VIDEO GAME IMPLEMENTATION: LEARNING OUTCOMES AND PERCEPTIONS

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Dedication

I dedicate this thesis to my family, who have stood by me, encouraged me, and supported me through all the twists and turns of this complex journey. To Dad, Mom, Sarah, Nicholas, Colin, Josh, and Sadie: thank you, and I love you.

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ABSTRACT

VIDEO GAME IMPLEMENTATION: LEARNING OUTCOMES AND PERCEPTIONS

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The purpose of this study was to examine whether student play of a video game designed and developed to teach the engineering process and basic computer programming skills influenced student engagement levels and student knowledge of the engineering process and basic computer programming skills. As the close of the first fifth of the 21st-century approaches, the importance of developing career-ready students has become imperative to address the projected needs of the United States' job market. With this increasing need to attract students to the various STEM professional fields, capturing students' interest in education is crucial. Data were collected from a purposeful sample of sixth to eighth-grade students and teachers in lower socioeconomic school campuses in Colorado, New Jersey, and Texas. Results indicated a strong relationship between the implementation of the game and the learning of basic engineering and computer programming skills as indicated by the high t-scores from the participating classes and positive feasibility perceptions from participating teachers.

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CHAPTER I:

INTRODUCTION

Video games, in various forms, have slowly crept into the zeitgeist since Atari burst onto the scene in 1981 with its Atari 2600 home game console (Atari, 2012). By April 2016, 65% of United States households owned a video game device, and 63% of those homes had at least one person who played games at least three hours a week. These game players are not typical teenagers; research indicates the average male game player is 35 years old and the average female game player is 44 years old (Entertainment Software Association, 2016). However, the largest population of game players fall within the adolescent and teenage years, with 27% of game players being under the age of 18 (Entertainment Software Association, 2016). Specifically, 91% of children in the United States ages 2-17 are playing video games (Van Camp, 2011).

Games are popular because they bring enjoyment, pleasure, and intrinsic motivation that supports continued play (McGonigal, 2011). A well-designed game can captivate a player for hours at a time and produce a level of engagement in the player that educators seek for their students. The challenge comes in how to successfully harness this engagement created by entertaining video games and duplicate it into engagement in educational video games.

An early example of educational video games is the handheld game Phonics Desk, from LeapFrog Enterprises. This game was developed in 1994 to teach letter recognition and led to the creation of a multi-million dollar company (Egan, 2001). Students currently enrolled in grades Kindergarten through twelfth do not know a world without learning through games, such as the handheld cartridge game systems from LeapFrog. If there is a twenty-year history of consumer demand for an educational video game that has been proven successful in the ability to teach the fundamental concepts of reading and math, then why do educators and administrators mistrust the efficacy of video games as effective teaching and learning tools?

Generation Z consists of a demographic of people born between 1995 and 2010. This generation is known as “Digital Natives” and views technology as an essential part of their life (Mohr & Eric, 2017). Generation Z grew up playing and learning using video games; naturally, that same generation expects that this instructional mode would be present in their formal classroom. However, a survey of pedagogy from the 1990s indicated that student-centered technologies were not the instructional mode found in the classroom. Rather, less engaging pedagogical practices were much more prevalent in schools (Heffernan, 2010). The latter half of the 20^{th} century was defined educationally by the prevalence of worksheets and pedagogical practice that was commonly known as “Drill and Kill”; a method focused on learning through repetition and reinforcement. Worksheets, easily mass produced, could be given to students over and over again until students were successful in their efforts. However, in this model, true learning did not occur. Students memorized content long enough to pass the assessment but did not retain the content after the assessment (Heffernan, 2010). The growing gap in the United States job market within the STEM Professional fields has proven that the educational practices of “Drill and Kill” which were successful in the past are no longer sufficient in preparing students entering college or the workforce. These outdated methods resulted with little to no retention of the content and students lack the knowledge required to be successful (Gresham, 2017). Additionally, businesses do not have the time nor do they want to dedicate the resources to teach foundational content knowledge that the student should have learned in middle and high school (B. Oliver, 2015).

Consequently, what society considered to be good educational practices fifty years ago are no longer enough for success in college and career readiness in the 21^{st}-

century (Qian & Clark, 2016). The 21st century needs a new kind of student, with a new kind of skill set, to meet the demands of the new technologically advanced workforce. The purpose of this study was to examine whether student play of a video game designed and developed to teach the engineering process and basic computer programming skills influenced student engagement levels and student knowledge of the engineering process and basic computer programming skills.

Research Problem

Members of the academic community, specifically in the K-12 environment, continue to underestimate the value of serious game implementation in the classroom. The problem is that there is a generation of students that have grown up playing games to learn basic developmental skills informally, yet when they enter formal learning situations, the pedagogy tends to be the same as it was twenty years ago. There is a need to implement innovative solutions that teach today's students the 21st-century skills to be career-ready upon graduation. 21st-century skills are student-centric; they are an interconnected set of skills with the impetus for developing critical thinking, collaboration, communication, and creativity. Jobs that will exist in the next 10 to 20 years will require the application of these 21st-century skills, through the integration of STEM content knowledge. These 21st-century skills create the framework for learning STEM content, specifically basic engineering and computer programming skills. Schools should be preparing students not only for engineering and computer programming jobs that exist today but also for the STEM jobs that are that have not been discovered or created yet.

It is likely that the career path for current K-12 students is going to involve a STEM focus (Wang, Moore, Roehrig, & Park, 2011). STEM, which stands for the cross-curricular application of Science, Technology, Engineering, and Math, is the content foundation for the application of 21st-century learning skills (Richards, Stebbins, & Moellering, 2013). The growth and popularity of STEM come from a growing awareness of the role that 21st-century learning skills play in the development of career-ready students. Despite the identification of the need to develop 21st-century learning skills through STEM content, not all stakeholders involved in the learning process agree with this innovative direction (Halverson, 2005).

Innovative and engaging methods for teaching STEM are required to meet the needs of the 21st-century learner. As the current generation of students has been raised on games as an instructional mode outside the classroom, one innovative approach is to use games as an instructional mode to teach students inside the classroom. Studies have investigated the relationship between games and student engagement (Clark, Tanner-Smith, & Killingsworth, 2016; Hanus & Fox, 2015; Like, 2013; Reynolds & Chiu, 2016). The studies show how games provide a strong level of engagement into a wide range of content for a wide range of learners, specifically in the middle school grade levels. Games increase engagement to play by integrating fun, motivation, challenge, and experience (Kappen & Nacke, 2013). Video game play and the impact on 21st-century skills, as discussed in the literature review, may provide an understanding of the various factors that can influence the learning through video game play.

Significance of the Study

This project focused on the playing of a serious game that targeted students between sixth and eighth grade and the impact on their skill development of basic engineering and computer programming skills. The game under study was designed to help students gain knowledge and experience in the application of the engineering process and basic computer programming skills in a game-based format.

A purposeful sample of 86 students in grades six through eight encompassing five classrooms across four different school districts in the United States participated in the study. Students were given a pre/post-test to gauge improvements in knowledge of the engineering process and basic computer programming skills. Students were observed in a classroom setting during regular school hours as they played the game.

Teachers of the various subjects for grades six through eight were asked to participate in the study. Before gameplay, students completed a pre-assessment to establish a baseline for their knowledge of basic engineering and computer programming skills. Participating teachers then allowed students to play the video game during regular classroom time until the students completed the game. After completion, a post-assessment was administered to measure growth in the engineering process and basic computer programming skills. Students participated in focus groups to provide feedback on their perception of the game experience. Additionally, participating teachers completed a perception survey and participated in focus groups to provide feedback on perceptions of product usage and the feasibility of implementation in the classroom.

Research Purpose and Questions

The purpose of this study was to examine whether student play of a video game designed and developed to teach the engineering process and basic computer programming skills influenced student engagement levels and student knowledge of the engineering process and basic computer programming skills.

R1: Does the Aegis video game improve student programming skills?

R2: Does the Aegis video game improve student math and engineering skills?

R3: What are the students' level of engagement with the Aegis video game?

R4: What are the teacher perceptions of the Aegis video game usage and feasibility as an instructional tool in the classroom?

R5: What are the barriers to the fidelity of implementation for the Aegis video game?

Definitions of Key Terms

1:1 (One to One) – School districts that provide technology, either a laptop or a tablet, for each student. The device, depending on the age of the student, will either stay in the classroom or may be taken to the student's home. Students generally return the device to the district at the end of the school year.

21st-Century Skills – Set of skills developed by the NEA that are suggested to be the foundation of learning and preparedness for career paths for students.

Active Learning – the method of learning where students learn a concept by doing that concept.

Affordance – Affordance is an object that defines its possible uses or makes clear how something is to be used. In the video game used in this study, the "Communiplanner" is an affordance. The "Communiplanner" is a device within the game that is used to store definitions of key terms learned within the game, a summary of levels completed, as well as a calculator.

Chromebooks – Laptops created by Google running ChromeOS operating system. These laptops are web-based and designed to operate in the cloud and not utilize any locally installed programs.

Code of Aegis – The video game used in the experiment. This game, developed by Tietronix in 2015, was distributed as version 1.00 to the participants.

Cohen's d – statistical analysis used to indicate the difference between two means. In this study, the two means examined were the pre and post-assessment.

Computer Programming – creation and application of code using blockchain coding made popular in other guided learning devices like Scratch.

Constructivism – An educational theory developed by Jean Piaget that states students learn and construct knowledge based on their experiences, either in or out of the classroom. It is the foundation for the concept of active learning.

Cross-Curricular – The implementation of more than one subject such as English, Math, and Science within a lesson or unit.

Middle School – Selection of academic grade levels that are between elementary and high school. Generally regarded as 5^{th} grade through 8^{th} grade.

Mixed Methods Research - The class of research where the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts or language into a single study

Operationalization - A process of defining the measurement of a phenomenon that is not directly measurable, though other phenomena indicate its existence.

P-value – measurement of the extremes in a study and represents the probability that the result had nothing to do with the experiment

STEM – Cross-curricular implementation of Science, Technology, Engineering, and Math skills

T-value – the score after performing a t-test. The t-value represents the difference between the mean or average scores of two groups while taking into account any variation in scores due to anomalies

Transmedia – telling a story across multiple platforms, such as books, movies, music, or video games.

Conclusion

For many years games have been used as a method of entertainment. However, with the advent of serious games, the belief that games could only be used as entertainment has evolved into the realization that games could be used as a learning tool. The impact of student engagement and knowledge of basic engineering and computer programming skills after playing a serious game in the middle school classroom will support that growing realization. Although barriers exist, innovative thought through the development and implementation of serious games will help to develop learning strategies that will prepare 21^{st}-century students for 21^{st}-century careers.

CHAPTER II:
REVIEW OF LITERATURE

The purpose of this study was to examine whether student play of a video game designed and developed to teach the engineering process and basic computer programming skills influenced student engagement levels and student knowledge of the engineering process and basic computer programming skills. Studies for playing serious games have analyzed the implementation of serious games in the development of manufacturing skills, engagement in higher education classrooms, and the impact on intrinsic and extrinsic motivation in high school students. Factors considered for this study include intrinsic motivation (Ciampa, 2014; Malone, 1980), teacher professional development (Gamrat, Zimmerman, Dudek, & Peck, 2014), and gamification in higher education (Cain & Piascik, 2015; Ejsing-Duun & Karoff, 2014). While studies have examined population differences in both serious games and engineering and basic computer programming skills in middle school students, they have mostly ignored possible relationships between the two topics.

Video Games for Entertainment

Parents have played games with their children for years. They played peekaboo, hide and seek, and participated in Easter egg hunts. All these are types of games that children have played since infancy and continued to play during their formative years. Infants engaged in playing games could also become children that are engaged in playing games. Games, such as sports, board games, or card games, bring joy and engagement to the player (Holbrook et al., 1984).

As technology and society advanced, so did the type of game played. In the late 1970s, video games began to appear in arcades. Then, in the 1980s, video games appeared on the personal computer and the home game console. As the demand from consumers for more advanced games increased, game systems such as Nintendo, Sega and PlayStation began offering games with a greater depth of story and visual appeal. "Although the earliest video games such as *SpaceWar!* and *Pac- Man* relied more or less on fastpaced button presses and increasingly complex logic puzzles as the primary means for entertainment, the medium has since evolved—as most forms of entertainment media do—into a tool capable of offering a wide variety of emotional experiences, from basal arousal to pain and poignancy" (M. B. Oliver et al., 2016, pp. 2–3). Video games also became mobile, with the development of dedicated handheld systems such as the Nintendo GameBoy, Sony PSP, and Atari Jaguar. Games also found their way onto cell phones and now smartphones. Currently in the United States, 77% of Americans own a smartphone (Pew Research Center, 2018). 17% of game players use a dedicated handheld system and 36% use a smartphone to play games (Entertainment Software Association, 2016). Simply put, people love games in every possible medium and dedicate their free time to playing those games (Entertainment Software Association, 2016; Statista, 2016).

Figure 2.1. Percentage of Leisure Time Spent Playing Video Games

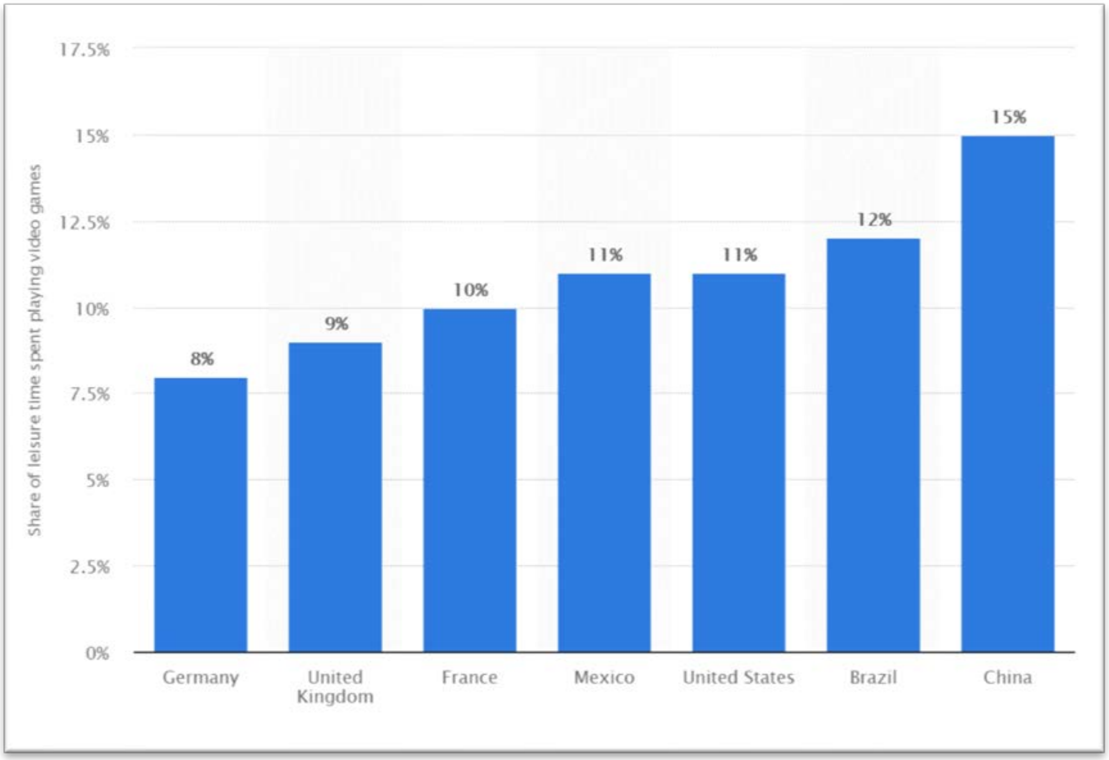

Figure 2.1: Percentage of leisure time used to play video games in selected countries as of May 2016. China at 15% represents the highest percentage, while Germany at 8% represents the lowest in this figure. The United States tied with Mexico for third at 11% (Statista, 2016).

As Figure 2.1 depicts, the population of the United States spends 11% of its leisure time playing video games. Five countries spend at least 10% of their leisure time playing video games, with the leader being China at 15%. People from all walks of life, including educators, are motivated to use their leisure time to play games. The challenge is how to translate the intrinsic motivation to play video games into a useful teaching tool in the classroom.

Video Games in the Classroom

As is widely recognized in research and literature, motivation is a critical factor in the learning process (Froiland, Oros, Smith, & Hirchert, 2012; Malone, 1980; Taylor et al., 2014). Early motivation theories can be traced back to Maslow's Needs Hierarchy and continued development through the Self Determination Theory (SDT) proposed by Deci and Ryan in 2000 (Maslow, 1943; Turner et al., 2010). Deci and Ryan took a multidimensional approach toward learning, measuring the autonomy of a decision and its value in learning. This approach builds on their 1985 study of intrinsic motivation which stated that when intrinsically motivated, individuals engage in the activity only for personal enjoyment, not for a reward or to satisfy a requirement.

