + 30 = 45$ ?

- A.  $35x = 45$
- B.  $5x = 75$
- C.  $5(x+30) = 45$
- D.  $5(x+6) = 45$  **Answer**

2. Circle all of the expressions that are equivalent to  $9(g+2)$ .

- A.  $11g$
- B.  $9g+18$  **Answer**
- C.  $9(g) + 9(9)$
- D.  $18g$
- E.  $18g + 9$

3. Find the value of x for the following equations.

- G.  $x+7=21$  **Answer:**  $X= 14$
- H.  $10=5x$  **Answer:**  $X= 2$
- I.  $3+2m=-1$  **Answer:**  $m= 2$
- J.  $\frac{x}{3}-3=5$  **Answer:**  $X = 24$
- K.  $3x+x-1=11$  **Answer:**  $X = 3$
- L.  $7= -3x+3+x-6$  **Answer:**  $X = 5$

4. Write an equation for the following scenario, then solve:

The cost of a pizza is \$19.99 plus \$1.50 per topping. How many toppings can you get on your pizza if you have \$25.49 to spend?

**Answer** =  $X = 3$

**Appendix J: Attitudes to Technology in Mathematics Learning Questionnaire**

**Dimension 1.** The following statements refer to the student's confidence when learning math and in particular, Algebra.

1. I have less trouble learning algebra than other subjects.
2. When I have difficulties with algebra, I know I can handle them.
3. I do not have a mathematical mind.
4. It takes me longer to understand algebra than the average person.
5. I have never felt myself able to learn math.
6. I enjoy trying to solve new algebra problems.
7. I find algebra frightening.
8. I find many algebra problems interesting and challenging.
9. I don't understand how some people enjoy spending so much time on algebra problems.
10. I have never been very excited about algebra.
11. I find algebra confusing.
12. Learning math is enjoyable.

**Dimension 2.** The following statements refer to the student's confidence when using digital games and technology. [The phrase "digital games" is used here to mean Digital Game Based Learning]. (Likert scale: strongly disagree, disagree, somewhat disagree, n/a, somewhat agree, agree, strongly agree)

1. I am quick to learn a new computer software needed for school.
2. Using technology helps me learn math better.
3. I have less trouble learning how to use a digital game than I do learning other things.
4. When I have difficulties using digital games, I know I can handle them.
5. It takes me much longer to understand how to use digital games than the average person.
6. I have never felt myself able to learn how to use digital games.
7. I enjoy trying new things in a digital game.
8. I find playing digital games is frightening.
9. I digital games to be interesting and challenging.
10. I don't understand how some people can spend so much time playing digital games.
11. I have never been very excited about playing digital games.
12. I find using digital games confusing.
13. I'm nervous that I'm not good enough with digital games to be able to use them to learn mathematics.

**Dimension 3.** The following questions refer to student's confidence when using DGBL and applications as a medium to learn and understand mathematics. [The phrase "digital games" is used here to mean Digital Game Based Learning]. (Likert scale: strongly disagree, disagree, somewhat disagree, n/a, somewhat agree, agree, strongly agree)

1. Digital games make it easier to explore mathematical ideas.
2. I know digital games can be fun, but I don't feel I need to use them to learn mathematics.
3. Digital games are good for entertainment, but not for my learning of mathematics.
4. I think using digital games is too new and strange to make it worthwhile for learning mathematics.
5. I think using digital games to learn mathematics wastes too much time.
6. I prefer to learn the traditional way, with pencil, paper and homework without using digital games.
7. Using digital applications makes it easier for me to understand math.
8. I like the idea of exploring mathematical methods and ideas using digital games.
9. I want to get better at using digital games to help me with mathematics.
10. The symbols and language of mathematics are bad enough already without the addition of digital games.
11. Having digital games available to practice with makes me more likely to try different methods and approaches when solving math problems.

