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A game-based learning approach to increase female participation in science, technology, engineering, and mathematics fields

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by

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DEDICATION

The work presented in this Master's Thesis is dedicated to many people whom I have had the benefit of learning from. To those from Auburn University who helped me become a better version of myself. To my family. To my GDES 12 family. To my former professors Kelly Bryant and Samantha Lawrie. To John Powell for setting me on this path. To those who have seen me succeed, fail, and face palm fabulously. To those who have unintentionally inspired or encourage me. Most importantly, this thesis is dedicated to the kid who just may decide to pursue STEM despite initial reservations. Calculus is challenging, but I promise you'll get over it. And finally to you the reader "because reasons."

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NOMENCLATURE

GBL	Game-Based Learning
SOS	Sorceress of Seasons
CS	Computer Science

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ABSTRACT

The game Sorceress of Seasons was developed to teach fundamental concepts of python programming to middle school students with the goal of increasing enthusiasm in the Science, Technology, Engineering, and Mathematics (STEM) fields, especially for middle school female students.

Currently there is a significant lack of professionals in STEM fields in the United States. Specifically, women are underrepresented in STEM fields, despite making up half of the workforce. Career interests are often developed in the middle school years; thus increase the pool of STEM professionals, , it is necessary to spark interest in STEM at an early age.

A Game based learning (GBL) approach was used to increase interest in STEM for middle school females. GBL is an effective approach as it utilizes gameplay with educational content to create and engaging environment where students can practice concepts in a real world context. However, computer and video games have historically portrayed females in stereotypical and unhelpful ways. As a result many of female gamers hesitate to play certain games, experience negative gaming experiences when they do play certain games, and this detracts from the number of female gamers. Thus before any game could be developed, first developed game design requirements that would result in games that are welcoming to females as well as effective in its learning goals.

Based on these requirements, the game Sorceress of Seasons (SOS) was developed to teach the concepts of variables, lists (arrays), and if statements. The game was then assessed with a group of middle school students in an evaluation. The goal of the evaluation was to verify that the requirements created a game that was welcoming to females, that the game was effective

in teaching some basic programming concepts, and that exposure to the game increased interest in STEM

From this, several of the requirements were supported based on feedback from students. Overall, student comprehension in programming concepts increased from the Pre-Experimental Assessment to the Post-Game Survey. Students indicated increased likelihood to pursue a career in a programming related profession after playing the game.

CHAPTER I

INTRODUCTION

The objective of this project is to increase female middle school students' interest and confidence in Science, Technology, Engineering, and Mathematics (STEM) courses through the use of game-based learning (GBL). By providing female middle school students with a game that enables them to get hands-on experience with computer programming, the experience may encourage more females to pursue STEM careers.

Currently, a dearth of STEM professionals exists in the United States (Beede, Julian, Langdon, McKittrick, Khan, & Doms, 2011). Problem solvers and innovators are necessary as this effects the ability to compete with the rest of world. Specifically, STEM fields related to Computer Science (CS) are in need of more professionals. With an estimated 1.4 million computing jobs to arrive by 2020 in the United States, only about a third of college graduates will be able to fill these jobs (Beede et al., 2011; National Science Foundation, 2015) This is not due to a lack of people in the United States. Rather, it is due in part to only utilizing a portion of the total workforce, relying on external populations to fill STEM positions, and excluding population groups such as women from the field (Ramakrishnan, 2014).

Women are underrepresented in STEM. While women made up approximately 48% of the workforce in the United States as of 2009, only 25% of all STEM professionals are female (Beede et al., 2011). There has been a rapid increase of bachelor degrees awarded with a majority earned by women since 1981. This trend is expected to grow through 2024 where females will be awarded approximately 400,000 more degrees then males (Beede et al., 2011). Unfortunately, while the total number of female college graduates has steadily increased, the percentage of those who belong to a STEM field had more or less stayed the same from 2000-

2009, remaining at 24% (Beede et al., 2011). Specifically, while participation in Physical/Life Sciences and STEM management by females had increased from 36% to 40% during that 10 year period. participation in Computer Science (CS) by women has decreased (Klawe, 2013). Meanwhile, wage differences between genders persist. Male engineers across are expected to make $17,000 more on average annually than women (Beede et al., 2011). STEM and non-STEM occupations have wage differences of 14% and 21% respectively. For every dollar earned by males, females earn $0.86 (Beede et al., 2011). Additionally women of color are not well represented within STEM (Ong, Wright, Espinosa, & Orfield, 2011).

The way STEM is perceived at an early age may indicate whether a young female will pursue these careers or turn to a different focus (Wyss, Heulskamp, & Siebert, 2012). Blickenstaff (2005) states that "*as long as women are underrepresented in STEM, a substantial number of intelligent, talented women are choosing other areas in which to study or work*" (p.370).

As it stands now, women are not choosing to pursue STEM fields. Despite an on-going effort to increase a female presence in STEM fields in the U.S., women still remain as a minority (Blickenstaff, 2005; Wang & Degol, 2013). Women are particularly discouraged from these fields through stereotypical depictions of careers in popular culture (Wyss et al., 2012) and an unclear perception of what these career fields actually consist of (Robinson & Pérez-Quiñones, 2014; Wang & Degol, 2013). This has resulted in an underrepresentation in information technology profession populations. Additional underrepresented groups such as women of color also follow this trend of hesitancy (Ong et al., 2011). Diversity in STEM is needed to induce innovate solutions to problem solving. In some cases, having a population with similar backgrounds can limit growth and methods to approaching problem solving.

The Role of STEM Education

External factors play a role in the choices students make. Preexisting expectations for success held by female students' parents, teachers, and fellow peers may influence choices made which may lead away from STEM pipelines (Blickenstaff, 2005; Eccles & Harold, 1992). Therefore, it is imperative that every effort is made to either encourage interest or prevent hindrances of student interest in STEM. This of course does not mean every student should be steered towards STEM, but rather the ones who are at least intrigued by STEM should not be inhibited from participation. As (Blickenstaff, 2005) states, *"Every person should have an equal opportunity to study and work in the discipline she or he chooses"* (p. 370). Stereotypes persist which imply that females are not good at subjects such as math despite females performing either equally or better than males in STEM (Hartley, & Sutton, 2013; Hyde, Lindberg, Linn, Ellis, & Williams, 2008). Some of the literature even questions whether society is ignoring the problem of underachievement in STEM by male students (Hartley, & Sutton, 2013). Many young females have the potential to succeed in STEM but are not in STEM professions. An important thing to note is that just because a female is good at math does not mean she will pursue STEM careers. Students who excel at math will often go into a non-STEM field if they also have proficiency with verbal subjects such as language arts (Lubinski, & Benbow, 2006). Still, there is a significant amount who are qualified but are deterred from participation. There is a correlation for students who leave or stay in STEM at the end of high school with levels of interests upon entering high school (Sadler, Sonnert, Hazari, & Tai, 2012). Thus, students will be more likely to become STEM professionals if they have positive attitudes and a desire to pursue STEM upon entering high school (Sadler et al., 2012). It is important to understand how students perceive

STEM subjects such as computer science as it allows them to combat stereotypes and will lead to increased interest.

When students enter middle school, many possess low expectations of ability (Wigfield & Eccles, 2000). These beliefs relate to an individual's self-determined ability to complete a task. For instance, according to Weiner (1985), ability is viewed as something which is inherent or that an individual has little control over. Views on ability can either have a positive or detrimental effect on an individual's motivation as positive motivation is born from perceiving a success through ability while negative motivation is born of attributing failure to ability (Wigfield & Eccles, 2000). These views are a key part of a student's self-concept (Desy, Peterson, & Brockman, 2011). A student who perceives their ability to be low in a subject is less likely to put forth more than minimal effort. This can also be effected by previous academic preparation (Blickenstaff, 2005). Thus, the importance of students' confidence with subjects such as science or math can be linked to their subsequent performance. To increase female middle school students' interest in STEM, it is important that they possess positive expectations of ability and their expectations of how they may perform (Wigfield & Eccles, 2000).

In a 2011 survey, results showed that female students between 6^{th} -12^{th} grades reported having more anxiety about science than males and have also reported to have a lower level of enjoyment than male students (Desy, Peterson, & Brockman, 2011). However, many of these same students still reported wanting to have a career in the health sciences despite their feelings of anxiety. An important finding from this survey is that a gender gap in STEM interest increases with the level of education (Desy et al., 2011).

Early exposure and understanding of the concepts of a particular career field can determine a student's interest level and the likelihood success in pursuing that career field

(Maltese & Tai 2010). For example, if students were able to master some fundamental element of programming languages, a key competency in computer science (CS), then those students may have a higher confidence and a better understanding of CS. Through increasing knowledge and enthusiasm at this level, students might be more likely to develop a strong interest in STEM as well as the skills necessary to succeed in fields such as CS. However interest alone is no guarantee that a child will pursue STEM.

In order to make a significant difference, the best time to effect a change in attitudes is between the ages of six and fourteen as it is a critical period in the mental development of a child (Eccles & Harold, 1992). This period is described as middle childhood. Middle childhood is a period that allows students to develop competencies, interest, and a healthy sense of confidence that they can master and control their worlds (Eccles & Harold, 1992). Middle school age (ages 10-14) students specifically are at a crucial age because it is usually when their interests, competencies, and confidence translate into their career paths (Maltese & Tai 2010; Wang & Degol, 2013; Wyss, 2012). As students begin to develop interests in STEM, they will begin to take more classes. There is a correlation between the amount STEM classes taken by students and their likelihood to enter into STEM (Lee, 2015).

Game-based Approach

Because of the need to introduce STEM subjects and assess interest before students begin high school, the target audience for this project was middle school aged students. These students would be exposed to programming through playing a computer-based game. They would be provided with an engaging experience with the goal of demystifying computer science. Game-Based Learning is a type of gameplay that has defined learning outcomes (Presnky, 2007) and was chosen for method of content delivery for several reasons. Previous applications have shown then GBL is effective. Games such as *Crystal Island* were implanted for K-5 students (Meluso, Zheng, Spires, & Lester, 2012). Crystal Island teaches students about landforms and ecosystems through exploration. After play students' knowledge and self-efficacy increased when compared to before the game. The main motivation for using this approach is that GBL combines learning with elements of a game to create an engaging experience. It also serves the purpose of appealing to both genders even though this specific application was designed with females as its primary users. The subject of computer science was chosen as it is an area which female participation is needed. Previous implementations such as CodeSpells have worked to address this (Esper, Wood, Foster, Lerner, & Griswold, 2014). A computer game Sorceress of Seasons (SOS) was developed to teach several basic concepts of computer science (CS) to middle school students. SOS was created by using principles of GBL. However, computer and video games have historically portrayed females in stereotypical and unhelpful ways, and as a result the vast majority of games are targeted towards males. Thus before any game could be developed, game design requirements that would result in games that are welcoming to females as well as effective in its learning goals were developed. The learning outcomes of SOS is that students will be able to comprehend basic concepts of programming such as variables, lists, and if statements.