Serious Games (SG) are games designed and developed specifically for a purpose other than strictly for entertainment, such as for learning a concept. Serious games are the natural intersection between learning and entertainment by utilizing the experience of gameplay but within in the classroom. Gee argues, "Contemporary learning theory has something to teach us about how to design even better and deeper games" (Gee, 2008, p. 21); suggesting that there is an intertwining of learning and serious games. These games, specially designed for education and inclusive of student learning outcomes, require the appropriate technology and instructional strategies to develop those games.

In 1999 LeapFrog Enterprises, a member of the Vtech Group, introduced the LeapPad. It was an evolutionary step from their favorite cartridge-handheld LeapFrog device as it combined an interactive printed book with the corresponding cartridge (VTech Electronics, 2018). The LeapPad evolved the concept of serious games with the currently available technology by providing a more multifaceted and interactive gameplay experience for the user. The transmedia experience of physically reading a book while also experiencing gameplay based on that book was something no other informal learning tool could offer. This innovative concept was a financial success for LeapFrog Enterprises and became the roadmap for the development of serious games in the modern retail world (Agate, 2017).

The pedagogical climate of "Drill and Kill" was popular at the time of the introduction of LeapPad. Despite the pedagogical climate at the time, other serious games used in education began to develop. Games such as Where in the World is Carmen Sandiego? and Oregon Trail were used to teach students social studies through interactive play, instead of simply memorizing dates and times of historical events. "For example, unlike films, books, or TV programs, games provide (and sometimes require) the opportunity for the player to be actively involved in story narratives and in making decisions regarding the course of events" (M. B. Oliver et al., 2016, p. 395).

Teachers and administrators saw the impact of engagement and learning through this growing genre of video games (Granic, Lobel, & Engels, 2013). According to game designer, researcher, and author Jane McGonigal, humans spend over 3 billion hours a week playing online video games (2010). Game players are engaged in gameplay because it brings them joy. This level of engagement is ravenously desired in the classroom by all teachers, "Successful games (i.e., those that bring about game-playing) could be analogous to the concept of behavior traps in which game designers are concerned with keeping players engaged in the game in the same way that educators are concerned with keeping children engaged with academic material" (Morford, Witts, Killingsworth, & Alavosius, 2014, p. 35). The more students are engaged in the curriculum, the more likely they are to be intrinsically motivated to continue learning (Morford et al., 2014). Intrinsic motivation creates an improved quality of effort and improved comprehension of learning outcomes in students (Mekler, Brühlmann, Tuch, & Opwis, 2017).

21st-Century Skills

Research has shown that video games for entertainment can promote meaningful learning through providing players with an adaptive challenge, curiosity, self-expression, discovery, immediate feedback, clear goals, player control, immersion, collaboration, competition, variable rewards, and low-stakes failure (Qian & Clark, 2016). In 2004, the National Education Association (NEA) established what became known as the "Framework for 21st-Century Learning," highlighting 18 different skills (National Education Association, 2014). However, this framework, with its many different skills, became too cumbersome and confusing for educators to understand and follow. Therefore those eighteen were consolidated and condensed into four skills, which became known as "The 4 Cs." (Figure 2.2).

Figure 2.2. The 4Cs of 21st-Century Skills

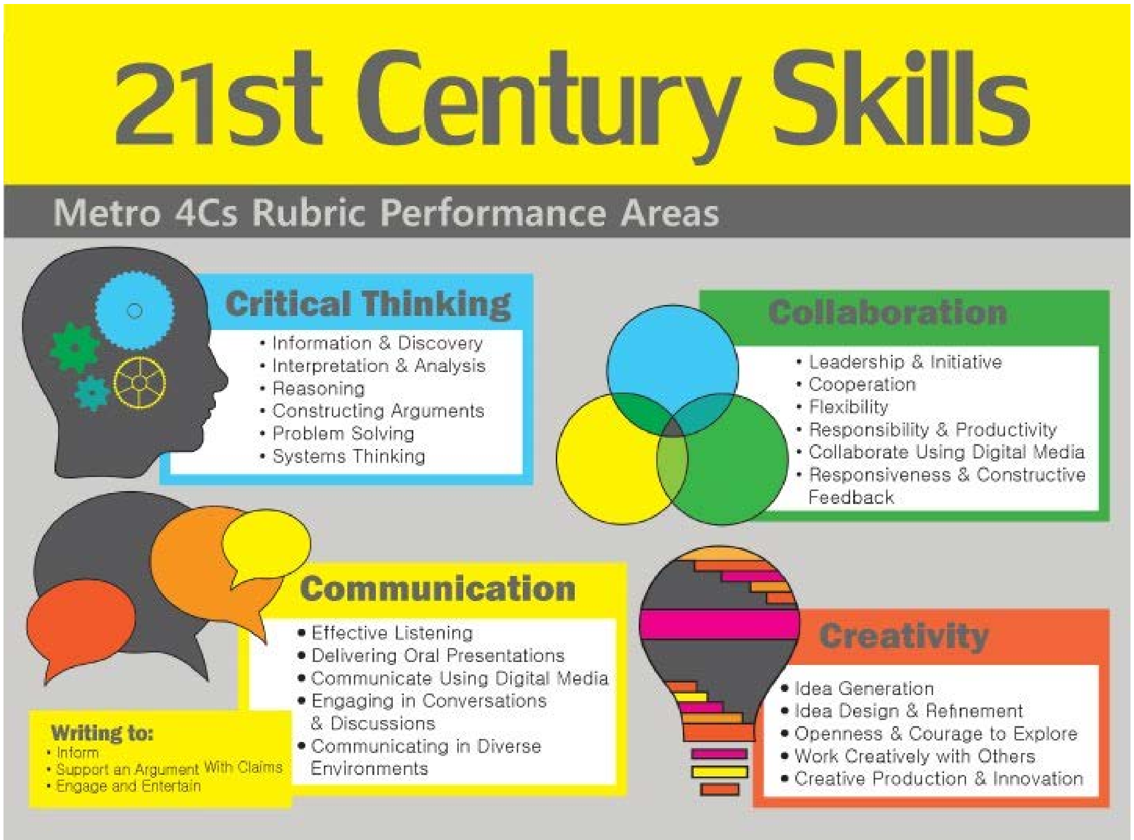

Figure 2.2: The 4Cs of 21st-century skills, as developed by the National Education Association. This infographic, created by Microsoft in Education, shows each of the subskills needed to develop each of those four primary skills (Microsoft, 2016).

Pedagogical practices moved to the 21st-century with the focus on the development and integration of these 21st-century skills into teaching and learning. By moving away from the "Drill and Kill" method and towards methods of learning that had a constructivist foundation, the teacher's role in the learning also needed to evolve (Kivunja, 2014). For example, when 21st-century skills are applied to stimulate collaborative learning, the teacher becomes a facilitator and not the driving force in the classroom. "Thus, in teaching our students along this pedagogical paradigm shift, we need to use the powerful technologies available today to educate children and help them become critical thinkers and problem solvers so that they acquire skills that will be the engines for their success in workplaces, trades, occupations, and professions of the 21st-century; thus meeting the moral purpose of education" (Kivunja, 2014, p. 85).

21st-century skills provide the framework for teaching STEM content, like computer programming and basic engineering skills. Computer programming and engineering involve 21st-century skills such as computational (systems) thinking, problem-solving, and constructive feedback. However, learning a computer programming language can be challenging for students (Major, Kyriacou, & Brereton, 2012). Robotics and robotic programs are one medium often used to increase interest in programming. LEGO® and other robotics competitions have become a pathway for students to learn about a variety of computer programming languages in a formal educational setting. However, learning to program using robots can be a daunting task. Students have to not only learn the programming language, but they must also understand the math and physics behind the robots and their movements (Lau, Tan, Erwin, & Petrovic, 1999). Additionally, the time investment for students and parents in the various robotics competitions leave little time for mentors or coaches to teach students programming and programming logic.

The Joan Ganz Cooney Center at Sesame Workshop released their "Games for a digital age: K-12 market map and investment analysis" report (Richards et al., 2013). They defined the landscape for learning games as a continuum from short-form to long-form games. Short-form games are designed to be played in a single class period or as part of an individual lesson. Long-form games continue beyond the single class period and potentially can spread over weeks of gameplay. "Long-form games have a stronger research base than short-form games and are focused on higher order thinking skills that align more naturally with new common core standards" (Richards et al., 2013, p. 4). The report states long-form games are significantly more engaging and "foster motivation which keeps students involved in the learning experience" (Richards et al., 2013, p. 14). Long-form games allow for better skill development of procedural gameplay skills, which could allow for more advanced skill development. Long-form gameplay also introduces an in-depth narrative aspect to a video game so a developed story can emerge. Reluctant and resistant readers are not engaged in long, in-depth stories but prefer short, easily digestible reading material (Nielen, Mol, Sikkema-de Jong, & Bus, 2016). The shorter content does not allow for a deep development of a storyline. Long-form gameplay offers that time investment to cultivate a developed storyline. Students that are reluctant or resistant readers may only develop their literacy skills while playing video games (Jolley, 2008).

In the computer and video gaming world, companies often use graphic novels for transmedia storytelling in games targeted at children and adults. However, graphic novels are a relatively new pedagogical tool in education. In 2004, the Maryland State Department of Education ran a pilot program by partnering with Disney Publishing Worldwide to use comic books in a classroom of third-grade students in hopes of increasing student engagement in language arts (Sonnenschein, Baker, Katenkamp, & Beall, 2006). Some of the issues that arose during the pilot included an unclear plot, unrealistic characters, not enough content, too few examples, and a need for more reader involvement. While the first two issues were language arts specific, the other issues could possibly be better addressed with a video game component to create a complete transmedia experience. The advantage of using video games is they add user involvement and can bring ample examples while presenting more content. Video games can also integrate multiple STEM and non-STEM subjects and are rapidly becoming essential in today's educational setting (Wang et al., 2011). Engaging games like Carmen Sandiego transport a player on an educational journey across the United States, the world, or even traveling through time. Video games add interactivity; allowing the player to run through numerous simulations without the concern of the cost of supplies or potential safety hazards (Halverson, 2005).

STEM in the Classroom

With the advent of and the popularity of serious games such as LeapFrog/LeapPad, Where in the World is San Diego? and Oregon Trail, video game developers began to be aware that the popularity of video games could translate into serious games. Serious games, with the focus on STEM content, could not only enhance the 21st-century learning skills but also provide an increased cross-curricular application of STEM and 21st-century skills such as computer science and computational thinking. A 25-year longitudinal study established the power of spatial skills in predicting achievement in science, technology, engineering, and mathematics career fields (Wai, Lubinski, Benbow, & Steiger, 2010). STEM areas of expertise have repeatedly been linked to long-term career success and are predicted to be especially critical in the next century (Wai et al., 2010). Serious games, implemented in the PK-12 curriculum, needed the proper technology to garner acceptance in school districts, and the 1:1 initiative was the catalyst for acceptance.

The inclusion of serious video games in the PK-12 curriculum is increasing at a rapid rate especially with the growing number of 1:1 initiatives. These classroom initiatives provide a tablet (Android, iOS, or Windows) or laptop to every student, are being adopted by multiple school districts. Serious games not only have a specific educational purpose but they have the potential to make a significant impact on student learning outcomes (Gee, 2008). Video gameplay provides excitement and cognitive stimulation for students while increasing motivation and engagement. Video games can be an asset to the classroom, where they can be used to support and assess student learning across a wide variety of content areas (Aldrich, 2009).

Game developers realize there is a gap in the educational game sector not fulfilled in the traditional entertainment game landscape. Video game designers are considering this gap analysis and developing creative ways to teach students how to computer program engagingly. Serious games could be utilized to teach computer programming and engineering skills as well as other STEM skills. Explicitly the serious games would teach the skills that were designed to make students career-ready in STEM job fields.

Research has identified the lack of sufficient teacher control of instruction and assessment as potential barriers to the acceptance of serious games in the K-12 classroom (Wendel, Göbel, & Steinmetz, 2011). Consequently, the assessment must be a crucial component of serious games if they are to be utilized as a pedagogical tool in the classroom. User feedback and performance assessments provide disaggregateable data and personalization of student learning that allows the teacher to meet the diverse needs of the learner while gauging progress in learning (Bellotti, Kapralos, Lee, Moreno-Ger, & Berta, 2013). For serious games, implemented into standard classroom instruction, teacher control of the instruction and assessment are vital requirements.

Barriers to Implementation

There are barriers to the implementation of serious games in the classroom. The lack of proper professional development on how to implement innovative pedagogy such as serious games in the classroom is a significant barrier. Occasionally, school districts purchase an innovative classroom tool without a clear goal or vision of its implementation in the classroom (Saltinski, 2014). Additionally, there is little to no adequate professional development to teach the teachers about the feasibility of the serious game as an instructional classroom tool. “PD needs to show teachers that this is a tool and which part of the tool is appropriate for various aspects of learning” (Stefanick, 2014, p. 1). Instead, teachers are often handed a tool, given little class time to learn how to use it, and then charged with figuring out a way to integrate the tool into teaching and learning without proper understanding and experience in using the tool.

Another barrier to implementation is time. Teachers may have difficulty managing the time required to learn a new skill and may not believe the return of potential improvement scores is significant in comparison to the time investment. Many serious games require an initial investment in time, but that time investment could allow the teacher to reap the rewards of investment when observing student growth. Traditional teachers also struggle in seeing the learning value in games and gaming; they still envision games only for entertainment purposes (Abrami, Poulsen, & Chambers, 2004).

Another problem is the lack of innovative spirit among administrators (Abrami et al., 2004). Administrators have to be extraordinarily aware of what is going on in the classroom concerning classroom production. If students are not progressing academically, as defined by most districts and education agencies as students passing state-mandated exams, then those administrators are under pressure to improve academically. Due to this, innovative teaching practices such as serious game implementation get abandoned in exchange for tried-and-true traditional pedagogy such as the "Drill and Kill" method. That lack of innovative freedom is a significant barrier to serious game implementation in the classroom (Stieler-Hunt & Jones, 2017).

Additionally, among the more common barriers to implementation is the financial investment. Some school districts cannot afford to maintain and upgrade classroom computers to the most current versions needed to run the more complex serious games.

Investment in technology can be expensive, especially in lower socioeconomic areas. Often, lower socioeconomic school districts use computers that are running operating systems that are three to four generations behind the current standard of computers that were purchased with minimum specifications five to ten years ago.

Conclusion

The body of research for playing serious games to teach STEM concepts such as basic engineering and computer programming skills continues to expand with greater knowledge and developing technologies. With a greater knowledge base and omnipresent emerging technologies, students should be career-ready in any STEM career path. However, the development of career-ready students with developed 21st-century skills in STEM careers remains a significant concern. This study examined how to stimulate the learning of basic engineering and computer programming skills using serious games. Findings may encourage further research into serious game implementation in the middle school classroom and development of other serious games that can increase learning of other 21st-century skills while still focusing on the STEM content. Chapter III addresses methodologies, research design, and procedures.

CHAPTER III:

METHODOLOGY

The purpose of this sequential mixed-methods study was to examine whether student play of a video game designed and developed to teach the engineering process and basic computer programming skills influenced student engagement levels and student knowledge of the engineering process and basic computer programming skills. This study collected data from a purposeful sample of 86 sixth to eighth-grade students attending middle schools located in various parts of the United States and from each of the teachers who participated in the study. Quantitative data was collected from students utilizing a pre- and post-assessment and from teachers using the *Teacher Perception Survey*. Quantitative data from the pre- and post-assessment was analyzed using Pearson's product moment correlations (r). Data from the collected from the *Teacher Perception Survey* responses was analyzed using frequencies and percentages. Qualitative data were collected from participating students and teachers utilizing focus groups and interviews. An inductive coding process was used to look for themes that may emerge from the participants' focus group. This chapter delivers an overview of the research problem, the operationalization of theoretical constructs, research purpose and questions, research design, a description of the population and sample, instrumentation, data collection procedures, data analysis, privacy and ethical considerations, and research design limitations.

Overview of Research Problem

Utilization of serious games in the classroom can positively affect student engagement and student knowledge taught in the games. This study will examine whether the playing of a video game designed and developed to teach the engineering process and basic programming skills influences student engagement and increases students' knowledge of the engineering process and basic computer programming skills. This study aims to increase awareness of implementation of serious games in the EC-12 classroom. Other benefits of the study include the reciprocal information back to game designers to enhance elements for the design of serious games in the classroom.