**Appendix K: Student In-Depth Interview Questionnaire**

1. At what age did you start playing digital games?
2. How were you introduced to playing digital games?
3. Why and when do you play digital games?
4. How do you feel about playing digital games created specifically for learning?
5. Have you ever played a digital game created specifically for learning?
  - a. If yes, then what was the name of the game?
    - i. Why did you play this game?
    - ii. Did you like playing this game?
6. How do you feel about playing digital games created specifically for math?
7. What were your thoughts about playing DragonBox 12+?
8. What did you like about playing DragonBox 12+?
9. What did you not like about playing DragonBox 12+?

**Appendix L: Teacher Survey****I identify my gender as.... (Select one)**

- a. Male
- b. Female
- c. Non-Binary
- d. Prefer not to disclose

**I identify my age as.... (Select one)**

- a. 24 and under
- b. 25-29
- c. 30-39
- d. 40-49
- e. 50-59
- f. 60+

**I have been teaching for \_\_\_\_\_ years.**

- a. 0-5
- b. 6-10
- c. 11-15
- d. 16+

**I use \_\_\_\_\_ in the classroom.** (Likert options: never, yearly, monthly, weekly, daily)

- 1. Internet for developing lesson plans/ideas
- 2. Apps
- 3. Digital Manipulatives i.e. Calculators/graphing calculators
- 4. Management programs for student data
- 5. Computers
- 6. Active Boards (e.g., White Board)
- 7. Mobile devices
- 8. Tablets (e.g., iPads)
- 9. Digital video cameras

**I use technology in my classroom to...** (Likert scale: never, occasionally, often, always)

- 1. Perform drill and practice
- 2. Provide tutorial/remediation
- 3. Perform calculations
- 4. Explore relationships
- 5. Graph data

6. Develop math models
7. Solve application problems
8. Develop programs
9. Other \_\_\_\_\_

**I would use technology in the classroom more if...** (Likert scale: strongly disagree, disagree, somewhat disagree, n/a, somewhat agree, agree, strongly agree)

1. I had technology available at home
2. I had more technological training
3. I had more time to become accustomed to integrating technology
4. Technology was more accessible in my school
5. I had a conglomeration of ideas to integrate technology
6. Other, state reason below. \_\_\_\_\_

**To be good at mathematics, it is for important for students to...** (Likert scale: strongly disagree, disagree, somewhat disagree, n/a, somewhat agree, agree, strongly agree)

1. Remember formulas and procedures
2. Understand mathematical concepts, principles, and strategies
3. Be able to think creatively
4. Understand how mathematics is used in the real world
5. Be able to provide reasons to support their solutions

**When using technology...** (Likert scale: strongly disagree, disagree, somewhat disagree, n/a, somewhat agree, agree, strongly agree)

1. There is less student collaboration
2. Student create products that show higher levels of learning
3. Students find it harder to solve exercises or problems
4. There are more discipline problems
5. Students are more motivated
6. Students go to inappropriate sites
7. There is more student collaboration
8. Plagiarism becomes a bigger problem
9. The abundance of unreliable sources is disturbing
10. Students are easily able to solve exercises or problems
11. Students are more willing to work on problems for which there is no immediately obvious method of solution
12. Students are able explain the reasoning behind an answer

**I think...** (Likert scale: strongly disagree, disagree, somewhat disagree, n/a, somewhat agree, agree, strongly agree)

1. Electronic media will replace printed text within five years

2. Most technology would improve my ability to teach
3. Technology has changed the way that I teach
4. Students are more knowledgeable than I am when it comes to technology
5. School systems expect us to learn new technologies without formal training
6. There is too much technological change coming too fast without enough support for teachers
7. Technology is a good tool for collaboration with other teachers when building unit plans
8. Technology is unreliable