A goal of the intervention is to successfully convey basic concepts of programming. By providing an engaging experience that enables students to practice actual programming, it is the aim that these types of innervations would eventually inform and inspire students to pursue careers related to computer science.

Thesis Overview

The thesis is organized as follows:

1. *Chapter 2: Related Work*. This chapter discusses key barriers to participation in STEM, related to work to increase female participation in STEM, and a review of a games-approach to learning.
2. *Chapter 3: Game Design Requirements*. This section will describe work done to develop design requirements for games that are gender neutral and welcoming.
3. *Chapter 4: Game Description*. This section will describe the development process, and the resulting game, Sorceress of Seasons *(SOS)*, based on game design requirements and principles for GBL
4. *Chapter 5: Experimental Method. This section will describe* an evaluation with middle school students that assessed the ability of the approach to increase interest in STEM careers.
5. *Chapter 6: Experimental Results*. Results of the evaluation are presented.
6. *Chapter 7: Discussion*. Results are discussed with respect to the initial hypothesis and the issues raised in the Introduction and Related Work section.
7. *Chapter 8: Conclusion*. Final conclusions and future work are presented.

CHAPTER II

RELATED WORK

In this chapter, previous work which informs the project will be discussed. Elements which describe the need for the intervention are addressed such as the barriers which may inhibit participation in STEM by female students. This is important as identifying barriers of exclusion leads to developing new approaches toward inclusion. Existing work to encourage participation are reviewed for lessons learned and guidance. These include several previous efforts for interventions involving K-12 students. Finally, work is discussed in relation to computer science and the practical application of GBL which utilizes aspects of programming.

Barriers to Participation

Throughout the career of the average American female professional, there are several barriers which discourage participation in STEM such as STEM having been historically dominated by males. Conversely, there are fields that are deemed "suitable" for women by society's standards (Fine, 2010). These include fields such as K-12 education, nursing, liberal arts careers, social work, and early childhood care (Preschool or day care). Some of these barriers to woman in traditionally male-dominated fields include blatant sexism, social norms, misconceptions, lack of role models, and environmental cues. These barriers may influence their young female students over time through interactions and observation of those who express the attitudes. Of the many barriers which discourage participation in STEM, the ones discussed in this section are the influence stereotypes and the lack of role models or mentors for female students. These barriers may influence their female students over time through interactions and observation of those who express the attitudes.

For female students, external factors such as perceived teacher support and peer influence can often affect how attitudes of ability and STEM interest are developed (Wigfield & Eccles 2000). The way specific STEM subjects are taught and perceived socially may serve as a barrier to female participation. Social factors such as feelings of isolation, intimidation, along with possibly having lower self-confidence in STEM domains despite equal or higher achievement contribute to a lack of females in the field (Rosenthal, 2011).

Social stigmas associated with computer science were expressed by middle school females. For example, while participating in a study involving paper prototyping (Robinson et al. 2014). Several middle school female participants expressed their previous views of computer science being *"boring," "pretty stupid," "Kind of nerdy, "*and *"hard."* It was only after they had completed the activity that their opinions changed. One participant's reasoning behind this change was simply due to her prior lack of exposure. She credits not knowing what was possible with computer science as the justification and reasoning for those initial opinions. This trend was common among the group as others claimed that computer science was *"fun," "pretty cool," "exciting," "interesting,"* and *"very informative"* at the study's close (Robinson et al. 2014).

More specifically, two participants indicated that they *"might want to try it out more"* and *"it was something I might take interest in when I'm older."* The students were also asked if they would want to become a computer scientist. Most of the participants who said no indicated that while it wasn't their first choice, they now considered it a possibility instead of not even considering it. A couple even indicated that they could now see computer science's relation to their first choice career.

As previously mentioned, attitudes and perception play a large part in determining whether or not a student goes into a STEM field after high school (Sadler et al., 2012). Another perception issue is the how students view careers. Females are more likely to view science and technology as not having relevance. It is important for them to see the connections between what they are learning in school and what is happening in the real world. This can explain why many tend to gravitate towards professions which are focused on a social context where they can see how what they are doing has a direct impact (Christensen et al., 2014).

Increasing Female Participation

Combating barriers

This concept of focusing on the social context was applied to an approach to increase female enrollment within computing careers at Harvey Mudd College (Klawe, 2013). Three key innovations were identified as being detrimental to female participation. Females *"do not find CS interesting, believe they will not do well in CS, and feel uncomfortable in the computing culture"* (Klawe, 2013; p. 57). In order to change this, the school modified how CS was structured making sure that introductory courses highlighted the importance of CS in society. Focus was shifted away from learning how to program in favor of solving problems with computational thinking. Additionally, first year female students were invited to a conference were they met female professionals. This approach was then applied to in other schools such as Bucknell University, Northwestern University, and several University of California locations such as Riverside and San Diego.

Female participation in information technology was also addressed in a study that allowed younger female students to be exposed to serval related subjects (Werner, Campe, Bean, & Denner, 2005). Topics such as game design, challenging stereotypes, pair programing, and identity forming were presented in regards to social/self-identity. Each area provided a learning experience for the females who participated which showed how strategies can be implemented to overcome initial reservations.

In the design area, students learned to prototype, build mental models, and sequence trouble shooting which to some degree was based on uncertainty. Within this method, the participants were able to use the computer as a form of self-expression. To challenge traditional stereotypes, females were exposed to working professionals in STEM who provided help within the troubleshooting sequence and insight into their experiences in the technology profession. Also, the students were shown how to get involved in game production through the process of pair programming. Pair programming allowed for a collaborative environment where one team member acted as the driver for the programming, and the other acted as a support. This way the student filling the support role could collaborate with the person operating the program while still learning, contributing, and pointing out ideas. Lastly, identity was the biggest factor in challenging stereotypes as it addresses the participant's own personal feelings about programming. The females developed a desire to seek out problems due to the new found confidence in programming and received positive reinforcement from parents, instructors in addition to their peers which made the entire experience more enjoyable and rewarding. This is an example of how important students attitudes are and how the contribute to success.

Outreach programs

While a plethora of barriers exist which can detract from the appeal of STEM and desire to participate, there are several outreach initiatives which help to counteract barriers. Some of these offer mentoring, role models in a classroom setting, and career role models in the workforce. A wide spectrum of outreach programs provide diverse population of students with access to STEM aids. Outreach for both males and females has been conducted to increase interest in information technology (Machina & Gokhale, 2015). For females, these include programs such as Girls Who Code, Black Girls CODE, the Society of Women Engineers, and Women in Science and Engineering.

Girls Who Code is an organization dedicated to closing the gender gap in STEM (Adams & Reed, 2015). They seek to inspire students by exposing them to real world role models. They specifically focus on computing fields such as Computer Science (CS). *Black Girls CODE* seeks to increase the participation of women of color within STEM fields to address both gender and ethnic gaps (Tiku, 2014). They teach young girls and pre-teens subjects such as programming and game design so that they may develop in-demand skills while they are developing their own interests. *GirlStart* is an organization which strives to close the gender gap is by providing K-12 after school programs, a Summer Camp, a *GirlStart* Conference, and community programming (Krishnamurthi, Ballard, & Noam, 2014). GirlStart does not have a specific niche for its programming. As of 2014, 91% of participants for GirlStart demonstrated proficiency within scientific inquiry and engineering design (Krishnamurthi et al. 2014).

Two organizations which are more focused on undergraduate and professional development are the *Society of Women Engineers* (SWE) and *Women in Science and Engineering* (WISE). While also engaging in K-12 outreach, SWE performs outreach at universities and has a nationwide presence. WISE meanwhile is focused more on outreached performed at universities by providing programs which encourage women to pursue stem careers.

These outreach programs tend to target female students in the highs school and college level. The work described here targets middle schools female students. If successful, the game principles developed here could be applied to programming in outreach programs that also target younger female students.

Games and Game-Based Learning

Games

There is not a clear consensus as to what defines a game (Alaswad & Nadolny, 2015). Literature defining games goes back to Ludwig Wittgenstein and has had different definitions since (Feyerabend, 1955). How a specific game is defined depends on its content and context of play. Modern games differ by genre, such as first person shooter, role playing, arcade, and many others. Some suggest that games can consist of four key parts: goals, rules, feedback systems, and voluntary participation (McGonigal, 2011). The goal is what players work towards achieving. Rules exist to define how a player can achieve a goal. The feedback system informs players how close they are to achieving the goal and informs them when they have reached it. Voluntary participation refers the people playing. They have accepted the goals, rules, and feedback of the game. These players a voluntarily accepting a difficult challenge.

Marc Prensky and James Gee have overlapping opinions on what defines a game. Their definitions apply to their respective fields of expertise. According to Prensky (2007, p. 119), games are defined by six key principles: Rules, Goals and Objectives, Outcomes and Feedback, Opposition, Interaction, and Story. Similarly, Gee (2003) lists 16 key elements with a focus on Identity, Production, Well-Ordered Problems, Challenge and Consolidation (Cycles of expertise), Information Distribution (Just-in-time and on demand), Situated Meanings, and Sandboxes.

The enjoyment process (Starks, 2014) is depicted in Figure 1 consists of Engagement, Challenge, Flow, Persistence, and Mastery. Without enjoyment, the player will not have the motivation to play and miss out on the opportunity to learn the content contained within a game. One of the best ways to engage a player is to create an immersive environment (Gee, 2003; Prensky, 2007). There are multiple ways to accomplish this by either creating a realistic environment, or using a first person viewpoint.

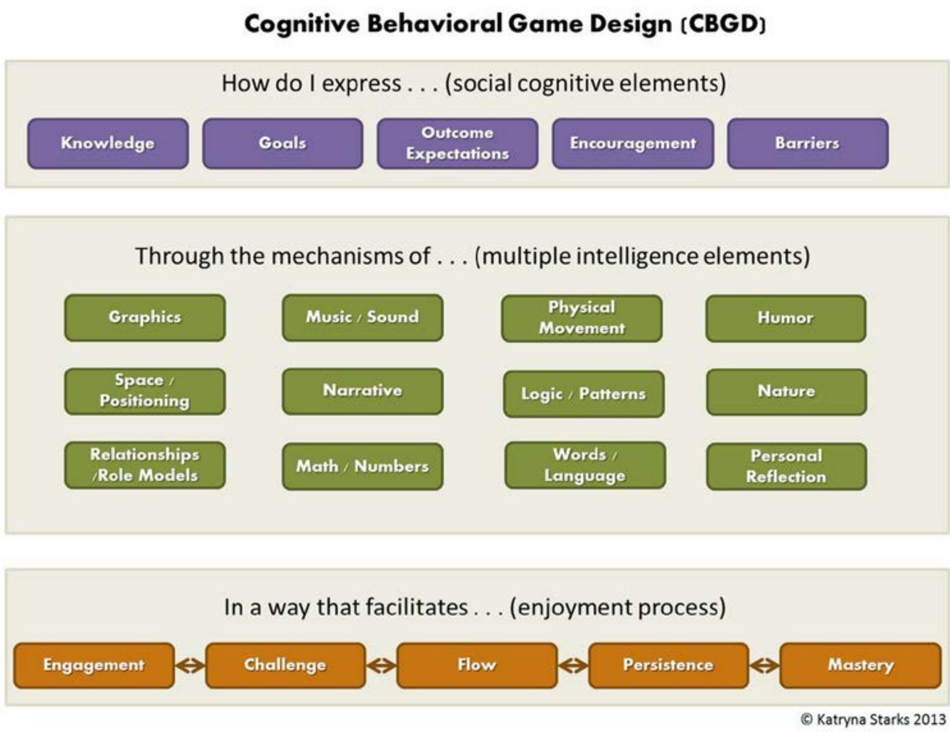

Figure 1: Cognitive Behavioral Game Design, Starks 2014

Players will need a reason to continue playing the game. It is primary motivation for play as some middle school students (usually males) enjoy competition (Olson, 2010). In a survey conducted by Olsen (2010), females were less attracted to competition. However, a significant number of females who were regular gamers noted that they did enjoy competition (Olson, 2010). However, competition or challenge inspires social connectivity as well as the possibility of a reward. Challenge may also refer to difficulty. If a game is too easy, a player may lack the motivation to continue or simply not gain anything from the experience.