Operationalization of Theoretical Constructs

This study consisted of two theoretical constructs: (a) student learning of basic computer programming and engineering skills and (b) teacher perception of the efficacy of serious game implementation. Student learning of basic computer programming and engineering skills describes their improved knowledge of those concepts from the start of the video game until the completion of the video game. Data were measured based on the disaggregation of the *Code of Aegis Student Pre-Assessment Survey* and the *Code of Aegis Student Post-Assessment Survey* (Peters, Sansing, & Lawing, 2015). Teacher perception describes the teacher's perception of how effective the video game is through the lens of engineering process knowledge, programming skill development, and pedagogical strategies. Teacher perception was measured using the *Teacher Perception Survey* developed during the beta testing stage of the video game (Peters et al., 2015).

Research Purpose, Questions, and Hypothesis

The purpose of this study was to examine whether student play of a video game designed and developed to teach the engineering process and basic computer programming skills influenced student engagement levels and student knowledge of the engineering process and basic computer programming skills. The following research questions guided this study:

R1: Does the Aegis video game improve student programming skills?

H_a: The Aegis video game does improve student programming skills.

R2: Does the Aegis video game improve student math and engineering skills?

H_a: The Aegis video game does improve student math and engineering skills.

R3: What are the students' level of engagement with the Aegis video game?

H_a: Students will have a high level of engagement with the Aegis video game.

R4: What are the teacher perceptions of the Aegis video game usage and feasibility as an instructional tool in the classroom?

H_a: Teachers will have a positive perception of the usage and feasibility of the Aegis video game as an instructional tool in the classroom.

R5: What are the barriers to the fidelity of implementation for the Aegis video game?

Research Design

A sequential mixed methods design was used for this study. The design had two phases; a quantitative phase followed by a qualitative phase. The justification for utilizing a mixed methods design is, "If findings are corroborated across different approaches then greater confidence can be held in the singular conclusion; if the findings conflict then the researcher has greater knowledge and can modify interpretations and conclusions accordingly" (Johnson & Onwuegbuzie, 2004, p. 19). A purposeful sample of 86 sixth to eighth-grade students from various middle school content classrooms throughout the U.S. participated in the study. The students completed a pre- and post-assessment to measure their knowledge growth from playing the video game and participated in focus groups. Corresponding teachers also completed the *Teacher Perception Survey* and participated in focus groups. Quantitative data were analyzed using frequencies, percentages, and a paired sample t-test. Qualitative data were analyzed using an inductive coding method.

Population and Sample

The population for this study was 86 sixth to eighth-grade students. Video game play occurred in five different middle, or intermediate school classes across four different school districts located in the various parts of the U.S. District AISD and CISD are located in Texas, BISD is located in New Jersey, and DISD is located in Colorado. All five classes in the four school districts provided data from the traditional school day setting. Implementation occurred in one class in AISD, BISD, and CISD, and in two classes in DISD.

There is a wide variation in student enrollment among the various districts, as shown in Table 3.1. AISD has a student enrollment of over 3,000 for each of the investigated grade levels, while BISD and DISD have student enrollments of under 1,200 for each of the investigated grade levels. CISD has a student enrollment of over 13,000 for each of the investigated grade levels. The diversity of the populations in each of the school districts also has a wide variation. AISD and CISD have a non-caucasian population of over 90%, while BISD and DISD have a non-caucasian population of under 33%. Even though there is a significant difference in student population and diversity enrollment, each school district is considered to be of low socioeconomic status in comparison to other school districts relative to the surrounding geographic area of the United States.

Table 3.1

Student Demographics per District (2016-2017 School Year)

Demographics	AISD	BISD	CISD	DISD
Race/Ethnicity				
Black	28.7%	1.3%	23.9%	1.3%
White	4.1%	68.5%	8.7%	74.3%
Hispanic	52.7%	15.4%	62.1%	17.7%
Grade Level				
5^{th}	3401	66	16,666	1120
6^{th}	3283	52	14,041	1135
7^{th}	3004	58	13,543	1160
8^{th}	3059	61	13,581	1148

A purposeful sample of 86 students were selected for this study from five classes in four school districts. Within each school district, one teacher and their six through eighth-grade students were selected for participation. One teacher in DISD selected two classes for participation in the study. Teachers were selected based on their content area and interest in the project. Content areas were focused on the STEM subjects; science, technology, engineering, and math classes. An additional consideration for teachers outside the STEM subjects was given to those who were the coordinators of their campus' after-school robotics program or those interested in integrating STEM concepts cross-curricular with non-STEM subjects. Teachers who worked with special populations such as special needs were also considered as they usually are self-contained and teacher multiple subjects to the same selection of students throughout the day.

Video Game

The video game under study is a complete STEM-based educational resource for students; inclusive of math, science, engineering, and technology. Through engagement of an interactive computer-based game combined with the storytelling power of a graphic novel, the game was designed to enhance engineering and basic computer programming skills through student exploration of robotics activities using problem-solving and critical thinking skills. Students applied knowledge in a single-player two-dimensional format as they advanced through graphic novel chapters while progressing through multiple levels of programming skill development. The game uses a virtual environment for robot construction, flow-charting, code building and three-dimensional simulation/testing, which assesses defined learning objectives for students in middle or intermediate school (i.e., grades 5-8). Figure 3.1 is a screenshot of an engineering component of the game.

Figure 3.1. Screenshot of Engineering Component within Video Game

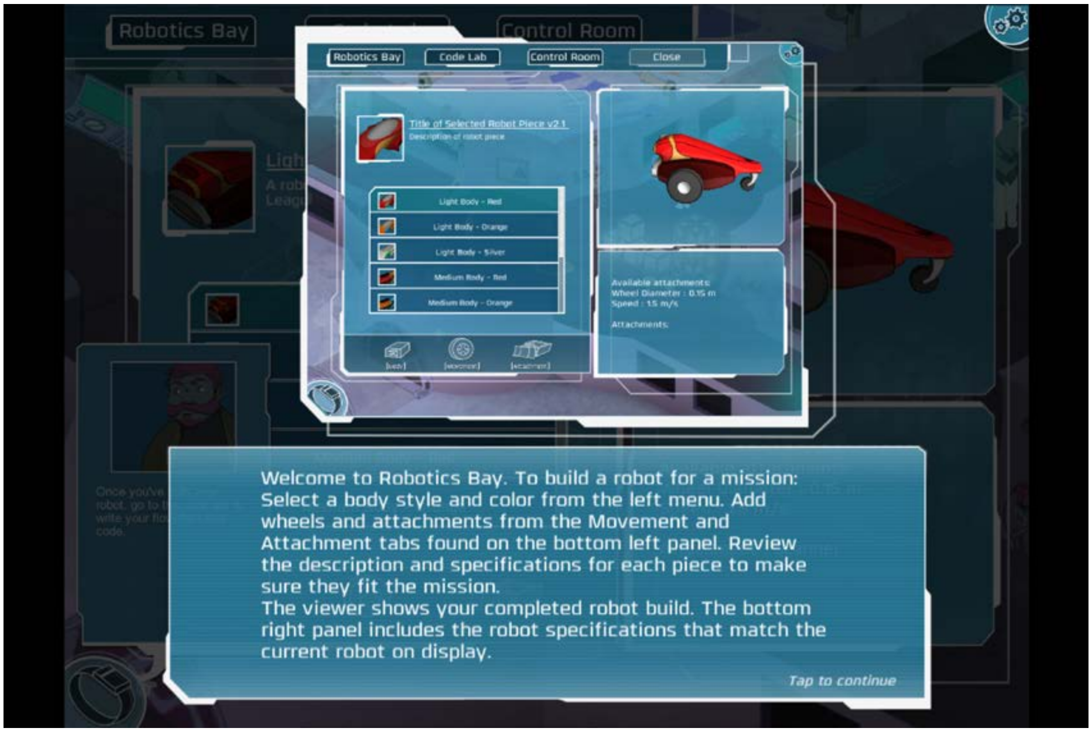

Figure 3.1: Within the game, the player could design and modify the robot that will be used to accomplish a task.

In Figure 3.1, the screenshot is an example of the engineering component of the video game. This application of 21^{st}-century skills, precisely the critical thinking skills, allows the player to design and redesign the robot to accomplish the task in the game. The player cannot advance in the game until completion of the task, so the player must utilize their critical thinking skills to design the appropriate robot to accomplish the task.

The skills and knowledge embedded in the video game were aligned with education standards from International Technology and Engineering Educators Association (ITEEA) and Next Generation Science Standards (NGSS), covering engineering design and technology, and the math concepts were aligned with the Common Core State Standards (CCSS). Standards alignment were also done for the

Texas Essential Knowledge and Skills (TEKS) in English Language Arts and Reading, Technology Applications, and Mathematics for grades 6-8 for the Texas school districts. Consideration was made to do International Society of Technology in Education (ISTE) Student Standards alignment; however, due to time constraints, this was not done. The ISTE Student Standards alignment will be proposed to be part of future iterations of the game.

The programming within the game and the output produced by the game targets the NXT 2.0 robotics platform using Robot C programming language. Students adhere to a simplified and guided programming method using "drag and drop" code blocks similar to other guided practice coding instructional programs. Figure 3.2 is a screenshot of the guided block computer programming method utilized within the video game.

The process visually expressed in Figure 3.2 enables students to focus on the programming logic, problem-solving, and math and science required to complete the mission rather than struggling through the language syntax. As students complete missions using this programming method, they are scaffolded through the instruction and introduced to additional programming functions, Robot C parameters, and specific robotics programming knowledge. Students can export the code created in the game to run in physical robots. In the game, after validating the code, the student is allowed to download the ROBOT-C code files. Students can save the code and transfer it to a physical robot built with CORTEX, EV3, IQ, or NXT to run the code created in the game. Version 1.00 of the game was the iteration that was distributed to the investigating school districts, as that was the most stable version available at the time of the investigation.

Figure 3.2. Guided Block Computer Programming Method

Figure 3.2: Screenshot of the guided block programming method within the video game. This style of programming is commonplace in teaching beginning coding and used in Scratch, code.org, and other foundational coding programs.

Instrumentation

Teacher Perception Survey

A validated *Teacher Perception Survey* was administered to the participating teachers. Validation of the survey occurred throughout the development of the game and included assessment of the storyline, characters, and gameplay. Specific evaluation activities occurred at the Texas Computer Education Association (TCEA) annual convention and in the school setting at two school districts in Texas. The school districts involved in the validation were not involved in the current study. Prior to data collection at the convention and Texas school districts, a researcher-constructed survey was constructed by curriculum content experts to measure teacher perceptions regarding the quality of Aegis in terms of game utility and task accomplishment. Following construction, the teacher survey was subjected to validation review by a panel of subject matter experts in the field of teacher education, technology, and assessment. The 20-item survey was designed to measure teacher perceptions of the video game through the lens of the following characteristics: (a) Engineering process knowledge, (b) Programming skill development, and (c) Pedagogical strategies. The *Teacher Perception Survey* consisted of 20 five-point Likert scale (1 = Very Poor, 2 = Poor, 3 = Fair, 4 = Good, 5 = Very Good) response items divided into two categories. By dividing the survey items into either Game Utility or Task Accomplishment, both pedagogy and content were evaluated by the teacher. A third category was used to collect the demographic data of the teacher. The online survey was created in Qualtrics, a cloud-based survey and data collection instrument. The *Teacher Perception Survey* was distributed to teachers using either an anonymous web link or via a Quick Response (QR) Code.

Engineering Process Knowledge and Programming Skills Summative Assessment

A computer skills summative assessment survey was administered to measure changes in engineering skill development and increased knowledge of basic computer programming skills of students from before playing the video game until completion of the game. The student assessments were constructed by curriculum content experts and the technology classroom teachers and aligned to game content to measure the academic achievement in programming and math and engineering skills. Following construction, the student assessment was subjected to validation review by a panel of subject matter experts in the field of teacher education, technology, and assessment. The student pre/post assessment consisted of 18 skills assessment multiple-choice items with A-D answer choices and two scenario-based assessment items. The assessment also included five demographic questions to allow for data disaggregation after completion of the game.

Each item was aligned with the learning objectives of the game. Examples of the summative assessment items include:

- A detailed description of what a computer program must do, expressed in natural language rather than programming language is,
- A value with unexplained meaning which could confuse programmers reading the code is known as, and
- Which of the following describes a sequence of commands that were repeated until a condition is no longer valid.

Data Collection Procedures

Prior to data collection, the researcher gained approval from the University of Houston-Clear Lake's (UHCL's) Committee for Protection of Human Subjects (CPHS) and the school districts in which the study took place. Next, the participating middle school principals were contacted via email with information regarding the purpose of the study and the process for collecting the surveys, outlined in Appendix B.

Additionally, parent and student consent and assent were required since the participating students were under the legal age of consent. The consent and assent form for students between the ages of 7-12 is Appendix C, and the consent and assent form for students between the ages of 13-17 is Appendix D. Teachers were also required to complete an authorization to participate in the study (Appendix A), and the CPHS mandated a letter from the campus principal expressing support (Appendix E) before data collection could start. Once the researcher collected appendices A-E, the pre-assessment could be administered to the participating students. Various types of data during the study were collected: pre/post summative assessment of student achievement, the *Teacher Perception Survey*, classroom observations, and focus groups involving students and teachers separately.

Quantitative

Summative assessment data was collected before the students played the game. The same assessment was given to the students at the conclusion of the game to measure differences in comprehension and skill development of basic computer programming and engineering skills. The online pre/post assessment was created in Qualtrics and distributed to students using either an anonymous web link or via a QR Code. Figure 3.3 represents the QR code that was distributed to students for the pre-assessment. A separate anonymous web link and QR Code was used for the post-assessment as to differentiate between data sets.

Figure 3.3. QR Code of Student Pre-Assessment Survey

Figure 3.3: QR Code utilized to distribute the pre-assessment survey to the students that participated in the study.

The QR Code was utilized, in addition to the direct survey link, as an alternative method for students to complete the pre-assessment. Three of the four teachers that participated in the study had to use other classrooms besides their own. By creating and distributing the QR Code for the student pre-assessment, the pre-assessment could be taken on a cell phone in any classroom, including the participating teacher's classroom. This distribution method eliminated the technology barrier for completing the pre-assessment. The post-assessment was distributed using only the direct link, as the students in each of the five classes completed the post-assessment on the computers that were used during gameplay. The pre- and post-assessment survey were conducted before starting the video game and after the video game was completed. Gameplay took between three to four weeks for all participating classes. The participating teacher were notified of the availability of the pre-assessment via email at the beginning of the data collection period. Follow-up emails were sent to the teachers once a week during the first two weeks of data collection, and twice a week for the final two weeks of data collection. Upon receipt of the pre- and post-assessment survey results, the data were entered into quantitative research software Statistical Package for the Social Sciences (SPSS) for further analysis.

Upon completion of the video game and the post-assessment, participating teachers completed the *Teacher Perception Survey*. The teacher perception survey was distributed to the participating teachers via an email link as well as with a QR Code. Figure 3.4 represents the QR code that was distributed to teachers.

Figure 3.4. QR Code of Teacher Perception Survey

Figure 3.4: QR code provided to the teachers to complete the Teacher Perception Survey.

The utilization of QR codes for distribution of the *Teacher Perception Survey* provided an alternative for teachers to access the survey. The QR code could be scanned by the teacher's cell phone and the survey can be completed using a mobile device instead of at their desk. In the *Teacher Perception Survey*, the teachers were asked to rate their game perceptions regarding game utility or in task accomplishment. Examples of response items include:

- Teaching pertinent vocabulary related to robotics, programming, and engineering,

- Improving student writing skills concerning using complete sentences to describe the steps needed to complete a task or fix a problem,
- Teaching students the engineering design process, and Training teachers for purposes of implementation.

All data were secured in a password-protected folder on the researcher's computer and in the researcher's office within a locked file cabinet always. At the culmination of the study, the data will be maintained by the researcher for five years, which is the time required by CPHS and participating district guidelines. The researcher will destroy the contents of the file once the deadline expired.

Qualitative

Student engagement in the video game was further examined using a focus group protocol. The student interview protocol, found in Appendix H, was designed with open-ended questions that focused on student engagement and usability of the game. The interview also focused on improvements for the game in future iterations. The focus group consisted of 4-6 students per class group and lasted approximately 30 minutes.

An individualized teacher interview was done with each participating teacher. Due to the distance, the interviews were done separately. Interview questions, found in Appendix I, focused on the usage and feasibility of the video game as an instructional tool in the classroom. The interview also addressed barriers to the implementation of the video game into the classroom. The interviews lasted approximately 30 minutes with the teacher and were done either in person or via Skype, depending on the distance from the researcher.