**I need...** (Likert scale: strongly disagree, disagree, somewhat disagree, n/a, somewhat agree, agree, strongly agree)

1. More time to integrate technology into my curriculum
2. More training to use technology
3. More support from administration when it comes to my technology needs
4. More technical support to keep computers and applications running
5. More access to technology tools to integrate in my classroom instruction
6. More opportunities to collaborate with colleagues on how to use technology
7. More options for professional development in the areas of technology
8. Help aligning the integration of technology with the implementation of Common Core State Standards

**Appendix M: Teacher In-Depth Interview Questionnaire**

1. Which mathematics subjects do you currently teach?
2. What are your thoughts on using manipulatives (pictures, concrete materials, symbol sets, etc.) as tools when teaching math?
3. Do you think technology is necessary in teaching and learning mathematics?
4. Have you ever used a game to teach math?
  - a. If yes, please elaborate on the type of game used?
    - i. Was it digital?
    - ii. What concepts did you use it to teach?
    - iii. In your opinion was it effective?
2. Have you ever played a digital game created specifically for learning?
  - a. If yes, then what was the name of the game?
    - i. Why did you play this game?
    - ii. Did you like playing this game?
3. How do you feel about playing digital games created specifically for learning?
4. What were your thoughts about having your students use DragonBox 12+ as a learning tool?

**Appendix N: Attitudes to Technology in Mathematics Learning Questionnaire  
Results**

<b>Quest. No.</b>	<b>Dimension 1: Student confidence when learning math</b>	<b>Average Raw Score</b>	<b>Average Likert Rating</b>
3	I do not have a mathematical mind.	2	Disagree
4	It takes me longer to understand algebra than the average person.	2	Disagree
5	I have never felt myself able to learn math.	2	Disagree
7	I find algebra frightening.	2	Disagree
9	I don't understand how some people enjoy spending so much time on algebra problems.	3	Somewhat Disagree
10	I have never been very excited about algebra.	3	Somewhat Disagree
11	I find algebra confusing.	3	Somewhat Disagree
12	Learning math is enjoyable.	4	Neutral
1	I have less trouble learning algebra than other subjects.	5	Somewhat Agree
2	When I have difficulties with algebra, I know I can handle them.	5	Somewhat Agree
6	I enjoy trying to solve new algebra problems.	5	Somewhat Agree
8	I find many algebra problems interesting and challenging.	5	Somewhat Agree

<b>Quest. No.</b>	<b>Dimension 2: Student confidence when using digital games and technology</b>	<b>Average Raw Score</b>	<b>Average Likert Rating</b>
6	I have never felt myself able to learn how to use digital games.	1	Strongly Disagree
11	I have never been very excited about playing digital games.	3	Somewhat Disagree
12	I find using digital games confusing.	3	Somewhat Disagree
5	It takes me much longer to understand how to use digital games than the average person.	2	Disagree
13	I'm nervous that I'm not good enough with digital games to be able to use them to learn mathematics.	2	Disagree
8	I find playing digital games is frightening.	2	Disagree
2	Using technology helps me learn math better.	4	Neutral
3	I have less trouble learning how to use a digital game than I do learning other things.	4	Neutral
10	I don't understand how some people can spend so much time playing digital games.	4	Neutral
4	When I have difficulties using digital games, I know I can handle them.	5	Somewhat Agree
1	I am quick to learn a new computer software needed for school.	5	Somewhat Agree
9	I find digital games to be interesting and challenging.	5	Somewhat Agree
7	I enjoy trying new things in a digital game.	6	Agree

Quest. No.	Dimension 3: Student confidence when using DGBL and applications as a medium to learn and understand mathematics	Average Raw Score	Average Likert Rating
4	I think using digital games is too new and strange to make it worthwhile for learning mathematics.	2	Disagree
5	I think using digital games to learn mathematics wastes too much time.	3	Somewhat Disagree
10	The symbols and language of mathematics are bad enough already without the addition of digital games.	3	Somewhat Disagree
1	Digital games make it easier to explore mathematical ideas.	4	Neutral
7	Using digital applications makes it easier for me to understand math.	4	Neutral
3	Digital games are good for entertainment, but not for my learning of mathematics.	4	Neutral
9	I want to get better at using digital games to help me with mathematics.	4	Neutral
6	I prefer to learn the traditional way, with pencil, paper and homework without using digital games.	4	Neutral
2	I know digital games can be fun, but I don't feel I need to use them to learn mathematics.	5	Somewhat Agree