The flow of a game can be critical. Flow can be categorized by elements of challenge and consolidation (Chen, 2007). In this element, cycles of expertise are employed to manufacture user competency over time. Similar to an undergraduate learning concepts for a test, the gamer uses practice to familiarize themselves with concepts in order to progress through a game's story or narrative. They hone their skills along the way until the final exam or level's boss is encountered. The flow of a game plays a key role in enjoyment as it is the optimal form of challenge (Starks, 2014).

When dealing with a challenge, it is important that the player remain persistent. Finally, a game requires mastery for enjoyment. Consistent with Flow, the game presents easier competencies which the player can master. Gradually the game presents increasingly difficult objectives or goals which require persistence.

The game developed in this work utilizes game play in order to encourage students to overcome difficult problems such as learning computer science concepts. By presenting students with learning within a game, they may push through difficult subjects which they might not within normal education.

Video games and learning

Computer and video games are usually considered as entertainment (Connolly, Boyle, MacArthur, Hainey, & Boyle, 2012). However, entertainment games provide engaging activities. Several theories suggest that "*learning is most effective when it is active, experimental, situated, problem-based and provides immediate feedback*" (Connolly et al., 2012, p. 661, McGonagall, 2011). Many aspects of video games are appropriate for learning and can influence education

(Gee, 2003; Shaffer, Halverson, Squire, & Gee, 2005). Video games allow the user to participate in new environments (Shaffer et al., 2005). This allows players to inhabit roles which are not regularly available which provides an entirely unique experience. In playing the game *Madden* (EA Sports, 2015), the player can assume the role of an American Football athlete, coach, and executive. They build their team, determine its strategies, and execute the strategies within the realm of the game. Additionally, players are not required to learn things out of context as they are directly placed within the environments where information they are provided is in context. Players learn by doing (Gee, 2003). Furthermore, games are effective due to the change in content presentation alone. It was shown through using animations for math lessons that a slight change to learning materials can enhance student learning as animations or images improves the synchronization of verbal and visual information (Luzon & Leton, 2015). Additionally, a game was created which increased high-school students' interest in theatre (Mareno et al. 2015).

Good games incorporate principles which can be used in academic contexts such as information delivery (Gee, 2003). Difficult concepts can be taught to novices if they are simplified to be a manageable challenge (Maloney, Resnick, Rusk, Peppler, & Kafai, 2008). People or players often forget information after it is learned out of context. Thus effective games find some way of allowing information to exist somewhere in the game where players can access it when necessary. A recent study demonstrated how video games such as Angry Birds and Cut the Rope can teach physical concepts which can be assessed through the use of concept maps (Sun, Ye, & Wang, 2015). The game Angry Birds requires players to understand concepts of trajectories and force while Cut the Rope is a puzzle based game where players must successfully deliver an item such as food to a frog.

A plethora of games have been developed which positively teach or influences students such as games for prosocial behaviors (Connolly, Boyle, Macarthur, Hainey, & Boyle, 2012). Prosocial behavior can be defined as actions intended to help others (Gentile, 2009). In a study, it was determined that games such as Super Mario Sunshine and Chibi Robo had a positive effect on middle school students as both games require the player to perform an action which helps others (Gentile, 2009; Nintendo, 2015). In Chibi Robo, the player assists their family with chores, and in Super Mario Sunshine, the player ventures around an island cleaning dirt with a water pack. In the study, students played these prosocial games along with violent and neutral games. It was shown that students who played the prosocial games were more likely to perform positive prosocial behaviors than when playing the other games.

Negative impacts of playing games

Even though video games are popular, they are not without detriments (Connolly et al., 2012). Games are viewed as promoting violence, gender stereotypes, and addiction. Many video games display acts of violence and require the player to perform acts of violence to reach in game goals. Notable work on negative aspects of games expresses that what gamers practice within the game transfer into real world actions. Especially with adolescents, the more time spent practicing violent behavior results in an increased likelihood for verbal or physical altercations (Gentile et al., 2004). Also, playing violent video games decreases prosocial behavior (Anderson & Bushman, 2001). Conversely, practicing a positive experience may lead to positive outcomes. The approach described in the thesis acknowledges the literature on the negative aspects of games and mitigates them as best as possible to provide a positive gaming experience.

There is also gender stereotyping in games. There are fewer female characters in games and their roles are often limited to stereotypical associations (Boyle et al., 2012; Dill, & Thill, 2007). Female characters are typical stylized in a manner which is overly sexualized (Dill et al., 2007). This can influence feelings of poor body image which can potentially lead to pathogenic dieting in both sexes (Dill et al, 2007; Martins, N., Williams, D. C., Harrison, K., & Ratan, 2009). Males can perceive influence through media which may lead to compulsive bodybuilding and steroid use. Females can develop poor self-esteem due to an unrealistic body image.

Games can also negatively influence interactions between males and females (Dill et al, 2007). There is the possibility of viewing sexual harassment behaviors as acceptable by media over-saturation. Males are more likely to show more sexual abuse supportive attitudes after expose to advertisements or media featuring women as sex objects. Some games glamorize domestic abuse such as the *Grand Theft Auto* series which may have an effect on male-female interaction.

Game-Based Learning

There are many approaches to applying the principles of games to education. Serious Games are virtual simulations of real-world scenarios which serve the purpose of solving a problem (Connolly et al, 2012). They typically serve a purpose other than entertainment (although they can still be entertaining). Serious games can be used in applications for the military, education, government and healthcare (Susi, Johannesson, & Backlund, 2007). Gamification refers to games and is the use of game design elements in non-game contexts (Deterding et al., 2011). Whereas gamification focus purely on aspects of a game, Game-Based Learning (GBL) balances subject matter with game play. The goal is to allow the learner to retain information acquired from game play and apply it in the real world. GBL gameplay can be described as a causally linked series of challenges in a simulated environment. When it is applied with a proper curriculum, GBL can effectively teach a subject (Schenke, Rutherford, & Farkas, 2014). In the context of this project, students play SOS and should acquire competency in programming with python. As Rieber (1996) states "*Having children play games to learn is simply asking them to do what comes naturally*" (p. 52).

Digital Game-Based Learning (DGL) expands GBL theories by applying them in the context of a computer or video game (Presnky, 2007). While there is not a clear definition of it, DGL can be applied to an existing video game or a DGL application can be developed from a curriculum. Interestingly enough DGL can also be applied to any kind of learning such as business, technical educational or simulations as previously mentioned. GBL/DGL is the right approach to addressing the STEM issue because it targets the root of the problem which is interest. It has also been shown to be an efficient means for learning (All, Patricia Nu, Castellar, & Van Looy, 2015).

In recent studies, GBL was used in team environments to provide a learning experience. To address the issue of nutrition, the cloud diet assessment system (CDAS) was created to promote healthy habits. CDAS compares dieting techniques between a group of students to promote competition which was focused on achieving the recommended daily nutritional intake (Yang et al., 2015). Another study looked at Game-Based Team Learning (GBTL) compared across groups and pairs (Martín-Sanjos, Juan, Seguí, & García-García, 2015). This study found that GBTL is just as effective in pairs or larger groups. The game Virtual Age was also utilized for learning within a scholastic setting where students' in game behavior was related to their gaming performance and learning outcomes for the concept of evolution (Cheng, Lin, & She, 2015).

Programming has been featured in projects for teaching undergraduate students. Object orientated programming was taught to students using a tangible user interface (TUI) (Corral, Balcells, Estevez, Moreno, & Ramos, 2014). Students learned C# programming by using small cubes which outputted wireless signals. While this is not necessarily a game, this project demonstrates creative ways to teach programming as students were able to practice programming in a visual context.

Games and programming

Previous studies attempted to utilize GBL to increase female participation in CS/Programming. Some examples that are relevant to the work and development of the game are discussed briefly in this section.

Peer instruction is a valuable asset for novice CS students (Zingaro & Porter, 2014). This is demonstrated in The Girls Create Games Program's use of *Pair Programming* (Werner, Campe, Bean, & Denner, 2005). The Girls Create Games Program (GCGP) involved a class which devoted to teaching female students programming through the creation of their own games. The students worked in a program called Creator in pairs. From this experimenters observed that the social interaction between the two students created strong atmosphere of learner where pairs support and encouraged each other. The use of pairs in program begins to addresses Prensky's design principle of interaction. In addition, it is important to note that previous studies have shown that females enjoy and appreciate games which have been design specifically for them (Stewart-Gardiner, Carmichael, Latham, Lozano, & Greene, 2013).

Storytelling Alice is a programming environment where students learn basic concepts by creating animated movies and games. It has been used in many studies where participants have tested the validity of pair programming and use it to assess importance of narratives in learning motivate further use and exploration within the programming environment (Kelleher, Pausch, & Kiesler, 2007). Comparisons were made between female middle school students' time spent in the programming environment for those who programmed with a narrative story aspect and those without one. The found that the narrative elements of the program led to students spending more to experimenting with programming.

Scratch is a visual programming environment designed for early-education where students can use their creativity to make their own stories and animations (Maloney et al., 2008). The syntax for scratch uses programming blocks which are put together by children to create programs. The blocks coming in various shapes and sizes. Similar to building block sets, certain pieces will only fit with other pieces in ways which make logical sense. It was created to suit the interest of students between the ages of 8 and 16. Scratch programming favors exploration and self-discovery as users learn by doing instead of traditional instruction. It motivates students to work with peers. It's important for students to stay motivated or interested with games to avoid wear out or decreases in interest (Yang et al., 2015).