Data Analysis

Quantitative

Upon completion of the survey collection, the data was downloaded into Excel. Once downloaded the data were uploaded into IBM SPSS for analysis. To answer research questions one and two, the frequency and percentages of the responses from the pre- and post-assessment disaggregated by question were compared. Additionally, a Pearson's Product Moment Correlation (r) was conducted to determine if there is a relationship between playing a video game and student achievement in basic engineering and computer programming skills. The effect size was measured using the coefficient of determination (r^2), and a significance value of .05 was used for this study. All variables are continuous in measurement. District CISD only had seven participants, so a Wilcoxon Signed Ranks Test was used in place of Pearson's Product Moment Correlation. Effect size was calculated to determine to what extent the video game had on the learning of computer programming and math and engineering skills.

To answer research question four, the frequency and percentages of the Teacher Perception Survey were disaggregated and categorized based on the Likert Scale response. The responses were sorted and examined for patterns in terms of usage and feasibility of classroom implementation. This quantitative data, along with the qualitative data collected from the teacher interviews, were used to answer research question four.

Qualitative

Following the analysis of the quantitative data, the findings were utilized to develop the student focus group questions to provide a more in-depth understanding of the relationship between playing a video game and student engagement. To answer research question three, qualitative data gathered from the focus groups were examined, analyzed, and coded for themes. The data were sorted and categorized by themes. Obtaining additional data allowed the researcher to study the constructs in greater detail further. The open-ended questions were aimed at providing an in-depth understanding of the general pattern that emerged from the quantitative of the study. Once the four categories were established, codes were again organized into subcategories and findings recorded.

Validity

The qualitative analysis process entailed validation by using the evaluation of individual student responses by campus. To ensure validity, data obtained from the surveys and focus groups were cross-checked and compared amongst participating groups. The data collected during the focus group sessions was subject to member-checking by having student participants review the preliminary results and transcripts to enhance the validity of the responses provided. The questions and results were peer-reviewed by experienced educators including district-level administrators to ensure questions are valid. The peer reviews served the purpose of obtaining feedback related to questions posed to students related to their perceptions regarding the classroom environment. Member checking was used to ensure the voices of participants is accurately captured and thus increasing the validity of the findings.

Privacy and Ethical Considerations

Before the collection of any data, the researcher gained approval from the UHCL’s CPHS and the school districts in which the study took place. Given that the intended survey instruments are pre-existing, the researcher asked for verbal approval for its use. All participants were provided with detailed information related to the purpose of the study and directions for completing the surveys. Parent consent and student assent forms were collected from participants before collecting any survey data. The data collected remains securely locked in a cabinet and pin drive in the researcher’s office. The researcher will maintain the data for five years as required by the CPHS and school district guidelines. After the deadline has passed, the researcher will destroy all data files associated with the study.

Regarding risk to any participant, teacher or student, the participants were informed that there was no risk involved in participating. There were no foreseeable risks to the subjects, whether a physical injury, psychological injury, loss of confidentiality, social harm, and so forth, involved in the conduct of the research.

Limitations of the Study

The research design consisted of several limitations. First, the video game has technical specifications that could potentially limit the utilization and implementation of the game. Without the appropriate technology, the video game would either function slower than expected or not function at all. The game is server-based; therefore the game’s autosave data is uploaded into cloud. The campus infrastructure needed to be sufficient for all participating students to play the game at the same time without any disruption of gameplay. Each of the five classes was aware of the technical limitations. After consultation with each of the campus information technology specialists, it was determined which classrooms would be appropriate to run the video game. This determination resulted in some classes going to the library while another class was assigned to the computer lab.

Second, the teacher's experience in basic computer programming and engineering may have influenced the ability to answer content questions from the students. For non-STEM teachers, the lack of content knowledge could be a barrier to implementation and affect the validity of the data. Third, classroom management could also potentially skew the data collected. Teachers with low classroom management have students that are regularly off-task. Students off-task will not read the narrative of the game and may not comprehend as much as those students that were on-task.

Third, BISD and DISD were located in New Jersey and Colorado, respectively, and were not readily accessible for the researcher. The distance prevented direct classroom observations and also prevented face to face interactions with the participating teachers. All classroom observations, focus groups, and interviews for BISD and DISD were done remotely using either Skype or FaceTime.

Fourth, the video game was designed for middle school students, which was defined as students between fifth and eighth grade. In this study, fifth and seventh-grade students are underrepresented. The teachers that participated in the study taught sixth and eighth-grade students except for CISD, which was a mixed grade level.

Conclusion

The purpose of this study was to examine whether student play of a video game designed and developed to teach the engineering process and basic computer programming skills influenced student engagement levels and student knowledge of the engineering process and basic computer programming skills. Chapter III provided information regarding the research design, procedures, and instrumentation, as well as data collection and analysis for these constructs. The interest in analyzing these constructs is to find possible connections between the learning and serious game implementation. Chapter IV reports the data analysis and study's findings.

CHAPTER IV:

RESULTS

The purpose of this study was to examine whether student play of a video game designed and developed to teach the engineering process and basic computer programming skills influenced student engagement levels and student knowledge of the engineering process and basic computer programming skills. This chapter presents the finding of quantitative and qualitative data analysis of the study. First, an explanation of the participants' demographics of the study is presented, followed by results of the data analysis. This chapter presents the data analysis for each of the five research questions. It concludes with a summary of the findings.

Participant Demographics

A purposeful sample of 86 students participated in the video game play, surveys, and focus groups for this study. The demographics of the combined participants were similar to the general population data from the districts. Table 4.1 shows the demographic data of all participants of the study. Of the 86 participants, 42 students indicated that they were female (48.8%), while 44 students identified themselves as male. 11 students (12.8%) identified themselves as Black/African-American, 29 students (33.7%) identified themselves as White/Caucasian, 20 students (23.3%) identified themselves as Hispanic/Latino, 11 students (12.8%) identified themselves of two or more races, and 15 students (17.5%) identified themselves as other races. Of the 86 participants, fifty-three (61.6%) were in the sixth grade, two (2.3%) were in the seventh grade, and thirty-one (36.0%) were in the eighth grade.

Table 4.1

Demographics of Participants per District

Demographics	All	AISD	BISD	CISD	DISD
1. Gender					
Male	51.2% (n = 44)	58.8% (n = 10)	61.5% (n = 8)	57.1% (n = 4)	44.9% (n = 22)
Female	48.8% (n = 42)	41.2% (n = 7)	38.5% (n = 5)	42.9% (n = 3)	55.1% (n = 27)
2. Race/Ethnicity					
Black	12.8% (n = 11)	29.4% (n = 5)	15.4% (n = 2)	42.9% (n = 3)	2.0% (n = 1)
White	33.7% (n = 29)	5.9% (n = 1)	38.5% (n = 5)	14.3% (n = 1)	44.9% (n = 22)
Hispanic	23.3% (n = 20)	52.9% (n = 9)	23.1% (n = 3)	14.3% (n = 1)	14.3% (n = 7)
3. Grade					
6^{th}	61.6% (n = 53)	0.0% (n = 0)	0.0% (n = 0)	57.1% (n = 4)	100.0% (n = 49)
7^{th}	2.3% (n = 2)	0.0% (n = 0)	0.0% (n = 0)	28.6% (n = 2)	0.0% (n = 0)
8^{th}	36.0% (n = 31)	100.0% (n = 17)	100.0% (n = 13)	14.3% (n = 1)	0.0% (n = 0)

District AISD

District AISD was located in southeast Texas. The class that participated in the study was an eighth-grade English Language Arts class. The teacher was a female with 15-20 years of classroom experience. The class investigated was 58.8% male and 41.2% female. All students were eighth-graders ages 13-15. Regarding race/ethnicity, the class was 52.9% Hispanic/Latino, 29.4% Black/African-American, and 5.9% White/Caucasian.

District BISD

District BISD was located in northern New Jersey. The class that participated in the study was an eighth-grade Arts and Technology Applications class. The teacher was a female with 20-30 years of classroom teaching experience. The class investigated was 61.5% male and 38.5% female. All students were eighth-graders ages 13-15. Regarding race/ethnicity, the class was 38.5% White/Caucasian, 23.1% Hispanic/Latino, and 15.4% Black/African-American.

District CISD

District CISD was located in southeast Texas. The class that participated was a special population class of sixth through eighth-grade students who were deaf. The teacher was a female with 0-5 years of teaching experience. Her primary teaching assignment is Science, but she is expected to incorporate English Language Arts and Reading as well as Sign Language into the curriculum. She has a teaching assistant at all times to assist the children in learning the proper Sign Language for the curriculum that was covered in class. The teaching assistant was a female with 10-20 years of experience as a special population support staff member. The class investigated was 57.1% male and 42.9% female. The class was 57.1% sixth graders, 28.6% seventh graders, and 14.3% eighth graders ranging in age from 11-14. Regarding race/ethnicity, the class was 42.9% Black/African-American, 14.3% Hispanic/Latino, and 14.3% White/Caucasian.

District DISD

District DISD was located in northwest Colorado. District DISD provided two sixth grade computer science classes for the study. Data were collected as DISD01 and DISD02 to differentiate between the classes. The teacher was a male with 10-15 years of teaching experience. He was also the robotics coach for the school. The classes investigated were 44.9% male and 55.1% female. All were sixth graders ages 11-12. Regarding race/ethnicity, the class was 44.9% White/Caucasian, 14.3% Hispanic/Latino, and 2.0% Black/African-American. District DISD is a 1:1 school district, which means that each student had a piece of technology (laptop or tablet) provided by the school district that is theirs to use for the entire school year.

Research Question One

Research question one, *Does the Aegis video game improve student programming skills?*, was answered using frequencies, percentages, Wilcoxon Signed Rank Test, and paired sample t-tests to measure a change in learning basic computer programming skills. The pre-assessment contained 12 multiple choice questions related to computer programming skills. The responses related to computer programming skills are provided below.

Total Student Comparison

None of the solicited students had any computer programming experience before playing the video game. All participating students were administered a pre-assessment before introducing the game, which was used to assess the student's prior knowledge of basic computer programming skills. Table 4.2 displays the number of correct responses in addition to the percent correct per question on the pre-assessment questions involving basic computer programming skills across all classes.

Table 4.2

Pre-Assessment Computer Programming Data by Question for All Participants

Question	Correct Responses	Percent
Q4 - A narrative is a	23	27.1%
Q5 - A detailed description of what a computer program must do, expressed in natural language rather than programming language is	14	17.1%
Q6 – "Move forward 5 meters, turn right 90 degrees, and…" is an example of	7	8.2%
Q7 - In a flowchart, an oval is used to	26	31.3%
Q8 - What is used to show the directional flow of the program in a flow chart?	60	71.4%
Q9 - A value with unexplained meaning which could confuse programmers reading the code is known as a	20	23.3%
Q12 - Which of the following describes a sequence of commands that are repeated until a condition is no longer true?	47	56.0%
Q13 - A "while loop" with a variable as a counter can be used to repeat a simple process	39	46.4%
Q14 - A diamond shape in a flowchart with the code "count < 4" is a	31	37.3%
Q16 - When a section of the program runs, either one group of code or another, or even skips code based on a condition is	22	26.8%

Question	Correct Responses	Percent
Q17 - An "if statement" is used to create	25	30.5%
Q18 - A diagram that helps visualize a plan using different shapes to represent different types of commands is a	34	40.5%

Table 4.2 shows that of the 12 computer programming questions on the pre-assessment, greater than 50.0% of participating students responded correctly to only two questions, and none of the questions were responded correctly by 75.0% of students. Question eight was based on concepts that were taught in late elementary and early middle school math classes which explains why this was the question with the highest score. Fewer than 33.0% of students correctly responded to seven of the questions. Questions five (17.1% correct) and six (8.2% correct) were questions about the vernacular used in computer programming. The pre-assessment data show that generally, the students had very little knowledge of basic computer programming skills before playing the game.

After completing the video game, students were administered a post-assessment consisting of the same questions as the pre-assessment. The post-assessment was used to measure the change, either positive or negative, in the knowledge of basic computer programming skills by the students after playing the video game. Table 4.3 expresses the correct responses in addition to the percent correct on the post-assessment across all classes, broken down per question.

Table 4.3

Post-Assessment Computer Programming Data by Question for All Participants

Question	Correct Responses	Percent
Q4 - A narrative is a	53	61.6%
Q5 - A detailed description of what a computer program must do, expressed in natural language rather than programming language is	44	51.2%
Q6 – “Move forward 5 meters, turn right 90 degrees, and…” is an example of	26	30.2%
Q7 - In a flowchart, an oval is used to	60	69.8%
Q8 - What is used to show the directional flow of the program in a flow chart?	64	74.4%
Q9 - A value with unexplained meaning which could confuse programmers reading the code is known as a	42	48.8%
Q12 - Which of the following describes a sequence of commands that are repeated until a condition is no longer true?	61	70.9%
Q13 - A “while loop” with a variable as a counter can be used to repeat a simple process	59	68.6%
Q14 - A diamond shape in a flowchart with the code “count < 4” is a	52	60.5%

Question	Correct Responses	Percent
Q16 - When a section of the program runs, either one group of code or another, or even skips code based on a condition is	46	53.5%
Q17 - An “if statement” is used to create	35	40.7%
Q18 - A diagram that helps visualize a plan using different shapes to represent different types of commands is a	55	64.0%

Table 4.3 shows that of the twelve computer programming questions on the post-assessment, greater than 50.0% of participating students responded correctly to nine questions, and none of the questions were responded correctly by 75.0% of students. In comparison, the pre-assessment had only two questions that were correctly responded by greater than 50.0% of students. Fewer than 33.0% of students correctly responded to only one of the questions, Question six, which also was the lowest scoring question on the pre-assessment. Table 4.4 shows the change in the correct responses between the pre-assessment and the post-assessment computer programming skills questions.

Table 4.4

Pre/Post-Assessment Computer Programming Skills Comparison by Question

Question Number	Pre-Assessment Percentage	Post-Assessment Percentage	Difference (+/-)
4	**27.1**	**61.6**	**+34.5**
5	**17.1**	**51.2**	**+34.1**
6	8.2	30.2	+22.0
7	**31.3**	**69.8**	**+38.5**
8	71.4	74.4	+3.0
9	23.3	48.8	+25.5
12	56.0	70.9	+14.9
13	46.4	68.6	+22.2
14	37.3	60.5	+23.2
16	26.8	53.5	+26.7
17	30.5	40.7	+10.2
18	40.5	64.0	+23.5

Each computer programming question in the pre-/post-assessments showed growth. 11 of the 12 computer programming assessment questions showed double-digit growth, with three showed a 30.0% improvement in scores. Only one question showed less than 10.0% growth, but that was also the highest scoring question on the pre-assessment.

Additionally, a paired sample t-test was conducted to assess whether there was a statistically significant mean difference between the pre- and post-assessment for all participants in the study. Table 4.5 provides the results of the paired t-test. Findings suggested that there was a statistically significant mean difference bwteeen the pre- and post-assessment scores, t(85) = -8.75, p = 0.000, Cohen's *d* = 1.24, and $r^2 = 0.277$. The video game had a large effect on the improvement of student knowledge of basic computer programming skills, and 27.7% of the variance in those scores is attributable to playing the video game.

Table 4.5

Total Student Computer Programming Assessment Results of Paired Samples t-test

Group	N	M	SD	t-value	df	p-value	Cohen's *d*	r^2
Pre-Assessment	86	4.05	1.53	-8.75	85	< 0.0001*	1.24	0.277
Post-Assessment	86	6.92	2.89					

*Statistically significant ($p < 0.05$)

AISD

A paired sample t-test was conducted to assess whether there was a statistically significant mean difference between the pre- and post-assessment of the participants in district AISD. Table 4.6 provides the numerical results for AISD. Findings suggested that there was a statistically significant mean difference between the pre and post-assessment scores, t(16) = -3.48, p = 0.003, Cohen's *d* = 1.066, and $r^2 = 0.221$. The video game had a large effect on the improvement of student knowledge of basic computer programming skills, and 22.1% of the variance in those scores is attributable to playing the video game.

Table 4.6

AISD Computer Programming Assessment Results of Paired Samples t-test

Group	N	M	SD	t-value	df	p-value	Cohen's *d*	r^2
Pre-Assessment	17	3.71	1.26	-3.48	16	0.003*	1.066	0.221
Post-Assessment	17	5.41	1.87					

*Statistically significant ($p < 0.05$)

BISD

A paired sample t-test was conducted to assess whether there was a statistically significant mean difference between the pre and post-assessment of the participants in District BISD, in regards to the engineering process and basic computer programming skills. Table 4.7 provides the numerical results for BISD. Findings suggested that there was a statistically significant mean difference between the pre and post-assessment scores, $t(12) = -3.77$, $p = 0.003$, Cohen's $d = 0.99$, and $r^2 = 0.194$. The video game had a large effect on the improvement of student knowledge of basic computer programming skills, and 19.4% of the variance in those scores is attributable to playing the video game.