**Appendix O: Wilcoxon Signed-Ranks Test Table**

n	alpha values						
	0.001	0.005	0.01	0.025	0.05	0.10	0.20
5	--	--	--	--	--	0	2
6	--	--	--	--	0	2	3
7	--	--	--	0	2	3	5
8	--	--	0	2	3	5	8
9	--	0	1	3	5	8	10
10	--	1	3	5	8	10	14
11	0	3	5	8	10	13	17
12	1	5	7	10	13	17	21
13	2	7	9	13	17	21	26
14	4	9	12	17	21	25	31
15	6	12	15	20	25	30	36
16	8	15	19	25	29	35	42
17	11	19	23	29	34	41	48
18	14	23	27	34	40	47	55
19	18	27	32	39	46	53	62
20	21	32	37	45	52	60	69
21	25	37	42	51	58	67	77
22	30	42	48	57	65	75	86
23	35	48	54	64	73	83	94
24	40	54	61	72	81	91	104
25	45	60	68	79	89	100	113
26	51	67	75	87	98	110	124
27	57	74	83	96	107	119	134

n	alpha values						
	0.001	0.005	0.01	0.025	0.05	0.10	0.20
28	64	82	91	105	116	130	145
29	71	90	100	114	126	140	157
30	78	98	109	124	137	151	169
31	86	107	118	134	147	163	181
32	94	116	128	144	159	175	194
33	102	126	138	155	170	187	207
34	111	136	148	167	182	200	221
35	120	146	159	178	195	213	235
36	130	157	171	191	208	227	250
37	140	168	182	203	221	241	265
38	150	180	194	216	235	256	281
39	161	192	207	230	249	271	297
40	172	204	220	244	264	286	313
41	183	217	233	258	279	302	330
42	195	230	247	273	294	319	348
43	207	244	261	288	310	336	365
44	220	258	276	303	327	353	384
45	233	272	291	319	343	371	402
46	246	287	307	336	361	389	422
47	260	302	322	353	378	407	441
48	274	318	339	370	396	426	462
49	289	334	355	388	415	446	482
50	304	350	373	406	434	466	503

(“Wilcoxon Signed-Ranks Table,” 2020)

**Appendix P: Wilcoxon Signed-Ranks Test**

<b>Participant</b>	<b>Pre-test assessment score</b>	<b>Post-test assessment score</b>	<b>Difference (Post-Pre)</b>	<b>Positive</b>	<b>Absolute difference (Post-Pre)</b>	<b>Rank</b>	<b>Signed Rank</b>
DBASP01	0.89	0.78	-0.111	-1	0.111	5	-5
DBASP02	0.78	0.67	-0.111	-1	0.111	5	-5
DBASP03	0.89	0.89		1	0.000	OMI T	OMIT
DBASP04	0.78	1.00	0.220	1	0.220	2	2
DBASP05	0.78	0.67	-0.110	-1	0.110	7	-7
DBASP06	0.44	0.78	0.340	1	0.340	1	1
DBASP07	0.78	0.89	0.110	1	0.110	7	7
DBASP08	0.78	1.00	0.220	1	0.220	2	2
DBASP09	0.89	0.89		1	0.000	OMI T	OMIT
DBASP10	0.67	0.89	0.220	1	0.220	2	2
DBASP11	0.67	0.67	0.003	1	0.003	9	9

Sum of positive (S+)	23.00
Sum of negative (S-)	17.00
N	9.00
W statistic	17.00
Critical W	8.00
Mean (W)	33
SD (W)	126.5
Test statistic (W)	-0.122529644
P-Value	0.79191746