A more recent event driven object orientated programming project for children is Functional Reactive Programming (FRP) which utilizes a 3D environment to show connection between multiple concepts from STEM such as CS, math, physics, and art (Clearly et al., 2015). Similarly to scratch students are able to use their creativity in this setting (Cleary, Vandenbergh, & Peterson, 2015). It is designed for students in grades 8-12.

Code Spells is a serious game which uses principles of DGL to teach Java in a 3D virtual environment (Esper, Wood, Foster, Lerner, & Griswold, 2014). Building upon novice programming environments such as Alice and Scratch, Code Spells seeks to teach programming without requiring students to use materials outside of the game environment.

The work on game-based learning, examples of positive and negative games, and an understanding of the barrier to female participation in STEM were used as the basis for the development of the set of requirements described in the next chapter.

CHAPTER III

SYSTEM REQUIREMENTS

This section describes the requirements necessary to build a successful Game-Based Learning application for encouraging female middle school students to pursue STEM careers such as computer science. Again, it is important to encourage female students to participate in STEM at a young age as it is when students are developing their individual preferences (Eccles, 1992). The level of interest in STEM which students possess upon entrance into high school can determine if they will continue in the STEM pipeline (Sadler et al., 2012). There are six key dimensions which are derived from previous work (Prensky, 2007; Gee, 2003; McGonigal, 2011). These include a female protagonist, an engaging narrative, induced uncertainty, game mechanics, social aspects, and fun.

Protagonist

The first requirement which is necessary for the project is the inclusion of a female character who is not subjected to objectification and gender role stereotypes. One of the primary reasons some females do not enjoy playing video games as much as their male counter parts is how women are represented in video games (Martin et al., 2009). Therefore it is necessary to design a game with characters whom are not offensive (Grimes, 2003).

Narrative

The second requirement is the use of a story to engage learners. Some of the best games grab attention by telling fantastic stories (Rollings & Adams, 2003). Part of the reason some games are able to capture attention so well is because they incorporate the concept of flow (Csikszentmihalyi, 2005). According to Chen (2007) flow refers to "*A sense of control and concentration on the task at hand*" (Chen, 2007; p.33). Flow is also described as "*a subjective* *state that people report when they are completely involved in something to the point of forgetting time, fatigue, and everything else but the activity itself* " (Csikszentmihalyi, 2005; p.230). In video games, there are many choices to be made which requires thought. Dwelling on choices can interrupt gameplay or flow and cause players to become irritated.

If a game is complex, its story is usually complex too. For example, a sports based game such as the Madden franchise does not need a compelling story as it is a game which draws from the real life events for professional American Football. Meanwhile, a game such as the Final Fantasy Franchise requires a complex story as it not only creates its own fictional world, but the scale requires great attention to detail from the user. Small story aspects such as character's backgrounds can play a large part in the choices the user makes as well as the consequences of those choices. In games such as World of Warcraft and Dungeons and dragons, a player is associated with their characters race, class, and guild, or group of gamers. Based on these factors, a player may be influenced to destroy a village or attack someone because of their identity and character motives (Williams, Kirshner, 2015; Ewalt, 2014).

Furthermore, aspects of storytelling or story schema play a role in organizing cognition (Rieber, 1996). A story schema is used for comprehension and recall (Rand, 1984). Many studies show that a strong story schema can help individuals remember key details of events. Storytelling is often used in educational settings as it also allows students to represent thoughts symbolically (Ryokai, Lucelle, Russell, 2003).

For these reasons a story can be an effective tool in creating a serious game. In creating story aspects it is important to have them somehow tie back into the content which is being taught to that learners can access them later. When they are needing to remember important information. Games which use storytelling have been shown to be effective within the learning process by captivating interest (Giannakos, Chorianopoulos, & Jaccheri, 2012).

Uncertainty

Motivation is a key factor in the learning process. Uncertainty provides motivation and can increase interest (Ozcelik, Cagiltay, and Ozcelik, 2013). Uncertainty can be considered as a challenge or obstacle within a game as players do not always immediately understand what to do. Such is also common with learning as students are assessed on their ability to solve problems through applying previously learned knowledge (Iacovides, Aczel, Scanlon, Taylor, & Woods, 2012). Similarly to Gee's well-ordered problems, players are given challenges according to their level of competency (Gee, 2003).

Mechanics

Maloney et al., 2008 argues that "*systems can make programming more accessible for novices by simplifying the mechanics of programming, by providing support for learners, and by providing students with the motivation to program.*" This statement accurately sums up the importance of appropriate mechanics. Systems such as Scratch teach programming in a context where concepts can be comprehended through mastery of a system, however they are not taught in realistic contexts.

Social Aspects

In addition to appropriate levels of uncertainty and simplified mechanics in programming, social aspects included in gameplay may increase the appeal of programming for middle school students. Strategies such as pair program have been used in academic settings where students learn programming from professors as well as from their partner (Williams & Upchurch, 2001). "*Pair programming is a collaborative form of programming where two people* *work side by side at once computer*" (Denner, Werner, Campe, & Ortiz, 2014, p. 277) and can aid in satisfaction for programmers. Many students find introductory computer science programs to be frustrating which leads to a fourth of students to drop out (Williams et al., 2001). At first glance this can be brushed off as students failing out. Programming is difficult and does require a lot of work, but that does not necessarily mean that it should be a frustrating experience. Students may be on the cusp of an initial breakthrough but are discouraged by their inability to make connections which may lead them to lose interest.

Pair Programming can increase confidence. Previous studies such as the Girls Create Games Program have looked at pair programming and how interaction between two students during programming can be effective (Werner & Denning, 2009). Discussion and reflection on a specific task can help students develop a complex understanding (Denner et al., 2014). At the university level studies have compared pair programming to solo (or traditional) program and receive similar results. However, for the age range of this project it is beneficial. Young males and females more than any other age group often play games in groups. In a study from 1995, experimenters found that pairs of 9-13 year old students working at a single computer were more successful at solving computer puzzles than and are more driven to continue playing than solo players or pairs working at two separate computers (Inkpen, Booth, Klawe & Upitis, 1995). However, the study did find that students had difficulty sharing a single device.

In addition simply pairing students randomly is not necessarily a guarantee of success. Students should be matched up with someone whom can match their level of expertise and contribute to their learning experience by offering something which an individual may not already possess (Denner et al., 2014). The greatest gains in computer based tasks aside from programming can be made with partners sharing different skill sets. Students learn more when they are forced to explain what they are doing as they must think about the task and explain it in ways which others can comprehend which puts the student in the role of the teacher.

Because of these reasons it is imperative that some degree of social interaction be included in the development of a GBL application for teaching programming. To incorporate some form of cooperative learning is a necessary to act as motivation for learning.

Fun

The inclusion of a social aspect can also lead to a positive or fun experience. As previously mentioned, young males and females are more likely to play games in groups. The engagement factor is not only what will keep players playing the game but will also bring them back for additional sessions. In the study which was ran, one of the participants was dying to know when the game would be available for them to download online.

In literature, engagement can span from casual gameplay to internet gaming addiction (Billieux, Deleuze, Griffiths, & Kuss, 2015). One of the most popular and addictive games is World of Warcraft (WoW). WoW is a Massive Multiplayer Online Role Playing Game (MMORPG) that is played by an estimated 20 million players worldwide. Players create their character and join in the game online. One of the key elements of the game is advancement through acquiring new skills. Players can become addicted due to several aspects of game play which are expressed through psychological and neurobiological factors (Billieux et al., 2015). Part of which is social interactions which occur non-stop due the games environment. Another addictive aspect is the engaging story which immerses the player into a rich history which makes up one of the world's largest wikis (McGonagall, 2011). Combining social elements with immersive game play makes for a highly enjoyable or fun experience. Though, is important to note that some gamers who play MMORPGs suffer from game addiction (Billieux et al., 2015).

Additionally, other types of games are far less likely to cause game addition alone as the environment of online game play is persistent. Furthermore, the individual psychological factors play a part in the addiction.

CHAPTER IV

SORCERESS OF SEASONS DEVELOPMENT

Overview of the game

The requirements of the pervious chapter were realized in a new game developed and implemented for this research entitled, *Sorceress of Seasons* (SOS). The purpose of the game is to get students interested in CS. The main goal of the game is to teach fundamental concepts of computer programming. This chapter discusses the development process of SOS including the efforts to build the game using an iterative design process that drew from the graphic design process and the human-centered design process. It also explains how the game addresses the principles of GBL and the requirements for a successful GBL intervention. The concepts which SOS teaches are explained and put in the context of game play with justifications for inclusion. Finally, the game's story is expressed and tied into the games description.

Game Design Process

The iterative design process began after the requirements were developed for the game. A combination of graphic design process (Schenk, 1991) and user-centered design process (Pagulayan et al., 2012) was followed for the creation of SOS. The basic steps include defining the concept through brainstorming, sketching preliminary, critiquing comps, and then repeating the process with the chosen design until it meets desired specifications. It is important to note that these practices vary in detail. While Lupton and Phillips (2011) provide a loosely defined approach to this process, Gothelf and Seiden's *Lean UX* (2013) categorizes these into five steps (Gothelf & Seiden, 2013; Lupton & Phillips, 2011). This consists of problem definition, idea generation, critique, iterate and refine, and team idea generation.

This graphic design process begins with the designer defining the concept and problem. The problem refers to what the project is addressing whereas the concept is specifically the method utilized to address it. After sketching preliminary ideas, these are evaluated based on outside feedback from experienced game designers, CS experts, and peers. Game experts reviewed SOS and made suggestions for how to implement features. CS experts discuss the realism of the concepts within the game. Peers and pilot test subjects experienced the game and provided their analysis of what was successful or needing work. The primary, secondary, and tertiary elements are considered with the design. In SOS, the primary elements were centric the playable character, the secondary elements were items and other game aspects which interacted with the player such as the environment. Tertiary aspects included items or background features such as level design which provided a world for the character to exist in. From this a specific approach is determined which results in further developed comps. These are then evaluate with more scrutiny which results in a single focused approach for the product to be developed.

For SOS, the design process began with addressing the requirement of a female protagonist through the creation of the main character's game "sprite." A game sprite is a two-dimensional animation that is integrated into a scene (Lambert, 2013). This allows an object or character to seem like they are moving or interacting with the game environment when the player inputs a command or action such as movement or attacking an enemy.

In the initial design attempt, female video game avatars were compared to find an aesthetic which was not detrimental to female gamers. Games such as *The Legend of Zelda* Series (Nintendo, 2015a), *Azure Striker: Gunvolt* (Brown, 2014), *Shantae and the Pirate's Curse* (Thompson, 2014), and the *Metroid* Series (Nintendo, 2015b) were considered as they were 2D games which featured a female character to a degree (Nintendo, 2015; Thompson, 2014; Steam

Games, 2013; Brown, 2014). From these, the aesthetics of *The Legend of Zelda* Series, *Valdis Story: Abyssal City* and *Metroid* were used as a basis for the main character. The character Autumn was modelled after a character from *Valdis Story* and given aspects of other protagonists from *Zelda* and *Metroid* such as a futuristic mask and distinguishable hair to allow for the same core design to be applied to other seasonal warriors. Initial sketches were scanned and digitally drawn using Adobe InDesign and Fireworks to achieve the classic 8-bit character feel. Six peers reviewed the character design through informal one-on-one critiques and provided feedback which was in favor of it. Peers noted the simplicity of the character as a positive. However, they had wanted to see the character do more through providing animations, for different changes in state such as movement, rest, and attacking. Two additional rounds of character design followed after which peer review, lead to the sprite in Figure 2.