Table 4.7

BISD Computer Programming Assessment Results of Paired Samples t-test

Group	N	M	SD	t-value	df	p-value	Cohen's *d*	r^2
Pre-Assessment	13	5.46	1.51	-3.77	12	0.003*	0.986	0.194
Post-Assessment	13	7.46	2.44					

*Statistically significant ($p < 0.05$)

CISD

A Wilcoxon Signed Rank Test was conducted to assess whether there was a statistically significant mean difference between the pre and post-assessment of the participants in CISD, in regards to the engineering process and basic computer programming skills. Table 4.8 provides the numerical results for CISD. Findings suggested that there was not a statistically significant mean difference between the pre and post-assessment scores, $Z = 0.087$, $p = 0.931$, and Effect Size = 0.03 (small effect size).

Table 4.8

CISD Computer Programming Assessment Results of Wilcoxon Signed Rank Test

Group	N	M	SD	Z	df	p-value	Effect Size
Pre-Assessment	7	3.71	1.11	0.087	6	0.931*	0.03
Post-Assessment	7	3.71	0.76				

*Statistically significant ($p < 0.05$)

DISD01

A paired sample t-test was conducted to assess whether there was a statistically significant mean difference between the pre and post-assessment of the participants in DISD01, in regards to the engineering process and basic computer programming skills. Table 4.9 provides the numerical results for DISD01. Findings suggested that there was a statistically significant mean difference between the pre and post-assessment scores, t(24) = -5.53, p = 0.000, Cohen's *d* = 1.53, and r^2 = 0.372. The video game had a large effect on the improvement of student knowledge of basic computer programming skills, and 37.2% of the variance in those scores is attributable to playing the video game.

Table 4.9

DISD01 Computer Programming Assessment Results of Paired Samples t-test

Group	N	M	SD	t-value	df	p-value	Cohen's *d*	r^2
Pre-Assessment	25	3.68	1.41	-5.53	24	0.000*	1.528	0.372
Post-Assessment	25	7.28	3.02					

*Statistically significant ($p < 0.05$)

DISD02

A paired sample t-test was conducted to assess whether there was a statistically significant mean difference between the pre and post-assessment of the participants in DISD02, in regards to the engineering process and basic computer programming skills. Table 4.10 provides the numerical results for DISD02. Findings suggested that there was a statistically significant mean difference between the pre and post-assessment scores, t(23) = -7.24, p = 0.000, Cohen's *d* = 1.79, and $r^2 = 0.449$. The video game had a large effect on the improvement of student knowledge of basic computer programming skills, and 44.9% of the variance in those scores is attributable to playing the video game.

Table 4.10

DISD02 Computer Programming Assessment Results of Paired Samples t-test

Group	N	M	SD	t-value	df	p-value	Cohen's *d*	r^2
Pre-Assessment	24	4.00	1.61	-7.24	23	0.000*	1.793	0.449
Post-Assessment	24	8.25	2.94					

*Statistically significant ($p < 0.05$)

Research Question Two

Research question two, *Does the Aegis video game improve student math and engineering skills?*, was answered using frequencies, percentages, Wilcoxon Signed Rank Test, and paired sample t-tests to measure a change in learning about math and engineering skills from the pre- and post-assessment. The pre-assessment contained eight multiple choice questions related to math and engineering skills. The responses related to computer programming skills are provided below.

Total Student Comparison

None of the solicited students had any computer programming experience before playing the video game. All participating students were administered a pre-assessment before introducing the game, which was used to assess the student's prior knowledge math and engineering skills. Table 4.11 displays the number of correct responses in addition to the percent correct per question on the pre-assessment questions involving math and engineering skills across all classes.

Table 4.11

Pre-Assessment Math and Engineering Data by Question for All Participants

Question	Correct Responses	Percent
Q1 - The first full-scale working model that can be tested of a chosen solution is called a	53	62.4%
Q2 - Requirements of a project that must be met are called	37	44.0%
Q3 - The first step in the design process is	24	28.6%
Q10 - A unit used to measure angles is called a(n)	61	72.6%
Q11 - To determine the number of tire rotations needed to move a robot forward 200 meters, you need to know the	37	44.6%
Q15 - Your car is traveling on 77th Street as indicated by the RED arrow on the map above. When you arrive at 5th Ave, you will turn left for 90 degrees. Which statement best describes your turn?	51	60.7%
Q19 - From the items listed below, select a criterion of this assignment	28	32.6%
Q20 - From the items listed below, select a constraint of this assignment.	29	33.7%

Table 4.11 shows that of the eight computer programming questions on the pre-assessment, greater than 50% of participating students responded correctly to only three questions, and none of the questions were responded correctly by 75% of students. Question ten was based on concepts that were taught in late elementary and early middle school math classes which explains why this was the question with the highest score. Fewer than 33% of students correctly responded to two of the questions. Questions two (44.0% correct) and three (28.6% correct) were questions about the vernacular used in the engineering process. The pre-assessment data show that generally, the students had very little to moderate knowledge of math and engineering skills before playing the game.

After completing the video game, students were administered a post-assessment consisting of the same questions as the pre-assessment. The post-assessment was used to measure the change, either positive or negative, in the knowledge of math and engineering skills by the students after playing the video game. Table 4.12 expresses the correct responses in addition to the percent correct on the post-assessment across all classes, broken down per question.

Table 4.12

Post-Assessment Math and Engineering Data per Question for All Participants

Question	Correct Responses	Percent
Q1 - The first full-scale working model that can be tested of a chosen solution is called a	65	75.6%
Q2 - Requirements of a project that must be met are called	57	66.3%
Q3 - The first step in the design process is	52	60.5%
Q10 - A unit used to measure angles is called a(n)	60	69.8%
Q11 - To determine the number of tire rotations needed to move a robot forward 200 meters, you need to know the	59	68.6%
Q15 - Your car is traveling on 77th Street as indicated by the RED arrow on the map above. When you arrive at 5th Ave, you will turn left for 90 degrees. Which statement best describes your turn?	55	64.0%
Q19 - From the items listed below, select a criterion of this assignment	40	46.5%
Q20 - From the items listed below, select a constraint of this assignment.	39	45.3%

Table 4.12 shows that of the eight computer programming questions on the post-assessment, greater than 50.0% of participating students responded correctly to six questions, and one of the questions were responded correctly by 75.0% of students. In comparison, the pre-assessment had only three questions that were correctly responded by greater than 50.0% of students. None of the math and engineering questions had

fewer than 33.0% of students correctly responded. Questions 19 and 20 were the two questions that did not have greater than 50.0% of students correctly respond; those two questions were also two of the lowest scoring questions on the pre-assessment. Those two questions were the application of knowledge questions of math and engineering concepts instead of comprehension questions as the other six questions. This change in format could be the reason for the lower scores. Table 4.13 shows the change in the correct responses between the pre-assessment and the post-assessment computer programming skills questions.

Table 4.13

Pre/Post-Assessment Math and Engineering Skills Comparison by Question

Question Number	Pre-Assessment Percentage	Post-Assessment Percentage	Difference (+/-)
1	62.4	75.6	+13.2
2	44.0	66.3	+19.3
3	**28.6**	**60.5**	**+31.9**
10	**22.6**	**69.8**	**+47.2**
11	44.6	68.6	+24.0
15	60.7	64.0	+3.3
19	32.6	46.5	+13.9
20	33.7	45.3	+11.6

Each math and engineering question in the pre-/post-assessments showed growth. Seven of the eight math and engineering assessment questions showed double-digit growth, and two showed a thirty percent improvement in scores. Question ten showed a

47.2% growth between the pre- and post-assessment. Only one questions showed less than ten percent growth, but that was also the second-highest scoring question on the pre-assessment.

Additionally, a paired sample t-test was conducted to assess whether there was a statistically significant mean difference between the pre- and post-assessment for all participants in the study. Table 4.14 provides the numerical results for all participants.

Table 4.14

Total Student Math and Engineering Assessment Results of Paired Samples t-test

Group	N	M	SD	t-value	df	p-value	Cohen's *d*	r^2
Pre-Assessment	86	3.71	1.73	-4.587	85	< 0.001*	0.692	0.107
Post-Assessment	86	6.92	2.89					

*Statistically significant ($p < 0.05$)

Findings suggested that there was a statistically significant mean difference between the pre and post-assessment scores, $t(85) = -4.587$, $p = < 0.001$, Cohen's d = 0.692, and $r^2 = 0.107$. The video game had a medium effect on the improvement of student knowledge of math and engineering skills, and 10.7% of the variance in those scores is attributable to playing the video game. Specifically, the medium variance increases the likelihood that the game did have a moderate effect on increased knowledge of math and engineering skills and that the population size did not affect the data.

AISD

A paired sample t-test was conducted to assess whether there was a statistically significant mean difference between the pre- and post-assessment of the participants in AISD. Table 4.15 provides the numerical results for AISD. Findings suggested that there was not a statistically significant mean difference between the pre and post-assessment scores, t(16) = -1.838, p = 0.085, Cohen's *d* = 0.647, and r^2 = 0.096. The video game had a medium effect on the improvement of student knowledge of math and engineering skills, and 9.6% of the variance in those scores is attributable to playing the video game.

Table 4.15

AISD Math and Engineering Assessment Results of Paired Samples t-test

Group	N	M	SD	t-value	df	p-value	Cohen's *d*	r^2
Pre-Assessment	17	3.76	1.15	-1.838	16	0.085*	0.647	0.096
Post-Assessment	17	4,53	1.23					

*Statistically significant (p < 0.05)

BISD

A paired sample t-test was conducted to assess whether there was a statistically significant mean difference between the pre and post-assessment of the participants in BISD, in regards to the engineering process and basic computer programming skills. Table 4.16 provides the numerical results for BISD. Findings suggested that there was a statistically significant mean difference between the pre and post-assessment scores, t(12) = -3.33, p = 0.003, Cohen's *d* = 0.861, and r^2 = 0.157. The video game had a large effect on the improvement of student knowledge of math and engineering skills, and 15.7% of the variance in those scores is attributable to playing the video game.

Table 4.16

BISD Math and Engineering Assessment Results of Paired Samples t-test

Group	N	M	SD	t-value	df	p-value	Cohen's *d*	r^2
Pre-Assessment	13	5.31	2.02	-3.333	12	0.003*	0.861	0.157
Post-Assessment	13	6.85	1.52					

*Statistically significant ($p < 0.05$)

CISD

A Wilxocin Signed Rank Test was conducted to assess whether there was a statistically significant mean difference between the pre and post-assessment of the participants in CISD, in regards to the engineering process and basic computer programming skills. Table 4.17 provides the numerical results for CISD. Findings suggested that there was not a statistically significant mean difference between the pre and post-assessment scores, $Z = 1.841$, $p = 0.066$.

Table 4.17

CISD Math and Engineering Assessment Results of Wilcoxon Signed Rank Test

Group	N	M	SD	t-value	df	p-value
Pre-Assessment	7	1.29	0.49	-2.291	6	0.066*
Post-Assessment	7	2.29	0.95			

*Statistically significant ($p < 0.05$)

DISD01

A paired sample t-test was conducted to assess whether there was a statistically significant mean difference between the pre and post-assessment of the participants in DISD01, in regards to the engineering process and basic computer programming skills. Table 4.18 provides the numerical results for DISD01. Findings suggested that there was a statistically significant mean difference between the pre and post-assessment scores, $t(24) = -3.79$, $p = 0.001$, Cohen's $d = 0.800$, and $r^2 = 0.137$. The video game had a large effect on the improvement of student knowledge of basic computer programming skills, and 13.7% of the variance in those scores is attributable to playing the video game.

Table 4.18

DISD01 Math and Engineering Assessment Results of Paired Samples t-test

Group	N	M	SD	t-value	df	p-value	Cohen's *d*	r^2
Pre-Assessment	25	3.68	1.68	-3.787	24	0.001*	0.800	0.137
Post-Assessment	25	5.08	1.82					

*Statistically significant ($p < 0.05$)

DISD02

A paired sample t-test was conducted to assess whether there was a statistically significant mean difference between the pre and post-assessment of the participants in DISD02, in regards to the engineering process and basic computer programming skills. Table 4.19 provides the numerical results for DISD02. Findings suggested that there was a statistically significant mean difference between the pre and post-assessment scores, $t(23) = -4.55$, p = < 0.001, Cohen's *d* = 0.945, and $r^2 = 0.185$. The video game had a large effect on the improvement of student knowledge of basic computer programming skills, and 18.5% of the variance in those scores is attributable to playing the video game.

Table 4.19

DISD02 Math and Engineering Assessment Results of Paired Samples t-test

Group	N	M	SD	t-value	df	p-value	Cohen's *d*	r^2
Pre-Assessment	24	3.54	1.32	-4.553	23	< 0.001*	0.945	0.185
Post-Assessment	24	4.88	1.51					

*Statistically significant ($p < 0.05$)

Research Question Three

Research question three, *What are the students' level of engagement with the Aegis video game?*, was measured using classroom observations and student focus groups. Classroom observations were done to monitor students playing the video game for student engagement and time on task. Due to the distance between the researcher and three of the classes, observations and focus groups for those three classes were conducted virtually via either Skype or FaceTime. The other two observations and focus groups were conducted in person.

Student Engagement with Computer Programming

Overall, students appeared to enjoy the game and were actively engaged in gameplay; specifically the computer programming portions of the game. On multiple occasions when a student completed a programming task, there was an audible exclamation of joy. Figure 4.1 shows an example of students actively playing the video game.

Figure 4.1. Students Playing the Video Game

Figure 4.4: Image of students playing the video game during a classroom observation. The student just completed coding the robot and is anxiously waiting to see if the code was correct.

Figure 4.1 depicts multiple students actively engaged in the game. The student in the foreground was intently focused on the creation of the pseudo code in preparation for creating the block coding. The student in the background has completed his code and is watching the simulation to confirm that his computer programming code was correct.

Some students also organically collaborated with each other during the more challenging computer programming tasks. Additionally, students would assist each other on how to build flowcharts to create the necessary code correctly. During the focus groups, one student explained that she enjoyed the game because "it was cool learning the basics of how to code." Students recognized the need for utilizing problem-solving skills in the later portions of the game, where the computer programming was more difficult and required a multi-step approach to code correctly. Instead of expressing frustration, most students continued to alter the code, flowcharts, and robotic components until the code was correctly created. Students reported that the game was "engaging" and wished that "the story could continue." One student noted that "The first half did a good job of introducing you to the concepts and topics and explaining what you were doing.” The computer programming, weaved within the game as part of the narrative, also received positive feedback from most students. One student noted, “I liked defeating Nero [mini-boss] because she [the main character] was committed to making the robot work.”

Student Engagement with the Story

Many students responded positively to the graphic novel aspect of the storytelling in the video game and preferred that to the dialogue within the game. During classroom observations, many students were quietly focused on reading the dialogue in the story. One student commented that "the story was great and I was entertained while I was learning something." That was a common sentiment among multiple students that expressed positive reactions to the graphic novel/comic book layout of the story. The overall story was also very engaging to many students and found the narrative captivating. "I liked it [the first chapter] because I love reading and I loved the suspense of the dad getting kidnapped," expressed one student.

Regarding the visual appeal of the video game, students also expressed positive views toward the graphic design. One student noted that "I liked how it [the video game] looked because it helped with my reading." The prevailing sentiment among students was that the colors were pleasing and provided an enjoyable playing experience.

Challenges to Student Engagement

The most common issue with student engagement in the video game occurred when students struggled with basic tasks throughout the game. The cause of their struggles was that those students did not read the narrative and just clicked through the dialogue as to more quickly return to the computer programming tasks in the game. The students that did read the dialogue and the graphic novel portion did not experience those problems. The task of creating a narrative was trying for a couple of students, who felt that the instructions were not as precise as they expected. One student stated that "the narrative was the most difficult part because I did not know how specific to be or if I need to add other steps."

Students, primarily the lower grade students, also struggled with the math formulas and calculations in the video game. Students expressed frustration with calculating the various measurements required to create the required code accurately. Some of the frustration stems from the built-in calculator found in the Communiplanner, an affordance that is an integral part of the video game. A majority of those students utilized the in-game Communiplanner for assistance. The Communiplanner contains game content notes, math formulas, the completed game tasks, and a ten-key calculator. The calculator was not responsive to keyboard strokes and only functioned by utilizing the mouse and clicking on the numbers of the digital calculator. One student offered a solution to improving the Communiplanner calculator by noting, "I wish there were a notepad to keep track of the measurements."