Figure 2: Base Warrior Sprite

Other game details such as story and game play underwent this same design process. The story and level game play were both developed through the creation of a game document which described an outline for the entire game. After initial creation, several versions of the game document were submitted to game designers who had significant experience and gamers who understood good game design. In two working meetings, they provided feedback suggesting that the game play was slow and needed to motivate players to be engaged. Due to this, the game play was significantly changed to be move faster and have simpler instructions. Thus, the story was refined to match game play. The levels started out as sketches which detailed how the characters would proceed through the game. Also abilities were integrated into the levels. Figure 3 shows the initial approach to level design. The players starting point is indicated as well as plans for placing pieces of the level. After peer review this initial level design was revised to incorporate the special abilities of the characters as seen in Figure 3 (middle) and Figure 3 (right). Specifically, this also indicates how the lists concept was going to be originally applied within the game as object references.

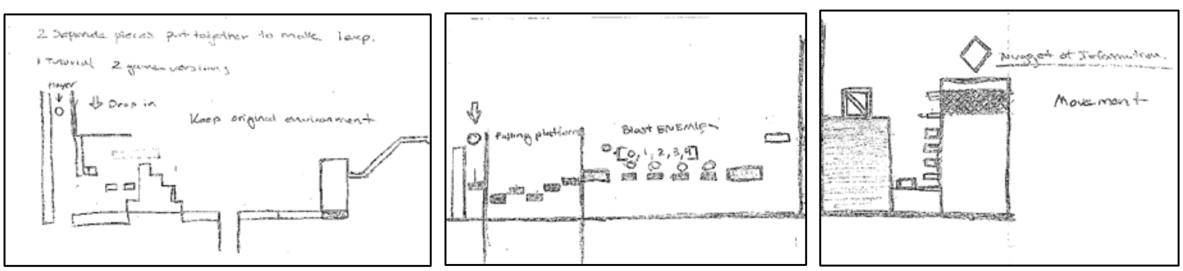

Figure 3: Level Sketch 1, 2a and 2b

In a subsequent iteration, these sketches were eventually brought into Adobe Illustrator and mocked up as rough concept designs as seen in Figure 4. The coin sprite of the previous sketches is still applied within this level.

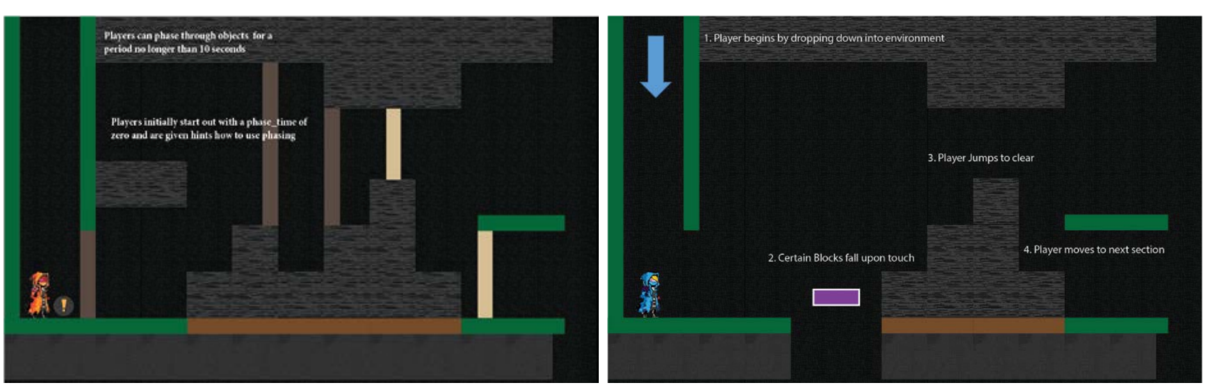

Figure 4: Level Concept Art 1 (left) and Level Concept Art 2 (right)

The lists concept is fleshed out further through the concept art in Figure 5 which depicts the levels design. However, after presenting this concept art for feedback, it was determined that the execution of the lists concept needed to be altered. Peers indicated that a more effective means to use lists would be to incorporate the idea of items which could be accessed. The bridge feature would possibly be confusing as players were not in possession of the bridge pieces.

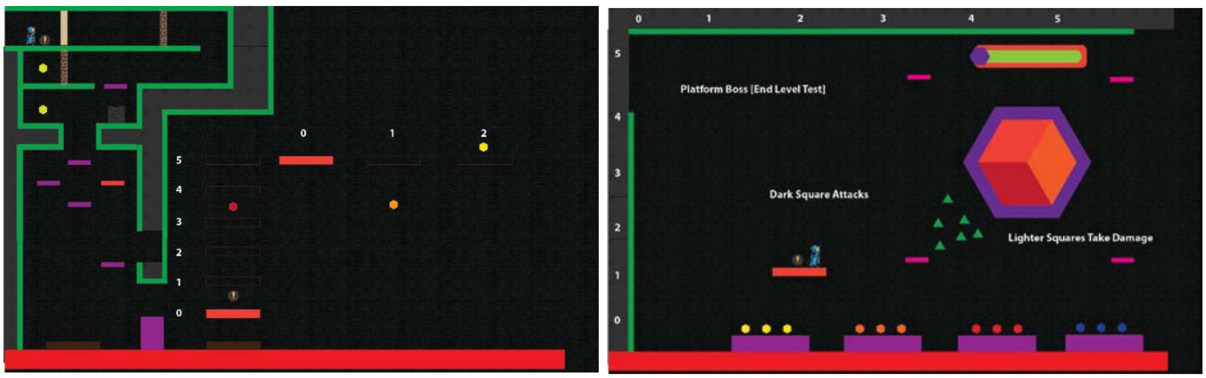

Figure 5: Lists Level Concept Art (left) and Lists Level Boss Concept Art (right)

After successful paper prototyping, the initial game was implementation in Unity (Unity Technologies, 2015) in order to produce a playable prototype for pilot testing with students. After the prototype or beta version was developed with the inclusion of several in game features, the focus of the iterations shifted from design of aesthetics to functionality. From the pilot tests, new iterations of the game were developed which concentrated on how programming was accomplished within SOS.

Introduction to Programming

Programming is an aspect of computer science which deals with the process of creating an executable computer program. Python programming was chosen as the language to be taught for several reasons. First, it is an object orientated programming language (OOP), a key method widely used in computer science (Franco, 2010). Some other computer languages include Java, C++, PHP, Visual Basic, ActionScript, JavaScript, MATLAB, and Ruby. Two of the more widely used languages are Java and C++. Python is a more suitable introductory language to learn than Java or C++ (Radenski, 2006) because Python is less syntax specific and needs fewer lines of code written in comparison than Java or C++. Other languages such as PHP and JavaScript also are easier for a beginner to use than Java and C++. However, they are more difficult for beginners to learn than Python. Although Python was originally designed for educational use (Lutz, 2008; Tollervey, 2015) CS practitioners quickly adopted it for professional use due to its simplicity (Radenski, 2006).

Concepts

Curriculum Approach

The coding concepts within the game are variables, lists and if-statements in Python. As previously alluded to, python programming was chosen due to its ease of use and history as a language for teaching python. The curriculum in SOS are consistent with the Computer Science Teachers Association (CSTA) standards model for sixth through ninth grade students (CSTA, 2011). The model focuses on computer science as students begin to use computational thinking to solve problems. Specifically, the game's format and concepts address CSTA standards 1-5 for level 2 (grades 6-9) which are as follows:

1. Select appropriate tools and technology resources to accomplish a variety of tasks and solve problems.
2. Use a variety of multimedia tools and peripherals to support personal productivity and learning throughout the curriculum.
3. Design, develop, publish, and present products (e.g., webpages, mobile applications, animations) using technology resources that demonstrate and communicate curriculum concepts.
4. Demonstrate an understanding of algorithms and their practical application.

5. Implement problem solutions using a programming language, including: looping behavior, conditional statements, logic, expressions, variables, and functions.

The game promotes the use of programming with variables, lists, and if statements to solve in-game problems. The implementation of the six requirements within SOS motivate students to solve puzzles and overcome obstacles. How the programming is presented in the game and accompanying surveys allows students to develop connections between the curriculum and the real world. Additionally, SOS touches on the International Society for Technology Education's standards for computer science educators such as the effective teaching and learning strategies (ISTE, 2015). The two strategies which the efforts of SOS closely relate to are:

1. Design activities that require students to effectively describe computing artifacts and communicate results using multiple forms of media
2. Create and implement multiple forms of assessment and use resulting data to capture student learning, provide remediation, and shape classroom instruction.

The three concepts are each taught in a level of the game: variables in level 1, lists is level 2, and if-statements in level 3. The three levels of the game build upon one another. Variables, first introduced in level 1, are then used in levels 2 and 3.

Concept for Level 1: Variables

Variables was selected as the first concept due to its simplicity and scalability. A variable is a storage location where a single piece of information is stored and referenced. The variable is a symbolic name that references the stored value. An example of a variable is `size=4` where `size` is the symbolic name and `4` is the value. The serves as a basis for players to be introduced to the environment and provided a platform of skill transfer to the topic of lists. Students are shown what a variable is and how it is used through in-game metaphors.

Concept for Level 2: Lists (or arrays)

Lists builds upon the topic of variables. A list is a data structure that concepts of a collection of variable, each identified by an index. An example would be pets = {dog, cat, bird} where pet[0]=dog, pet[1]=cat, and pet[2]=bird. Where variables only focus on one piece of data, lists focus on two or more.

Concept for Level 3: If statement

An if statement is a condition expression that allows for an action depending on whether the outcome of a Boolean expression is true of false. Another example might be if (hungry=true) then eat lunch. The previous two concepts allows users to practice until they master sub concepts of variables and list. In level 3, students are exposed to if statements and must use the variables concepts to produce a valid if statement. Participants are shown how an if statement depends on specific conditions being met.

Learning Goals

After completing a level of the game, students should be understand the associated concept and apply it within the game to accomplish a goal. By the end of level 3 of the game, students should be able to draw connections between the three concepts to be able to creating new examples in real world contexts. For variables should be able to demonstrate how variables hold data. For lists, participants should be able to demonstrate how multiple pieces of information can be stored and then called upon when it is applicable. For if statements, participants should be able to demonstrate how conditions trigger events.