Research Question Four

Research question four, *What are the teacher perceptions of the Aegis video game usage and feasibility as an instructional tool in the classroom?*, was measured using a post-experiment interview and the *Teacher Perception Survey*. Approximately 57.6% of all responses were either "Good" or "Very Good" regarding the video game's usage and feasibility as an instructional tool.

Teacher Perception Survey

The *Teacher Perception Survey* consisted of twenty questions using a five-point Likert scale (1 = Very Poor, 2 = Poor, 3 = Fair, 4 = Good, 5 = Very Good). The *Teacher Perception Survey* was distributed and completed digitally using Qualtrics. Table 4.20 shows the response by each teacher for the survey. The video game received positive responses regarding its usage and feasibility as an instructional tool in the classroom. Nearly 90% of all responses to the survey were from Fair to Very Good. Figure 4.2 shows the responses of the teacher perception survey by the Likert response.

Table 4.20

Teacher Perception of Task Accomplishment

Task	AISD	BISD	CISD	DISD
Please rate your perceptions of Aegis in terms of using games to teach concepts in the classroom.	Good	Fair	Good	Fair
Please rate your perceptions of Aegis in terms of using games to assess learning.	Good	Very Poor	Good	Fair
Please rate your perceptions of Aegis in terms of using games to enrich concepts for gifted learners.	Very Good	Good	Very Good	Good
Please rate your perceptions of Aegis in terms of using games to enrich concepts for struggling learners	Good	Fair	Poor	Poor
Please rate your perceptions of how well Aegis accomplished the task of engaging students.	Good	Fair	Good	Fair
Please rate your perceptions of how well Aegis accomplished the task of teaching pertinent vocabulary related to robotics, programming, and engineering.	Good	Fair	Fair	Good

Task	AISD	BISD	CISD	DISD
Please rate your perceptions of how well Aegis accomplished the task of improving student writing skills about using complete sentences to describe the steps needed to complete a task or fix a problem	Good	Very Poor	Poor	Fair
Please rate your perceptions of how well Aegis accomplished the task of teaching students the engineering design process.	Good	Fair	Fair	Fair
Please rate your perceptions of how well Aegis accomplished the task of teaching students what pseudo code is and how to write it.	Good	Fair	Fair	Fair
Please rate your perceptions of how well Aegis accomplished the task of teaching students how to use a flowchart when creating a program.	Good	Good	Good	Good
Please rate your perceptions of how well Aegis accomplished the task of teaching students how to choose and order code blocks correctly in order to complete a program task.	Good	Very Good	Fair	Good

Task	AISD	BISD	CISD	DISD
Please rate your perceptions of how well Aegis accomplished the task of teaching students how to apply knowledge of angles to program a robot to make left and right turns.	Very Good	Very Good	Fair	Fair
Please rate your perceptions of how well Aegis accomplished the task of teaching students how to calculate the time required to travel a specific distance at a given speed.	Very Good	Good	Good	Good
Please rate your perceptions of how well Aegis accomplished the task of instructing students on how to calculate the circumference of the wheel, and use the circumference to determine how many rotations are needed to move a certain distance.	Very Good	Fair	Good	Fair
Please rate your perceptions of how well Aegis accomplished the task of instructing students on how to recognize the symbol of a loop in a flowchart and explain how it works.	Very Good	Very Good	Good	Fair

Task	AISD	BISD	CISD	DISD
Please rate your perceptions of how well Aegis accomplished the task of instructing students on using a while loop with a variable as a counter to repeat a simple process multiple times.	Good	Very Poor	Good	Good
Please rate your perceptions of how well Aegis accomplished the task of instructing students on how to add comments to clarify code.	Good	Poor	Good	Poor
Please rate your perceptions of how well Aegis accomplished the task of instructing students on how to use an if-statement to create branching code.	Fair	Fair	Good	Fair
Please rate your perceptions of how well Aegis accomplished the task of training teachers for purposes of implementation.	Fair	Fair	Good	Good
Please rate your perceptions of how well Aegis accomplished the task of addressing barriers to fidelity and implementation of the Aegis software.	Good	Good	Good	Good

Figure 4.2. Teacher Perception Survey Responses by Likert Response

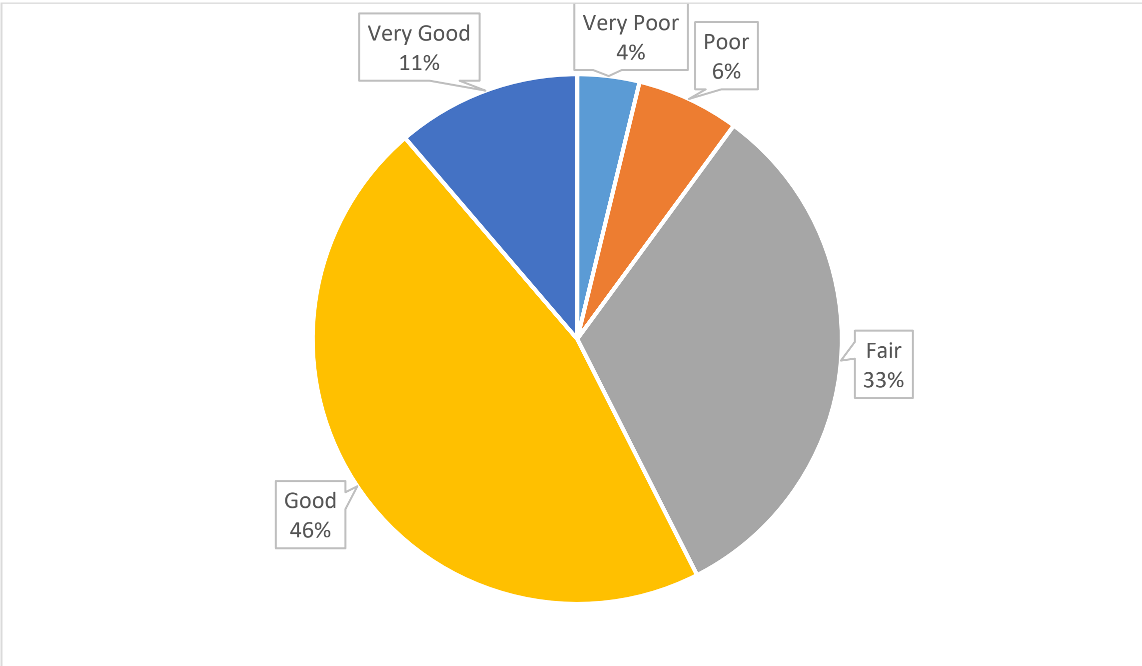

Figure 4.2. Teacher Perception Survey results from the Likert response. The most common response was "Good" with 46% of responses. The least common response was "Very Poor" with 4% of responses.

Overall, the teachers surveyed had positive reviews for the game. When disaggregated by the response, 57.6% of responses were either "Good" or "Very Good." The most common survey response was "Good," with 46.3% of all responses. The least common response was "Very Poor," with that option selected only 3.8% of the time. In fact, only one of the teachers marked “Very Poor” for any of the responses to the *Teacher Perception Survey*. This teacher struggled with the assessment portion of the game and with classroom management. The teacher stated multiple times that they did not have the time to grade the portions of the video game that were not automatically graded. This teacher was the only one to express discontent with grading the assessments. Approximately 10.1% of all responses were either "Poor" or "Very Poor," signaling that overall the teachers had a favorable perception that the game is useful in teaching basic computer programming and engineering skills.

Teacher Interviews

The post-experiment interview was conducted either in person or virtually, depending on the distance of the teacher to the researcher. Each interview took between 20-30 minutes. Teachers enjoyed the problem-solving aspects of the game. One teacher commented that "I liked the game portion because it was hard and fun." The teachers also recognized the importance of the computer programming in its relation to STEM development. Computer science, specifically computer programming, was referenced by each of the teachers as a growing field and that the video game successfully scaffolded the learning of the programming. One teacher commented, "I liked how it matched the learning, provided support for the learning, and gave them small pieces of learning at a time." Another teacher said, "It is always hard to make these concepts real, but this was a good way to do it." About the math component of the game, one teacher noted, "I also like its math connection as it is a much more fun way to teach the math/science concepts of calculating distance and circumference."

Teachers also commented that the students appeared to enjoy the visual aspects of the game. A prevailing sentiment was that the story was good and well thought out. Students enjoyed the comic book feel of the game and also were excited to start playing the game based initially on the visual aspects of the game. One teacher did comment that "if the story were less wordy and more compelling it would help their learning more." She did note that her students were pretty engaged in the story by the end of the game.

Some students, specifically, the fifth and sixth-grade students, struggled with the many facets of the game, including the vocabulary and the math concepts. According to one teacher, "If I could do it again, I would do it with my eighth-grade class because they have more math skills and higher reading skills and could move through the game more independently."

Research Question Five

Research question five, *What are the barriers to the fidelity of implementation for the Aegis video game?*, were measured qualitatively using the post-experiment teacher interviews. Teachers, during the interviews, were asked questions regarding the implementation of the video game into their instruction. Their feedback was categorized to identify any commonalities between the responses. Three commonalities emerged as barriers to implementation: time, curriculum restriction, and student reading levels.

Time

All four teachers identified time as the most significant barrier to implementation. In regards to time with the content, one teacher noted that “The topics were good, but they were at a level where they needed more time and instruction for my sixth graders and probably for my seventh and either graders as well.” This sentiment was echoed by the other teachers as well. Another teacher commented that despite the time investment, “it was a fun way to introduce the topics.” The return on time investment was not supported by all teachers, as one teacher noted, “I do not think most teachers have this kind of time to devote to one activity unless they can seamlessly incorporate it into other aspects of their curriculum.”

Curriculum Restrictions

All four teachers also identified the lack of flexibility in the curriculum as a barrier to implementation. The curriculum is established throughout the district; the reasoning behind this is that transient students will not fall behind just because they have moved to a different school within the district. Additionally, three different grade levels were investigated, and each has their defined curriculum. One teacher commented that "I could work it in with my sixth-grade class, but I do not think there is a time or a place in my seventh or eighth-grade Computer Science curriculum." Core content teachers in the study expressed concern with implementation into their curriculum. One teacher commented, "If I were still a math or science teacher, I would probably have a more difficult time fitting this in." Despite the concerns, there was support for inclusion in a curriculum. "Having the ability to have fun while learning is what science is all about. I liked the game because it was hard and fun."

Reading Level

An unexpected barrier to implementation mentioned by the participating teachers was the reading level of the game. Each teacher, for various reasons, commented that the reading level of the game provided a challenge for their students. The game was designed for students in fifth through eighth grades, with a reading level targeted at sixth grade. One of the teachers mentioned, "some students struggled, and I struggled a bit as to the best way to help them." The participating teachers all noted that the story was excellent and the characters were interesting, but that some of the words were difficult to understand.

The class from CISD presented a unique situation. CISD students were deaf and were the lowest scoring class on both the pre- and post-assessment. The teacher from CISD noted:

> *The reading level was an issue because students who are deaf tend to have lower reading and writing levels because for the first four to five years of life they do not have that kind of language input. When they get to school, they are already behind non-deaf students regarding reading and writing. Students playing the game would sometimes get frustrated and start clicking through a bit because of the reading struggles.*

Conclusion

This chapter presented the results of the quantitative and qualitative data analysis of this study. In the next chapter, Chapter V, a comparison takes place between this study's findings and prior studies recognized in the research literature as presented in Chapter II. The discussion will illustrate and comparisons and contrasting points between the findings. Implications of this study in education and future research will also be discussed.

CHAPTER V:

SUMMARY, IMPLICATIONS, AND RECOMMENDATIONS

Summary

The purpose of this study was to examine whether student play of a video game designed and developed to teach the engineering process and basic computer programming skills influenced student engagement levels and student knowledge of the engineering process and basic computer programming skills. Results indicated a strong relationship between video game play and the learning of basic engineering and computer programming skills as indicated by high t-scores from the participating classes. In addition, teacher perceptions showed positive and favorable responses to the implementation of serious games in the middle school classroom. This chapter will compare similarities and differences between the findings from this study and the existing literature by research question and attempt to cluster discussion around serious game implementation, student engagement, and teacher perceptions.

Research Question One

Research question one examined the relationship between video game play and the learning of basic computer programming skills. These skills are inclusive of the 21st-century skills of critical thinking and creativity (National Education Association, 2014). In this study, student learning of computer programming skills increased in four of the five classes and the total participants sample as measured by the pre- and post-assessment as well as t-scores and Z scores from the participating classes. This significant increase is consistent with the Aldrich (2009) study that found that video games could be used to support and assess learning in various content areas.

The results also support the research that indicates serious games could be successfully utilized to support the development of 21st-century skills required to produce career-ready students upon graduation (Romero, Usart, & Ott, 2015). Although there was a significant improvement in skill development by the students, the baseline created by the pre-assessment showed a significant deficiency in content knowledge of basic computer programming skills among the students. Students scored poorly in nearly every computer programming skill question in the pre-assessment, including those who did not answer any questions correctly. If students are to be career-ready with 21st-century skills, more rigorous development of these skills needs to start at the earlier, elementary grade levels (Casner-Lotto & Barrington, 2006).

When examining the data by participating class, four of the five classes showed a statistically significant amount of growth between the pre- and post-assessments. The positive results were consistent with the study that showed the playing of video games in other middle school classrooms had a positive effect in learning in multiple core subjects (Corbett, 2010). The results suggest that there is a positive effect on student knowledge about computer programming skills as a result of playing the video game.

District CISD is the anomaly; it was the only special populations class (the students were deaf) in the study. The teacher from District CISD stated that students who are deaf, due to the lack of verbal communication during their toddler and elementary school development, generally enter sixth grade reading at a second to third-grade reading level. Research supports this statement in regards to reading competencies of students who are deaf. Deaf students learn to "speak" in one language (sign language) and learn to read in a separate language (English in the United States); this disconnect can create an imperfect understanding of the defined reading language (Goldin-Meadow, Mayberry, & Read, 2001). The video game used in this study was developed for a target audience of middle school students with average middle school reading levels. Due to the higher reading levels, this could mean that struggling readers, such as the students who were deaf, could possibly have a more difficult time reading and comprehending the narrative within the game. This struggle could also explain the low pre- and post-assessment scores; students potentially struggled to understand the challenging computer programming vocabulary.

Research Question Two

Research question two examined the relationship between video game play and the learning of basic math and engineering skills. These skills are inclusive of the 21st-century skills of critical thinking and creativity (National Education Association, 2014). In this study, student learning of math and engineering skills increased in three of the five participating classes at a moderate to high rate as measured by the pre- and post-assessment as well as t-scores and Z scores from the participating classes. This increase is consistent with the Li et al. (2017) study that found an increase in the learning of engineering skills through the implementation of a serious game. The lack of a more significant improvement between the pre- and post-assessment could be due to the previous exposure and skill development of the participating students. Students have taken math since Kindergarten, while fewer students have been exposed to computer programming at the time of the study.

When examining the data by participating class, three of the five classes showed a statistically significant amount of growth between the pre- and post-assessments. The positive results were consistent with the studies that showed the playing of video games in other middle school classrooms had a positive effect in learning (Corbett, 2010; Israel, Wang, & Marino, 2016). These results suggest that there is a positive effect on student knowledge about math and engineering skills as a result of playing the video game.

District CISD is again the anomaly and performed the lowest of the five participating classes. District CISD showed a measurable improvement in computer programming skills, but due to the population sample, the results were not statistically insignificant. The improvement could support existing research that deaf students might have difficulty reading at their grade level (Goldin-Meadow et al., 2001). Math and engineering do not require as unique of a vernacular as computer programming does and possibly do not require as much reading as computer programming.

Research Question Three

Research question three examined the relationship between video game play and student engagement. Students showed a high level of engagement in playing the video game, as observed by classroom observations and as discussed in student focus groups. One distinguishing characteristic of engagement in games is the player may begin or end a game in the absence of coercion (Morford et al., 2014). Participating teachers chose to implement the video game into their classroom curriculum and assign a grade for student work during gameplay; therefore, participating students had no choice on when to begin or end playing the video game. Failure to participate in the game meant penalization and possible failure for the grading period.

Despite the lack of participatory freedom, the participating students still reported a high level of engagement in playing the video game. One of the major factors that contributed to the engagement in playing the video game was the narrative story portion of the video game. Engagement in reading the narrative story was important; much of the information needed to complete the tasks during gameplay came from the narrative story.

The students were, through the video game play, intrinsically motivated to continue playing the game. Intrinsic motivation is essential to engaged reading (Guthrie et al., 2004). The reported high engagement from the participating students could support the research that students are engaged while playing video games (Hoffman & Nadelson, 2010).