Game Description

The main protagonist of this implementation of SOS is Winter (see Figure 6, character in blue). Winter has a brief back story which is given in the tutorial focusing on her objective which is to save her friends. The design intention for multiple characters is to allow players to associate certain aspects of programming with each character. As a new character is rescued at the end of a level, players then have the option of playing with that character. Other playable Characters for the future include Spring and Autumn. The current implementation of the game has only the first character, Winter.

Figure 6: Winter, Spring, & Autumn Preliminary Designs

The game experience begins with a 15-minute tutorial video (Bonner, 2015). The tutorial serves two purposes. The game narration explains the plot of the game while the tutorial narration introduces players to the concepts of programming they will be using within the game. Upon completing the tutorial video players are immersed in the training level of the game where they explore the different abilities.

Tutorials

Players watch a tutorial which explains basic programming and how it applies to the game. Next, players receive short training inside a tutorial level which acts similarly to a sandbox for comprehension. Players then have access to all of the features which will be present inside the different levels of the game and are encouraged to practice each in order to complete the level. Upon completion or the usage of the allotted time for training, players then go through the successive levels which focus on variables, lists (arrays), and if statements. In order to reach the end players must demonstrate each of the skills presented in the previous levels culminated in performing the newest skill.

Level 1: Variables

Figure 7 is an illustration of the Level 1 layout. The purpose of Level 1 was to teach the programming concept of variables. This was done by using Teleportation blocks. In this level, they develop a proficiency in the concept through repetitive practice instilling the concept of variables.

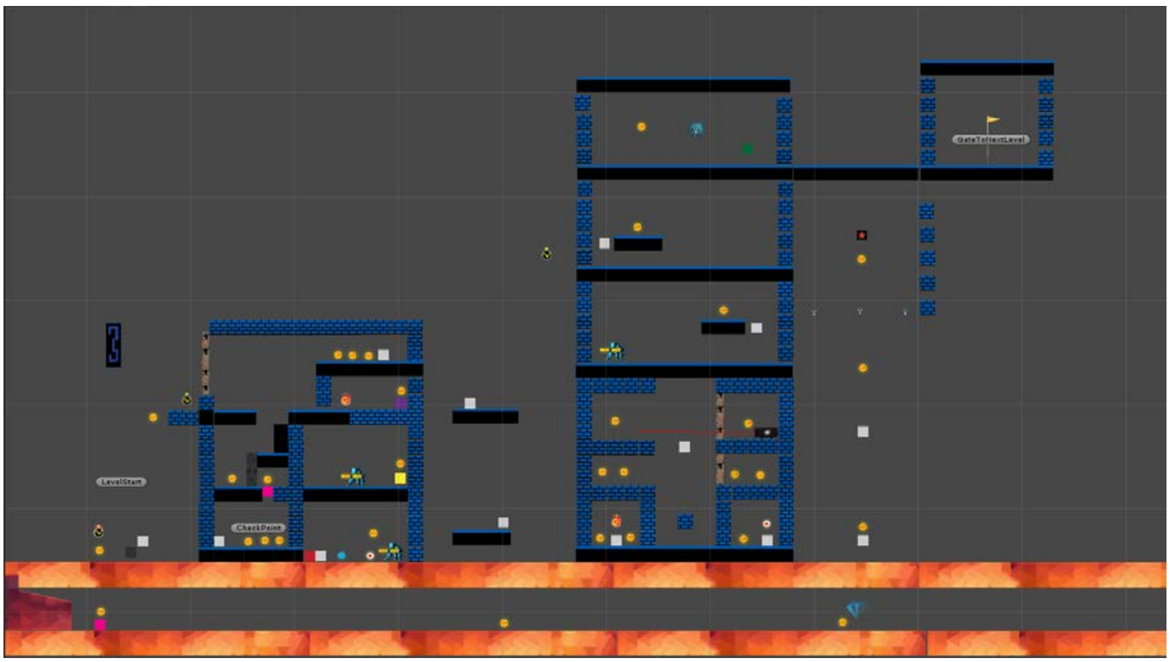

Figure 7: Level 1 Layout

Players assign data to the variable Teleport Direction via the command window, typing "Teleport Direction =…" and one of four phrases: Move Left, Move Right, Move Up, or Move Down. When finished, the code should resemble "Teleport Direction = Move Up". Players then hit Enter, and the code is executed. The visual feedback which players receive is the block's color. Depending on the direction, the white block will change color (see Figure 8; a larger version of Figure 8 can be found in Appendix B).

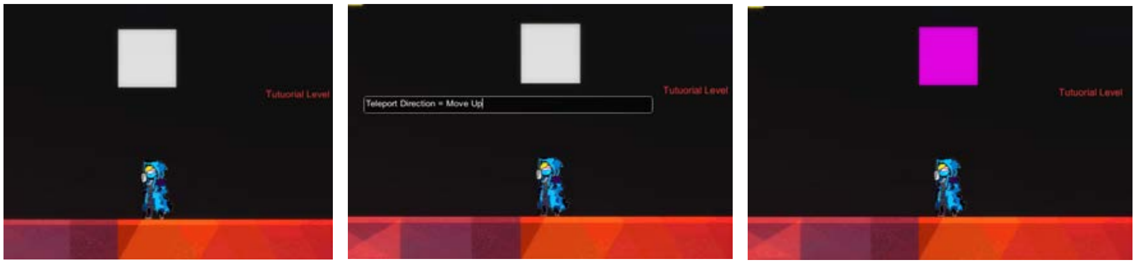

Figure 8: Teleport Block

Play begins once the unity window is opened. The player spawns to the left of the Level 1 Map. There they find the initial teleportation block. At this point the player has been instructed to collect as many yellow coins as possible and navigate to the end of the level in the 3rd tower. To get to that point, players must negotiate the level by programming the teleport blocks to transport their avatar to various locations throughout the level in order to collect coins and gain access to the 2nd or middle tower. The middle tower requires the player to program all blocks to pink in order to move to the top level of the structure. Once inside, the player needs to land on the fixed teleportation block to be transported into the 3rd Tower where the level will end.

Level 1 captures several of the design requirements mentioned in chapter 3. The female protagonist is present throughout the entire game. The mechanics of the game are not over simplified. While repetitive, the concept of the level is addressed as the variable is continuously assigned different data which changes the environment of the game. This level also has a degree of uncertainty as while the mechanics are easy to understand, the player must utilize the correct code in order to negotiate the level to reach the objective. The story is continued as the narration instructs the player to complete these levels to make it to the character Autumn. The social aspect is not present in this aspect of the game. However the degree of fun is determined in the solving of the puzzle that is this level.

The reason for the design of the structures was to have the player rely on the teleportation blocks to reach their goal. By having multiple rooms, this would force players to need to understand how to direct the blocks. The usage of permanently set blocks was to provide hints as to how players would need to progress or what they would need to accomplish. In the basement level of the structure, the permanent block is pink which sends players back to the start if the accidentally are send downwards. Also the directional arrow points towards the block providing a hint as how to get back to the main level.

Level 2: Lists

The purpose of level 2 was to introduce players to the concept of lists while simultaneously reinforcing variables and laying the ground work for If Statements. This level allows players to have practice with the concept lists and indexing in programming. Players are introduced to the concept in the tutorial and tutorial level where they have time to practice with the Ammo Coins. Ammo Coins serve as the metaphor in Level 2. They are connected to a list called Energy. Energy = [Red Energy, Blue Energy, Yellow Energy]. At various points in the game, the player needs to access a different kind of energy than the one they have in order to proceed. If they encounter a red wall they will need red energy to break it. If they encounter a blue or yellow wall they will need the corresponding energy to break it as well. In order to get the right kind of energy players must summon their command window and type in the correct index of the list energy to change their Ammo Coin to the correct type which are referenced in Figure 9.

Figure 9: Ammo Coin Icons

Energy[0] will give them red energy. Energy[1] will give the blue energy coin. Energy[2] will give the yellow energy coin. When the player's avatar collides with the coin their setgun variable will change to the corresponding color.

As players progress through Level 2 (see Figure 10; a larger version of the Figure 10 can be found in Appendix B), they begin to understand how to use the Ammo Coin and assorted energy. This serves two purposes. First, it reinforces the concept of variables as the energy type variable is associated with an in game feature. Also, players grasp the concept of a list and indexing starting from zero. The concept of indexing may be especially difficult to grasp initially as when thinking of any kind of list, they usually start with 1 instead of zero.

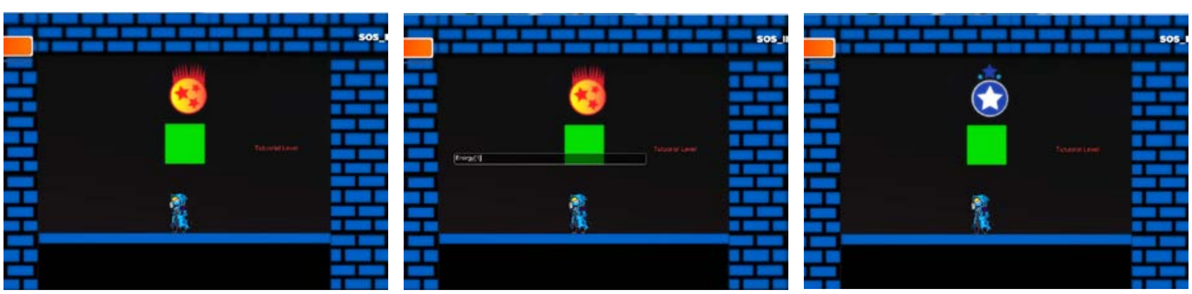

Figure 10: Ammo Coin Programming

This level addresses the design requirements of Uncertainty, Mechanics, and Fun. The social aspect is not present in this level but its residual effects may be felt in the performance of the player. There does exist a degree of uncertainty as players must understand how to use the

Ammo Coins after they disappear. While this is addressed in the tutorial, it is important for the success of the player that they remember how to use the coins in this stage. Additionally, while the mechanics seem simple, they are acurate how lists are used in authentic programming.

Level 3: If Statements

The purpose of Level 3 was to reinforce previous concepts and teach the programming concept of an If Statement. This level allows players to be able to program certain walls to be broken by any type of energy blast. The walls are black with a zigzagging line in the middle (see Figure 11).

Figure 11: Programmable Walls

The player must stand next to the wall they wish to program and type an If Statement to allow the wall to be broken by the player's current weapon. If the player was using a blue gun, they would write "If Walltype == red: setgun red will break". The variable Walltype refers to the color of the wall which they are wanting to break which is determined by the zigzagged pattern. Setgun refers to the current ammo setting for the blaster (see Figure 12).

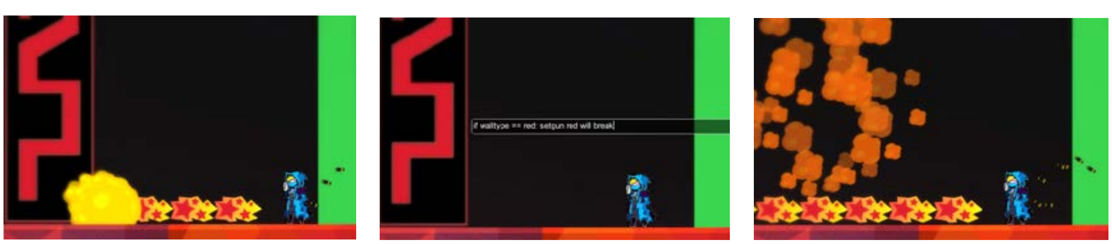

Figure 12: Programmable Wall Programming

This level (see) addresses the design requirements as it doesn't over simplify the mechanics of programming. It present authentic programming save for the code being on one line. The uncertainty in this level is less intense than the others as players know what they must accomplish. However, the player must combine all of the previous lessons learned in the game to proceed.

Like Levels 1 and 2, the social aspect is not present, but the residual effect from interaction with peers during the tutorial phase may be felt as lessons or advice may be applied. This level has a high potential for fun as players are putting all of the pieces together and moving through the game. It also allowes for the use of an ability that is not necessarily associated with the programming by using the phasing ability. The phasing ability allows players to either move through green and orange walls and temporaily be immune to enemy attacks. The narative story continues as the plyer rescues Autumn at the end of this level. This sets up the possibility of using the character Autumn in the next iteration of the game.

Implementation platform

The game is designed to run off of a flash drive with a unity executable file for each level. In the future, changes are to be made which will give the game the option of being put on a mobile device such as a smart phone or tablet. Additionally, a web based version which students can play on multiple devices is ideal.

The Unity Development Platform (Unity Technologies, 2015) was chosen for the development of the game. Unity is an open source tool cross platform game engine used to create games or interactive experiences for personal computers. Unity was specifically chosen for its large online community and provided resources. It is very flexible as it utilizes multiple languages such as Boo (similar to python), C# (pronounced C Sharp), and JavaScript. For the purposes of the project, C# was used as it has the most support online as the more widely utilized language. Unlike Game Maker Studio (GMS) (Yo Yo Games, 2015),Unity allows for development on both Mac & PCs with additional plugins or documentation for running on Linux.

Unity also allows for a degree of flexibility in comparison to the other development platforms like the Unreal engine (Epic Games, 2015) and GMS. The unreal engine is primarily 3D based with little documentation for 2D game development. As of 2014, Unity incorporated a 2D development mode which is comparable to GMS. Though it lacks the simplicity of development judge against GMS's drag and drop development, the option of 2D along with 3D viewing allows for the inclusion of 3D assets.

The Unity Development environment allows for toggling back and forth from various views, assets and game objects. It is also possible for incorporating online assets from the Unity Assets store through setting a unity account. For the purpose of the intervention development, it was necessary to utilize previously existing unity assets such as the Corgi Engine in order to build the initial implementation of the system which will be referred to as SS (Attempt 1 or SA-01).

Application of GBL principles

The game includes an aspect of narrative storytelling. During the tutorial section, players are introduced to the plot which explains the events leading to the start of the game. The narrator describes how the Sorceress has trapped the other three seasonal warriors and the only hope for rescue is the character Winter. The setting of the game is inside the first stage of a volcano as players must try to reach the end to save the character Autumn. While the plot description ends there, the hope is that through future expansion, more story can be implemented into the game as the number of levels increase.

The mechanics of programming are not oversimplified. Participates will type actual lines of code to affect the game state. While the metaphors for coding provide a measure of feedback for successful inputs, the process accurate reflects the process of writing code. Players must input the proper syntax for each coding concept to work. Players must continuously enter the proper syntax for the variable Teleport Direction. To select the proper Ammo for their blaster, players must have an understanding of how indexing works in lists. Additionally, players must understand the concept of an if statement in order to properly program a wall to be breakable.

While these tasks seem simple and repetitive, it is up to the player to understand how to use these actions within the world of the game. In doing so, the requirement of uncertainty is addressed. Within the game, players generally have an idea of what to do based on what is presented. In Level 1, users must navigate through a structure using the teleportation blocks. They must realize what direction they have to move in to reach the objective, and know what to enter into the command window the tutorial allows for players to slowly learn how to use the teleportation blocks through practice. Following this trend, all of the levels increases in difficulty as the player progresses towards to end.

SOS does not yet include a multiplayer feature allowing for competitive game play. This atmosphere of a group learning experience addressed the social aspect in a way which competitive game play could not. Also, it was in line with the concept of Game-Based Learning as it allowed the player or student to be in control of the learning process through exchanging information.

In the group sessions, students would exclaim when they discovered a new ability and show their fellow participants. If someone did not know how to do something, the concept was explained by another player.

Finally, the game possesses a fun factor as it is enjoyable to play: preliminary observation a majority of the game's players supported this claim, as students seemed to genuinely enjoy the process of game play which involved discovery.

Table 1 summarizes how the requirements developed in Chapter 2 were realized by the development of the game. Table 2 additionally summarizes how the game realizes the requirements of GBL.

Table 1:Methods that the game implements the Game requirements developed in Chapter 2.

Requirements	In Game Realization of Requirements
Female Protagonist	• The main playable characters of the game are female. • Title character/Antagonist is female as well. • Character depictions are not hypersexualized • Characters not confined to stereotypical female roles in games. • Characters perform tasks which could be done by either gender.
Narrative Story	• Presentation of story during tutorial video/level. • Continuation of story with goals in levels • Story develops further as players progress
Social/Communal	• Competition between classmates to get the highest score • Helping peers understand concepts in the tutorial phase • Comparison of performance after the game (scores)
Uncertainty	• Players encounter problems and puzzles which require strategy to overcome • Players are given several hints but ultimately must figure out puzzles for themselves • Exploration needed in order to understand environment
Mechanics of Game Play	• Command Window allows for simulated programming • Programming is authentic to actual python but simple enough to master. • Application of in game metaphors serve as hints but do not take away from programming in python
Fun or Enjoyable Experience	• Pacing of game, ability for in game discover. • Positive atmosphere/feedback • Aesthetics of game favorable to target audience

Table 2. Methods that the game implements with the GBL requirements of Prensky, 2007

Principles	**GBL Design Elements Addressed in Game**
Rules (how the game is played)	• How the game is played: • Addressed by Mechanics, Uncertainty, and Story
Goals and Objectives	• Goal of game to teach and reinforce fundamental concepts • Students learn each concept in tutorial and practice in the game • Players overcome challenges by applying concepts • repeat until concept to pass to next level • Addressed by Uncertainty
Outcomes and Feedback (measuring progress)	• When players input code into the command line they either change the environment or receive error feedback similar to a complier. • Addressed by Story, Experience, & uncertainty
Conflict/Competition/Challenge/Opposition (problems player is trying to solve)	• Competition is not in the game but in learning environment • Players can replay levels to look at their own improvement • Players are met with challenges preventing their success • Players overcome these challenges and build confidence comprehension • Addressed by Uncertainty
Interaction	• Players interact with the game • Players with other Players (outside of the game, comparison of success)
Representation or Story	• The gameplay is set in a narrative story to frame structure • Addressed by the games Story

CHAPTER V

EXPERIMENTAL METHOD

An Institutional Review Board (IRB) approved evaluation of the GBL SOS was conducted with middle school students (see Appendix C).

Research Objectives

The objectives of this research is to determine if GBL can increase knowledge and interest of Computer Science if the characteristics of the game reflect the preferences of its target demographic. Also, this study will attempt to determine if providing a realistic coding experience increase student's interest in STEM, specifically CS related careers.

Hypothesis

The hypothesis of the study is as follows:

1. Interest in STEM will increase when comparing before and after opinions of Middle School students after they play an educational game designed with their preferences in mind which teaches concepts of python programming.
2. Female students' attitudes and interests in CS will increase greater than male students after playing the game Sorceress of Seasons.

Participants

These students who participated in the study are representative of the target age range for potential users as they are between 10 and 14. The participants of the study were 15 middle students from a private school in Des Moines, Iowa. Eight of the students were male and seven were female. The distribution across grades is described in Figure 13 with a majority of students being in the fifth grade.

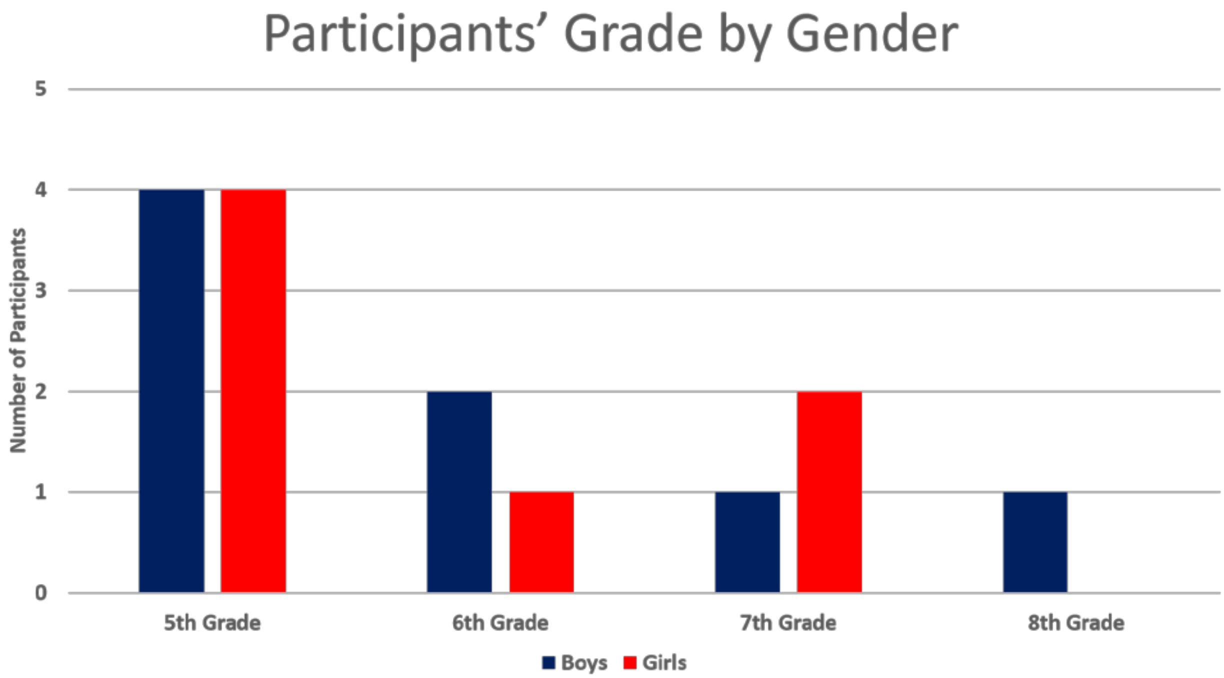

Figure 13: Grade Distribution

The participants identified themselves as having programmed before and their level of expertise. 14 of the 15 participants answered and half indicated that they had previously programmed. For perceived skill, six indicated that they did not have any expertise. Seven identified as beginners. Two students identified their skill level as intermediate.