Students reported they enjoyed learning how to create basic computer programming code within the gameplay. The participating students commented that the repeated iterations of coding the robot until a successful code was created were an enjoyable experience. This enjoyment supports the discussion from Van Eck (2006) that engaging games required constant input from the player, provided feedback to the player, and challenged the player. Students in multiple focus groups sessions referenced those factors as reasons for their enjoyment of the game.

Research Question Four

Research question four examined the teacher perception of the video game usage and feasibility as an instructional tool in the classroom. The participating teachers had a positive perception of the video game usage. From the *Teacher Perception Survey*, participating teachers universally responded positively regarding the usage of the video game to teach computer programming and engineering skills. This postitive response aligns with the study by Quain and Clark (2016) indicating how video games, when used for learning, could improve a myriad of STEM and 21st-century skills such as those investigated in this study. The results could also support the comments from Gee (2003) regarding how serious games have the potential to make a significant impact on student learning outcomes. Responses from both the *Teacher Perception Survey* and the teacher interviews also confirmed that the video game could be an effective tool in the classroom.

One teacher noted during their interview with regard to computer programming tasks, “For the most part, the tasks and coding was good and well-integrated into the story. It’s always hard to make those concepts real, but this was a good way to do it.”

Although participating teachers had a positive perception of video game usage in the classroom, the study showed a mixed teacher perception that the video game could be a feasible instructional tool in the classroom. Two of the four participating teachers noted the video game did a poor job in terms of using games to enrich concepts for struggling learners. The data from the pre- and post-assessments could support the teacher perception that video game play did not enrich concepts for the struggling learners because the students who were deaf scored the lowest on both assessments. The game did not provide accommodations for students who were deaf in this iteration, which contrasts the study by Bates (2015) that accommodations for students with disabilities are well-established practices in Universal Design for Learning (UDL) standards. All four teachers expressed very positive perceptions regarding the video game in terms of using games to enrich concepts for gifted learners by marking “Good” or “Very Good” as responses to the *Teacher Perception Survey*.

Research Question Five

Research question five examined the barriers to fidelity of implementation of the video game. During the teacher interviews, participating teachers reported that the barriers to fidelity could be overcome with district and administration support along with proper professional development.

During teacher interviews, each teacher noted that one of the most significant barriers to implementation is administrative support. One teacher commented, “Technology availability in the school system is a major one [barrier], but getting administration on board to try something new is the biggest one. They tend to stay away from new ideas and push us to use the ones that we've been using for years and years." This is supported by the research from Stieler-Hunt and Jones (2017) that noted the lack of innovation by administrators as the most significant barrier to implementation of serious games in the classroom.

In the *Teacher Perception Survey*, all teachers rated the video game's ability to address barriers to the fidelity of implementation of the software as "Good." This is in contrast to the Abrami et al. (2004) study which reported that teachers envision games only for entertainment purposes and not as a learning tool. This means that the teacher's perceive that the game could potentially overcome and fidelity barriers. Participating teachers also noted that the video game did a "Fair" to "Good" job of training teachers for implementation. The need for teacher training is supported in an interview with a former teacher about the importance of professional development in the application of a new technology tool in the classroom (Stefanick, 2014). Additionally, the role of the teacher in the video game is that of a facilitator instead of a direct instructor; therefore, teacher training is required to understand the application of the role of the facilitator. The teacher perception and role definition support the study from Kivunja (2014) that teacher's role in student learning must evolve to one of a facilitator, just as it would be with the playing of the video game in the classroom.

Implications

As a result of this study's examination of whether student play of a video game designed and developed to teach the engineering process and basic computer programming skills influenced student engagement levels and student knowledge of the engineering process and basic computer programming skills, implications for teachers and administrators began to emerge. For teachers, the research provided a deeper understanding of the effect of video games on learning (Corbett, 2010; Gee, 2003). For administrators, the research revealed the critical need for innovative solutions to improve student engagement in STEM-related content (Stieler-Hunt & Jones, 2017).

Implications for Teachers

This study revealed the need for teachers to consider the implementation of video games into their curriculum planning to improve student engagement and knowledge of STEM-related content such as computer programming and math and engineering skills. Students reported high levels of engagement and the data showed a significant increase in knowledge of computer programming and engineering skills. The data may imply that students enjoy learning through video game play. Teachers also observed the increased engagement in the content as the students played the game. Teachers must be aware of the correlation identified in this study and others between learning basic computer programming and engineering skills and video game play. The findings suggest that playing video games could also increase knowledge in other STEM content as well as further development of 21st-century skills.

Implications for Administrators

This study revealed the need for administrators to consider developing a strategic plan to encourage implementation of serious games into the classroom. This plan must include an improvement in campus technology hardware and infrastructure. The execution of the plan must include either updated classroom technology or a district 1:1 initiative is imperative to implementation. Most study participants were not in their regular classroom during the study, as their regular classroom was not supportive of gameplay. Infrastructure improvement is also critical to the success of serious game implementation. Internet logjams as a result of hundreds of students attempting to access the internet can be a significant deterrent and a demotivating factor for serious game implementation. Finally, a well-designed professional development curriculum would be a critical component for successful serious game implementation. Teachers that are well-prepared through a continuous professional development curriculum to implement serious games in the classroom could increase their chances of successfully implementing the video game.

Recommendations for Future Research

Findings from this study involved obtaining feedback, both quantitative and qualitative, from teachers and students. Although findings provided data and information about student engagement levels and knowledge of the engineering process and basic computer programming skills, recommendations for future research will help expand the knowledge base on video game play in the classroom. The following recommendations are based on data and findings from this study.

For a future study, considering special populations, a more in-depth examination of how the implementation of a narrative-centric serious game for special needs populations, as a method of improving reading comprehension skills, would be interesting. In the CISD focus groups, the students expressed a strong desire to play the game but noted that the computer programming language was difficult to understand. The teacher also expressed her concerns regarding the difficulty of the language within the game because she and her teaching assistant had to sign and define many words.

Another recommendation for future study would be to investigate how campus technology affects student engagement and classroom implementation of serious games. Four of the five participating classes made some accommodations due to the lack of appropriate technology or access to needed technology. Three of the participating classes were displaced from their classroom and moved into a shared workspace.

Lastly, exciting feedback was given by multiple student focus groups regarding game choice. Students expressed a desire that in future iterations of the game to include player choice regarding player/avatar design or that within the gameplay the "unlocking" or customizations upon completion of tasks. An investigation of how student choice in the personalization of characters affects student engagement in serious games would be a fascinating study as a deeper investigation of research question three.

Future research in these areas would extend current research on serious games, skill and content development, and student engagement. Additional research could provide valuable feedback and support for the implementation of serious games in the classroom to teach content through the application of 21^{st}-century skills.

Conclusion

This study examined whether student play of a video game designed and developed to teach the engineering process and basic computer programming skills influenced student engagement levels and student knowledge of the engineering process and basic computer programming skills. Chapter V served to make comparisons and contrasts between the results of this study and prior literature. The findings of this study suggest a strong correlation with video game play and the increased engagement and knowledge of the engineering process and basic computer programming skills.

This study is significant to both the video game industry and the field of middle school education in that it provides insights on methods of increased student engagement and learning of STEM content through qualitative and quantitative data analysis. With the increased use of video games in the classroom, further research could significantly impact video game development and technology integration into the middle school curriculum.

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APPENDIX A:

TEACHER INFORMED CONSENT TO PARTICIPATE IN RESEARCH

You are being asked to participate in the research project described below. Your participation in this study is entirely voluntary and you may refuse to participate, or you may decide to stop your participation at any time. Should you refuse to participate in the study or should you withdraw your consent and stop participation in the study, your decision will involve no penalty or loss of benefits to which you may be otherwise entitled. You are being asked to read the information below carefully and ask questions about anything you don't understand before deciding whether or not to participate.

Title: Video Game Implementation: Learning Outcomes and Perceptions

Student Investigator(s): Donald Becker
Faculty Sponsor: Dr. Jana Willis, PhD

PURPOSE OF THE STUDY

The purpose of this research is to study whether the implementation of a video game designed and developed to teach the engineering process and basic programming skills influences student engagement and increases students' knowledge of the engineering process and basic computer programming skills.

PROCEDURES

Students will take a pre-assessment to gauge their understanding of the content. Students will then play a video game for a total of about ten (10) hours spaced over a 2-3 week period. Upon completion of the game and the corresponding lessons, students will take a post-assessment to measure how much they have learned from playing the game. Afterward, a certain number of students will be asked to participate in a focus group that will provide feedback about the game.

EXPECTED DURATION

The total anticipated time commitment will be approximately ten (10) hours for the students to complete the game, the assessments, and potentially the focus group.

RISKS OF PARTICIPATION

There are no anticipated risks associated with participation in this project.

BENEFITS TO THE SUBJECT

There is no direct benefit received from your participation in this study, but your participation will help the investigator(s) increase awareness of implementation of serious games in the EC-12 classroom. Other benefits include the reciprocal information back to game designers to enhance elements for the design of serious games in the classroom

CONFIDENTIALITY OF RECORDS

Every effort will be made to maintain the confidentiality of your study records. The data collected from the study will be used for educational and publication purposes, however, you will not be identified by name. For federal audit purposes, the participant's documentation for this research project will be maintained and safeguarded by the Faculty Sponsor for a minimum of three years after completion of the study. After that time, the participant's documentation may be destroyed.

FINANCIAL COMPENSATION

There is no financial compensation to be offered for participation in the study.

INVESTIGATOR'S RIGHT TO WITHDRAW PARTICIPANT

The investigator has the right to withdraw you from this study at any time.

CONTACT INFORMATION FOR QUESTIONS OR PROBLEMS

If you have additional questions during the course of this study about the research or any related problem, you may contact the Student Researcher, Donald Becker, at phone number [redacted] or by email at beckerd@uhcl.edu. The Faculty Sponsor Jana Willis, Ph.D., may be contacted at phone number 281-283-3568 or by email at willis@uhcl.edu.

SIGNATURES:

Your signature below acknowledges your voluntary participation in this research project. Such participation does not release the investigator(s), institution(s), sponsor(s) or granting agency(ies) from their professional and ethical responsibility to you. By signing the form, you are not waiving any of your legal rights.

The purpose of this study, procedures to be followed, and explanation of risks or benefits have been explained to you. You have been allowed to ask questions and your questions have been answered to your satisfaction. You have been told who to contact if you have additional questions. You have read this consent form and voluntarily agree to participate as a subject in this study. You are free to withdraw your consent at any time by contacting the Principal Investigator or Student Researcher/Faculty Sponsor. You will be given a copy of the consent form you have signed.

Subject's printed name: ______________________________

Signature of Subject: ______________________________

Date: ______________________________

Using language that is understandable and appropriate, I have discussed this project and the items listed above with the subject.

Printed name and title: Donald L. Becker

Signature of Person Obtaining Consent: ______________________________

Date: ______________________________

THE UNIVERSITY OF HOUSTON-CLEAR LAKE (UHCL) COMMITTEE FOR PROTECTION OF HUMAN SUBJECTS HAS REVIEWED AND APPROVED THIS PROJECT. ANY QUESTIONS REGARDING YOUR RIGHTS AS A RESEARCH SUBJECT MAY BE ADDRESSED TO THE UHCL COMMITTEE FOR THE PROTECTION OF HUMAN SUBJECTS (281-283-3015). ALL RESEARCH PROJECTS THAT ARE CARRIED OUT BY INVESTIGATORS AT UHCL ARE GOVERNED BY REQUIREMENTS OF THE UNIVERSITY AND THE FEDERAL GOVERNMENT. (FEDERALWIDE ASSURANCE # FWA00004068)

APPENDIX B:

ADMINISTRATOR REQUEST TO CONDUCT RESEARCH

I have spoken with [Teacher] regarding the pilot of a serious game for my thesis project. I am finishing up my Master's degree in Instructional Design at University of Houston- Clear Lake and for my thesis I am conducting a study regarding the development and implementation of a serious game to students. The purpose of this study is to examine whether the implementation of a video game designed and developed to teach the engineering process and basic programming skills influences student engagement and increases students' knowledge of the engineering process and basic computer programming skills. This project focuses on implementation and evaluation of a serious game targeting to students between fifth and eighth grade. Here is a link to the game:

https://www.codeofaegis.com/

The video game under study focuses on the development of computer programming skills, along with application of the engineering process. The game is designed to help students gain experience in the application of the engineering process and basic computer programming skills in a game-based format.

The Student's Role

It will take up approximately 10 hours of time for the students to complete the game. The students will also need to take a pre-test (15 minutes) and a post-test (15 minutes) and possibly participate in a focus group (45 minutes) led by me.

The Teacher's Role

The teacher's role would be a facilitator for the game. The teacher would send me a class roster so I would create the class and enter the students. The teacher and I would have a meeting, either virtually or in person, and I would show the teacher what lesson materials are available and how to find them. Finally, the teacher would need to complete a short perception survey once all students have completed the game.

The Principal's Role

University of Houston-Clear Lake requires that commitment letters from each site be included as part of my application for the protection of human subjects, so I am requesting your signature on the attached letter. Please email back a signed version of this letter as soon as possible. Once all the pilot schools have returned their letter, then I can submit my application and then begin the implementation of the game.

Thank you for your support and I will make the results of the pilot study available to you to help with your future decisions of technology integration in the classroom. If you have any questions, please don't hesitate to contact me or my faculty advisor, Dr. Jana Willis, whom I have cc'd to this email.

APPENDIX C:

CONSENT-ASSENT FORM AGES 7-12

ASSENT OF MINOR TO PARTICIPATE IN EDUCATION RESEARCH

Student Researcher:

Donald Becker

School of Education

[redacted] beckerd@uhcl.edu

Faculty Sponsor:

Jana Willis, PhD.

School of Education

281-283-3568 willis@uhcl.edu

You are being asked to help in a research project called Video Game Implementation: Learning Outcomes and Perceptions and the project is part of my master's thesis at the University of Houston-Clear Lake. The purpose of this study is to determine if playing a video game designed to teach engineering process and basic computer programming skills influences student engagement and increase students' knowledge of basic computer programming skills. You will be asked to play a video game about engineering and robots. Before and after the game you will take a short test to see what you know and what you have learned from playing the game. In the study, you will also sit down with some of your classmates and tell us what you like and don't like about the game. Your help will be needed for about ten (10) hours of gameplay.

You do not have to help if you do not want, and you may stop at any time even after you have started, and it will be okay. You can just let the researcher know if you want to stop or if you have questions. If you do want to do the project, it will help us a lot.

Please keep the upper part of this page for your information. Thank you for your assistance.

* *

______ Yes, I agree to (allow my child to) participate in the study on Video Game Implementation: Learning Outcomes and Perceptions

______ No, I do not wish to (allow my child to) participate in the study on Video Game Implementation: Learning Outcomes and Perceptions

____

Printed Name of Assenting Child

____

Signature of Assenting Child Date

____

Printed Name of Parent or Guardian

____

Signature of Parent or Guardian Date

____

Printed name of Witness of Child's assent

____

Signature of Witness of Child's assent Date

THE UNIVERSITY OF HOUSTON-CLEAR LAKE (UHCL) COMMITTEE FOR PROTECTION OF HUMAN SUBJECTS HAS REVIEWED AND APPROVED THIS PROJECT. ANY QUESTIONS REGARDING YOUR RIGHTS AS A RESEARCH SUBJECT MAY BE ADDRESSED TO THE UHCL COMMITTEE FOR THE PROTECTION OF HUMAN SUBJECTS (281-283-3015). ALL RESEARCH PROJECTS THAT ARE CARRIED OUT BY INVESTIGATORS AT UHCL ARE GOVERNED BY REQUIREMENTS OF THE UNIVERSITY AND THE FEDERAL GOVERNMENT. (FEDERALWIDE ASSURANCE # FWA00004068)

APPENDIX D:

CONSENT-ASSENT FORM FOR AGES 13-17

Adolescent Participant Assent Form to Participate in Education Research

You are asked to help us in the project described below. Your parents or guardian have given their okay, but you get to decide if you want to be in this study or not. You may stop or quit the study at any time by telling one of us and it is okay. If you want to know more about the study, it is okay to ask questions.

Title of Study: Video Game Implementation: Learning Outcomes and Perceptions

Student Researcher:

Donald Becker

[redacted] beckerd@uhcl.edu

Faculty Sponsor:

Jana Willis, PhD.

281-283-3568 willis@uhcl.edu

Purpose: The purpose of this research study is to examine whether the implementation of a video game designed and developed to teach the engineering process and basic programming skills influences student engagement and increases students' knowledge of the engineering process and basic computer programming skills.

Procedures: You will be asked to play a video game that teaches the engineering process and basic computer programming skills in an interactive graphic novel format. You will take a short test before and after playing the game to assess what you have learned while playing. It will take about ten (10) hours for you to complete the game and the assessments. You also may be asked to participate in a focus group with some of your classmates for about an hour.

We will do everything to make sure that you do not get hurt in any way. We will be the only people who know what you say and do. There are no anticipated risks associated with participation in this project.

If you understand what you are being asked to do and you decide to help, you are asked to sign your name below.

____

Printed Name and Signature of Assenting Adolescent Date

____

Printed Name and Signature of Parent or Guardian Date
(if applicable)

____

Signature of Investigator Date

THE UNIVERSITY OF HOUSTON-CLEAR LAKE (UHCL) COMMITTEE FOR PROTECTION OF HUMAN SUBJECTS HAS REVIEWED AND APPROVED THIS PROJECT. ANY QUESTIONS REGARDING YOUR RIGHTS AS A RESEARCH SUBJECT MAY BE ADDRESSED TO THE UHCL COMMITTEE FOR THE PROTECTION OF HUMAN SUBJECTS (281-283-3015). ALL RESEARCH PROJECTS THAT ARE CARRIED OUT BY INVESTIGATORS AT UHCL ARE GOVERNED BY REQUIREMENTS OF THE UNIVERSITY AND THE FEDERAL GOVERNMENT. (FEDERALWIDE ASSURANCE # FWA00004068)

APPENDIX E:

ADMINISTRATOR LETTER OF SUPPORT TEMPLATE

March 12, 2018

University of Houston/ Clear Lake
Committee for Protection of Human Subjects
2700 Bay Area Boulevard
Houston, Texas 77058

Dear Committee Members:

Please accept this letter of support for the University of Houston-Clear Lake and Donald Becker interactive partnership, Video Game Implementation – Learning Outcomes and Perceptions.

We recognize that there is a need to increase skills and knowledge in the STEM areas and are pleased to be considered as partners for this important research project. The need for this research is relevant in our fast-paced society. I respect the process and products that originate at the university, and I feel confident that Andrea Burke, the teacher selected to participate, and students in our school will benefit greatly from their participation in this project.

We support this effort and pledge to help arrange meetings, send regular communication, ensure project requirements are completed, and implement the processes with fidelity to lead to quality research.

We pledge to help ensure project requirements are met, and the processes implemented with fidelity.

Respectfully,

APPENDIX F:

STUDENT ASSESSMENT SURVEY

Start of Block: Introduction

INTRO Code of Aegis Student Assessment Survey

End of Block: Introduction

Start of Block: Demographic Data

D1 Enter your Code of Aegis user ID

____

D2 What is your gender?

- O Male (1)
- O Female (2)

D3 What is your race/ethnicity?

- O American Indian or Alaskan Native (1)
- O Asian (2)
- O Black or African-American (3)
- O Caucasian or White (4)
- O Hispanic or Latino (5)
- O Native Hawaiian or Other Pacific Islander (6)
- O Two or more races (7)
- O Other Race not listed (8)

D4 What is your grade level?

- 5th Grade (1)
- 6th Grade (2)
- 7th Grade (3)
- 8th Grade (4)

D5 What is your age?

- Under 10 (1)
- 10 (2)
- 11 (3)
- 12 (4)
- 13 (5)
- 14 (6)
- Over 14 (7)

End of Block: Demographic Data

Start of Block: Skills Assessment

Q1 The first full scale working model that can be tested of a chosen solution is called a

- O Draft (1)
- O Genotype (2)
- O Model (3)
- O Prototype (4)

Q2 Requirements of a project that must be met are called

- O Rules (1)
- O Criteria (2)
- O Facts (3)
- O Precedents (4)

Q3 The first step in the design process is

- Identify constraints (1)
- Brainstorm/research (2)
- Define the problem (3)
- Collaborating (4)

Q4 A narrative is a

- Summary of events (1)
- Step-by-step description of a plan (2)
- Fictional story (3)
- Sequential anecdote (4)

Q5 A detailed description of what a computer program must do, expressed in natural language rather than programming language is

- O Pseudo code (1)
- O Quasi code (2)
- O Command code (3)
- O Instructional code (4)

Q6 “Move forward 5 meters, turn right 90 degrees, and…” is an example of

- O Command Code (1)
- O Pseudo Code (2)
- O Instructional Code (3)
- O Quasi Code (4)

Q7 In a flowchart, an oval is used to

- Show a process to be carried out (1)
- Provide comments (2)
- Represent the start or end of a program (3)
- Add dialogue (4)

Q8 What is used to show the directional flow of the program in a flow chart?

- Arrow (1)
- Diamond (2)
- Rectangle (3)
- Circle (4)

Q9 A value with unexplained meaning which could confuse programmers reading the code is known as a

- Function (1)
- Magic Number (2)
- Comment (3)
- Parameter (4)

Q10 A unit used to measure angles is called a(n)

- Acute (1)
- Degree (2)
- Diameter (3)
- Obtuse (4)

Q11 To determine the number of tire rotations needed to move a robot forward 200 meters, you need to know the

- O speed the robot is traveling (1)
- O amount of time the robot travels (2)
- O circumference of the robots' tires (3)
- O direction the robot is traveling (4)

Q12 Which of the following describes a sequence of commands that are repeated until a condition is no longer true?

- O Loop (1)
- O Increments (2)
- O Variable (3)
- O Repeat (4)

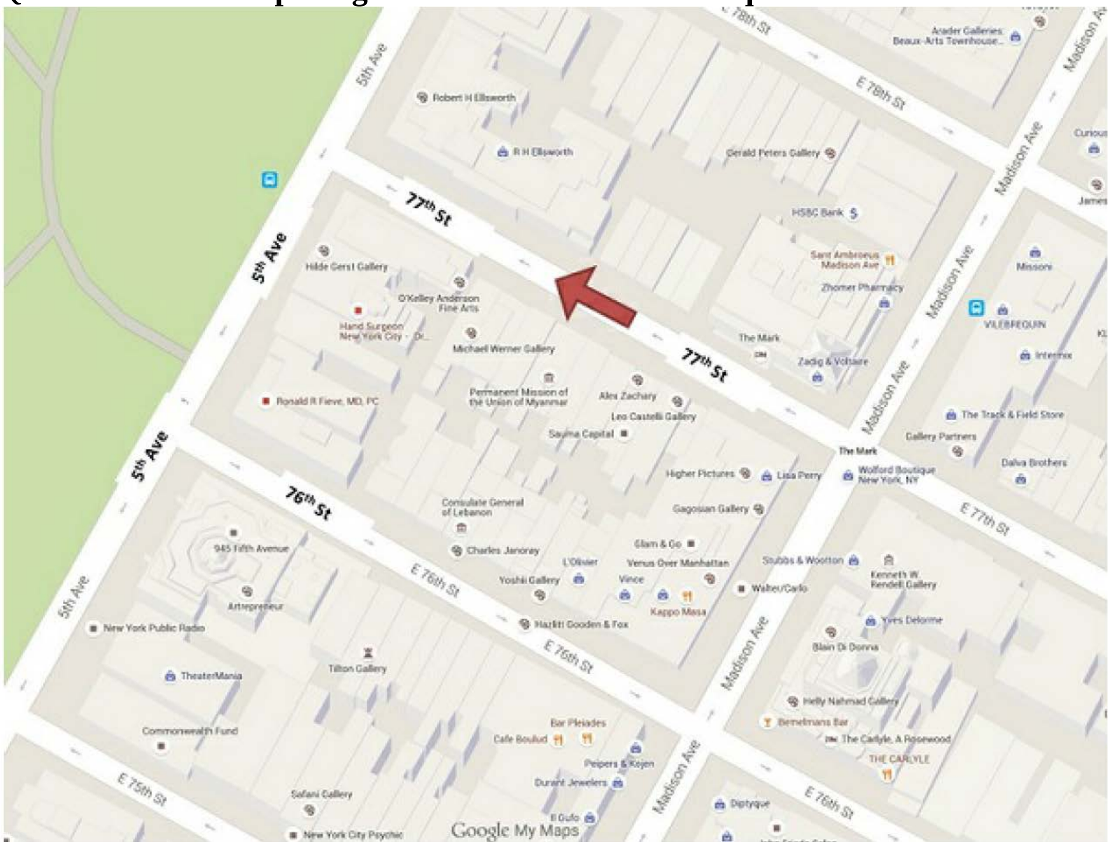
Q13 A “while loop” with a variable as a counter can be used to repeat a simple process

- Four times (1)
- Intermittently (2)
- Multiple Times (3)
- Twice (4)

Q14 A diamond shape in a flowchart with the code “count < 4” is a

- Program start diamond (1)
- Comment diamond (2)
- Decision diamond (3)
- Program end diamond (4)

Q15IMG **Use the map image below to answer the next question.**



Q15 Your car is traveling on 77th Street as indicated by the RED arrow on the map above. When you arrive at 5th Ave, you will turn left for 90 degrees. Which statement best describes your turn?

- Turn the car left for 90 seconds (1)
- Turn the car half-way around so that it is facing the opposite direction (2)
- Turn the car in a complete circle so it is facing the same way (3)
- Turn the car to the left so it is perpendicular to 77th street (4)

Q16 When a section of program runs, either one group of code or another, or even skips code based on a condition is

- Extending (1)
- Branching (2)
- Off-shooting (3)
- Forking (4)

Q17 An “if statement” is used to create

- O branching code (1)
- O off-shooting code (2)
- O looping code (3)
- O intertwining code (4)

Q18 A diagram that helps visualize a plan using different shapes to represent different types of commands is a

- O Tree Diagram (1)
- O Pseudo code (2)
- O Flow Chart (3)
- O Narrative (4)

End of Block: Skills Assessment

Start of Block: Scenario

TEXT

For the next two questions use the following information:

Your social studies teacher asks you to create a report that is due in one week. The topic should be on time zones in the United States and should include historical information about when time zones were created as well as geographical information about each time zone. You have been asked to present the report to your class and will have up to 10 minutes to present your report.

Q19 From the items listed below, select a criterion of this assignment

- O You may use the internet to do research. (1)
- O The report needs to contain historical information about when the time zones were created. (2)
- O You only have one week to complete the assignment. (3)
- O All of the above are criteria. (4)

Q20 From the items listed below, select a constraint of this assignment.

- You may use the internet to do research. (1)
- The report needs to contain historical information about when the time zones were created. (2)
- You only have one week to complete the assignment. (3)
- All of the above are constraints. (4)

End of Block: Scenario

APPENDIX G:

TEACHER PERCEPTION SURVEY

Start of Block: CoA Introduction

INTRO Code of Aegis Teacher Perception Survey

End of Block: CoA Introduction

Start of Block: Game Utility

Q1 Please rate your perceptions of Aegis in terms of using games to teach concepts in the classroom.

- O Very Poor (1)
- O Poor (2)
- O Fair (3)
- O Good (4)
- O Very Good (5)

Q2 Please rate your perceptions of Aegis in terms of using games to assess learning.

- O Very Poor (1)
- O Poor (2)
- O Fair (3)
- O Good (4)
- O Very Good (5)

Q3 Please rate your perceptions of Aegis in terms of using games to enrich concepts for gifted learners.

- Very Poor (1)
- Poor (2)
- Fair (3)
- Good (4)
- Very Good (5)

Q4 Please rate your perceptions of Aegis in terms of using games to enrich concepts for struggling learners

- Very Poor (1)
- Poor (2)
- Fair (3)
- Good (4)
- Very Good (5)

End of Block: Game Utility

Start of Block: Task Accomplishment

Q5 Please rate your perceptions of how well Aegis accomplished the task of engaging students.

- Very Poor (1)
- Poor (2)
- Fair (3)
- Good (4)
- Very Good (5)

Q6 Please rate your perceptions of how well Aegis accomplished the task of teaching pertinent vocabulary related to robotics, programming, and engineering.

- Very Poor (1)
- Poor (2)
- Fair (3)
- Good (4)
- Very Good (5)

Q7 Please rate your perceptions of how well Aegis accomplished the task of improving student writing skills with regard to using complete sentences to describe the steps needed to complete a task or fix a problem

- O Very Poor (1)
- O Poor (2)
- O Fair (3)
- O Good (4)
- O Very Good (5)

Q8 Please rate your perceptions of how well Aegis accomplished the task of teaching students the engineering design process.

- O Very Poor (1)
- O Poor (2)
- O Fair (3)
- O Good (4)
- O Very Good (5)

Q9 Please rate your perceptions of how well Aegis accomplished the task of teaching students what pseudo code is and how to write it.

- O Very Poor (1)
- O Poor (2)
- O Fair (3)
- O Good (4)
- O Very Good (5)

Q10 Please rate your perceptions of how well Aegis accomplished the task of teaching students how to use a flowchart when creating a program.

- O Very Poor (1)
- O Poor (2)
- O Fair (3)
- O Good (4)
- O Very Good (5)

Q11 Please rate your perceptions of how well Aegis accomplished the task of teaching students how to choose and order code blocks correctly in order to complete a program task.

- Very Poor (1)
- Poor (2)
- Fair (3)
- Good (4)
- Very Good (5)

Q12 Please rate your perceptions of how well Aegis accomplished the task of teaching students how to apply knowledge of angles to program a robot to make left and right turns.

- Very Poor (1)
- Poor (2)
- Fair (3)
- Good (4)
- Very Good (5)

Q13 Please rate your perceptions of how well Aegis accomplished the task of teaching students how to calculate the time required to travel a specific distance at a given speed.

- O Very Poor (1)
- O Poor (2)
- O Fair (3)
- O Good (4)
- O Very Good (5)

Q14 Please rate your perceptions of how well Aegis accomplished the task of instructing students on how to calculate the circumference of the wheel, and use the circumference to determine how many rotations are needed to move a certain distance.

- O Very Poor (1)
- O Poor (2)
- O Fair (3)
- O Good (4)
- O Very Good (5)

Q15 Please rate your perceptions of how well Aegis accomplished the task of instructing students on how to recognize the symbol of a loop in a flowchart and explain how it works.

- O Very Poor (1)
- O Poor (2)
- O Fair (3)
- O Good (4)
- O Very Good (5)

Q16 Please rate your perceptions of how well Aegis accomplished the task of instructing students on using a while loop with a variable as a counter to repeat a simple process multiple times.

- O Very Poor (1)
- O Poor (2)
- O Fair (3)
- O Good (4)
- O Very Good (5)

Q17 Please rate your perceptions of how well Aegis accomplished the task of instructing students on how to add comments to clarify code.

- Very Poor (1)
- Poor (2)
- Fair (3)
- Good (4)
- Very Good (5)

Q18 Please rate your perceptions of how well Aegis accomplished the task of instructing students on how to use an if-statement to create branching code.

- Very Poor (1)
- Poor (2)
- Fair (3)
- Good (4)
- Very Good (5)

Q19 Please rate your perceptions of how well Aegis accomplished the task of training teachers for purposes of implementation.

- O Very Poor (1)
- O Poor (2)
- O Fair (3)
- O Good (4)
- O Very Good (5)

Q20 Please rate your perceptions of how well Aegis accomplished the task of addressing barriers to fidelity and implementation of the Aegis software.

- O Very Poor (1)
- O Poor (2)
- O Fair (3)
- O Good (4)
- O Very Good (5)

End of Block: Task Accomplishment

Start of Block: Demographics

D1 What school district do you teach in?

- O Alief ISD (1)
- O Bedminster Township Public Schools (2)
- O Houston ISD (3)
- O Littleton Public Schools (4)

End of Block: Demographics

APPENDIX H:

STUDENT FOCUS GROUP QUESTIONS

Pull 4 students. Record their names, grades, genders, and ethnicity (as possible)

Student	Grade	Gender	Ethnicity

Student Interview Questions

1. What did you think of the first chapter of “Aegis?” Did you like it? Why or why not?
2. What did you like best about the first chapter of the game? Why?
3. What did you not like about the first chapter? Why? Were there things that were confusing or frustrating while playing it? Explain.
4. What did you think of the look (i.e. graphic novel, storyline, art, characters)?
5. What did you think of the user interface (usability and navigation, specifics like the Exclamation point, Triumphs, and Communiplanner)?
6. How do you think “Code of Aegis” could be improved? Explain.

APPENDIX I:

TEACHER FOCUS GROUP QUESTIONS

Teacher Demographics

- Age
- Race
- Teaching Assignment

Interview Questions

1. How do you think the students liked the game?
2. How would this game be valuable to the field of teaching?
3. How would this game enhance student learning?
4. What did you like about the game?
5. What do you think about the quality of topics in the game?
6. Do you think that gender played a role in the interest of the game?
7. Could this game be incorporated into your classroom instruction?
8. What would be some barriers on implementing this game in the classroom?