Tasks / Scenarios

Participants were asked to watch a tutorial and play the SOS game.

Tutorial. Participants watch a 15 minute tutorial video which was displayed via projector from the experimenter's laptop. The video served three purposes: 1) introducing three programming concepts, 2) introducing the story of the game, and 3) showing players how to play the game. The tutorial video uses combination of PowerPoint slides and captured gameplay with narration from one of the three narrators. The first narrator is the story teller, the 2nd is the tutor, and the 3rd serves as the games technician. The story teller introduces students to the story of the game explaining their character's backstory and motivation. The tutor succinctly explains the concepts of variables, lists, and if statements in python. Additionally, the tutor provides examples for the concepts in ways students can relate to as well as make the connection from the concepts being taught to the elements of gameplay. Meanwhile, the technician demonstrates elements of game play and how the game is played.

Game Play. Participants are given approximately 10 minutes to play through a tutorial level in order to practice with the controls of the game prior to playing the actual game. This level was open world allowing for experimentation and was not structured. Players practiced using the basic controls such as arrow keys, jumping and shooting along with special abilities such as phasing. Players also had an opportunity to practice with use of the command window. They could use the Teleportation Blocks, Ammo Coins, and Programmable Walls to build familiarity.

Dependent Variables

The dependent variables of the experiment are described in Table 2 which include requirements verification, STEM attitudes, performance, workload, and game assessment.

Table 3. Dependent Variables

Dependent Variable	Metric	Data Type	Frequency
Requirements Verification	Survey questions	Likert Scale (1-5)	Pre-Experiment Post-game
STEM Attitudes	Interest in programming (1 questions)	Likert Scale	Pre-Experiment Post-Game
	Career interest (2 questions)	Likert Scale	Post-Game
Performance	Assessments (3 areas)	Percentage (0-100%)	Pre-Experiment Post-Tutorial Post-Game
Workload	NASA TLX (6 sub-scales)	Rating (0-20)	Post-Game
Game Assessment	Surveys (2 question)	Likert Scale (1-5)	Post-Game

Requirements Verifications

Requirements verification refers to the application of the six game design requirements based on participants' responses to question 10.1 to10.9 on the Pre-Experimental Survey and questions 1.4 to 1.14 on the Post-Game survey (see Appendix A). Questions addressed each specific requirement with participants providing their opinions about the requirements' importance through Likert scale questions ranging from 1-5 (with 1 being strongly disagree and 5 being strongly agree). These Likert scale questions were developed using a similar format to the MISO survey's questions 1-3 (Friday Institute, 2014). The Pre-Experimental survey questions were (with relevant requirement in parenthesis, included here but not in survey):

- Question 10.1: The gender of the protagonist does not matter (Protagonist)
- Question 10.2: It is important to have a female protagonist in a game (Protagonist)
- Question 10.3: It is important to have a male protagonist in a game (Protagonist)
- Question 10.4: I enjoy a game that has an interesting story/narrative (Narrative)
- Question 10.5: I enjoy a game with a developed plotline/story (Narrative)
- Question 10.6: I like games that have puzzles (Uncertainty)
- Question 10.7: I like games that are challenging (Uncertainty)
- Question 10.8: The best games make me want to play for long periods of time (Fun)
- Question 10.9: I like games which I can interact with friend/other players (Social)

The Post-Game Survey on influence of requirements were (with relevant requirement in parenthesis, included here but not in survey):

- Question 1.4: Your character's gender effected interest (Female Protagonist)
- Question 1.5: The game's story made you want to play the game (Narrative)
- Question 1.6: The game had puzzles that were fun to figure out (Uncertainty)
- Question 1.7: You found the game to be challenging but not too hard (Uncertainty)
- Question 1.8:You were interested in playing the game for most of the allotted time (Fun)
- Question 1.9:You were interested in playing the game for the allotted time (Fun)
- Question 1.10:You would have liked to play the game with friends (Social)

- Question 1.11:You would have liked to have more hints or help within the game (Mechanics)
- Question 1.12:The game was too difficult to understand (Uncertainty)
- Question 1.13: You would consider this game fun to play (Fun)
- Question 1.14: I would recommend this game to my friends (Social)

STEM Attitudes

STEM attitudes refers to students opinions about computer science or programming related careers. After the study, participants were asked about their opinions during the post-game survey in questions 11.1 and 11.2 (See Appendix A). Both questions were developed based on the format of Likert scale questions used throughout the MISO survey (Friday Institute, 2014).

- Question 11.1: Your opinions about Computer Science, Computer Engineering, or Programming changed after playing the game
- Question 11.2: After playing the game, you are more likely to consider a career which uses programming

The post-game survey questions were presented exclusively at the end of the experiment. This was done to avoid the *question order effect* which suggests that initial questions may alter the context in which later questions are perceived, and may influence the answers (Schuman & Presser, 1981). Thus participants were only asked about their change in attitudes during the post-game survey, rather than the more traditional comparison of pre-trial and post-trial answers. If participants were asked about their interest in STEM careers before and after the game, they might discern the goal of the study and change their response in an effort to unconsciously assist the researchers in achieving a desired outcome.

This methodology has limitations as well as it depends on a student's ability to assess their own change in attitudes, and may be subject to the "halo effect", where students self-reported gains may be inflated by biases in the student's judgement (Pike, 1999).

Performance

Performance is determined through assessment questions within the pre-experiment, post-tutorial, and post-game surveys. Variables, lists, and if statements are assessed through nine questions on each of the surveys. Three of the questions asked about variables, four questions asked about lists, and two question asked about if statements. An additional question asks participants to define programming. Participants provide answers and then were graded after the scores are calculated. They were scored based on their performance within the three learning concepts as well as overall score that was an aggregate of all performance questions.

The concepts are addressed either through individual questions focusing on a specific concept or an integrated question. The integrated questions address all concepts but are scored by individual concepts. An example of an integrated question is shown in Figure 14.

6. Using the following statement, write a variable, list, and if statement:

Mike plays baseball, basketball, football and tennis. He plays team sports (basketball, football and baseball) throughout the year. Mike plays Football in fall, basketball in winter, and baseball in the spring. He only plays tennis in the summer.

Figure 14: Example Question

The purpose of this question was to assess participants' ability to apply programming logic to real world examples. It was created from referencing the books *Python for Kids: A Playful Introduction to Programming* (Briggs, 2013) and *Beginner Python: The Least You Need to Know (*Hayes, 2014) which focus on teaching python to students. These books simplify programming and use terminology that is appealing towards students. Specifically, Briggs' approach to terminology was utilized in the development of survey questions (Briggs, 2013).

Workload

Workload was measured via the NASA Task Load Index (TLX) (Hart & Staveland, 1988). The NASA TLX has six subscales, each rated from 0-10: mental demand, physical demand, temporal demand, performance, effort, and frustration.

Game Assessments

Game assessments were determined through Likert scale questions during the post-game survey. Participants rated their perceived effectiveness of the tutorials effectiveness and ease of use. Additionally, students rated the game's ability to teach concepts.

Procedure

Participants were presented with the game SOS as part of an experiment. In the parental consent form, parents were told that the purpose of the study was to determine if GBL would effectively teach practical programming to middle school students, and if the game would improve attitudes and interest towards STEM. In the child assent form, the purpose of the experiment was presented as an evaluation of how students would perform in school programs in school subjects if subjects were presented like a video game. The evaluation was conducted over two sessions as shown in Figure 15. There was one week between session 1 and session 2. Students were not specifically told how evaluations between male and female performance would be conducted.

Figure 15: Experimental Timeline

Participants began Session 1 after giving assent. They are given a Pre-Experimental Survey consisting of 19 questions which they have 20 minutes to complete. This survey asks about the students' demographics, their perceptions of CS and assesses their prior understanding of the concepts which will be taught. Before completing the actual NASA Task Load Index (TLX) Survey, students have an opportunity to practice completing one after the Pre-Experimental Survey. Students are provided with an example of the survey and informed how to fill it out correctly. Participants conducted the tutorial. Immediately after the tutorial session ended, participants were given the tutorial quiz to finish in 10 minutes. This consisted of six questions which only address the concepts of programming taught in the tutorial. This concluded the first session.

At the beginning of Session 2, students are reintroduced to SOS with a live demonstration by the experimenter which lasts approximately three minutes. The experimenter's laptop is hooked up to a projector and they demonstrate the game controls. The experimenter also demonstrates use of the command window and special abilities. Then participants were allotted 30 minutes to play through the game. If students reach the end of a level, their screen freezes and they are told to ask for the experimenter to come over and start them on the next level after recording their score. When time expires, students are instructed to pause their game, write down their score, and follow procedure similar to the end of levels before transitioning to the Post-

Game Survey. Participants completed the 19 question Post-Game Survey. This survey assesses their attitudes about programming as well as their thoughts about the game. The survey also asks questions to test students' comprehension of concepts taught in the game and compare their scores to previous assessments. This completed second session.

Limitations and Assumptions

Due to the involvement of minors, special care had to be taken with this experiment. The amount of time which could be students could participate was limited. Thus, access to students was determined by parents and the school which resulted in using a three session format. This allowed for flexibility with the school and parents. However, the gap between the Session 1 and Session 2 may have affected the results of the Post-Game Survey. If the experiment could have been conducted in one continuous session, or the sessions were ran two days in a row results might have been better.

Also, the fact that this was conducted at a Private School may have had an effect on the performance results. Some students indicated having taken advanced classes or even previous exposure to programming. The results are not reflective of a diverse sample size.

Testing Environment

The experiment took place in a classroom at the participants' school on two separate sessions one week apart. It was conducted immediately after the school day in parallel to the students' normal after school activities. Each of the participants was seated at a traditional school desk and used a laptop running either an Apple or Windows operating system. A flash drive was provided with a unity executable file which contained the game. Students were also provided with a printout of slides from the tutorial video which they could refer back to during the game but not during assessments.

A teacher from the school that the students were familiar with was present for the entirety of the experiment. The school's principal was present for the last 30 minutes of first session.

Data Analysis

Data analysis was conducted using ANOVAs and Tukey tests. A 1x3 ANOVA was used to assess performance between pre-experiment, post-tutorial, and post0game surveys. A 2x3 ANOVA's was conducted for gender comparisons across the same three surveys. Student's t-tests were used to check for significance between genders in the pre-experiment and post-game survey questions that asked about the influence of the requirements. Likewise, Student-s t-tests were performed for differences between genders for the change in reported STEM attitudes. In all cases, significance of data was determined by alpha values under 0.1. Values ranging from 0.05 to 0.1 were categorized as marginally significant while values below 0.05 were categorized as being significant.

CHAPTER VI

RESULTS

This section describes the results from the GBL study. The Influence of the presented GBL design requirements are compared between the 15 participants through survey data.

Requirements Results

Baseline Student Opinion on Requirements

Figure 16 presents a comparison between genders for each of the pre-experiment questions on the reported influences of requirements. There were no significant differences found for any of the questions.

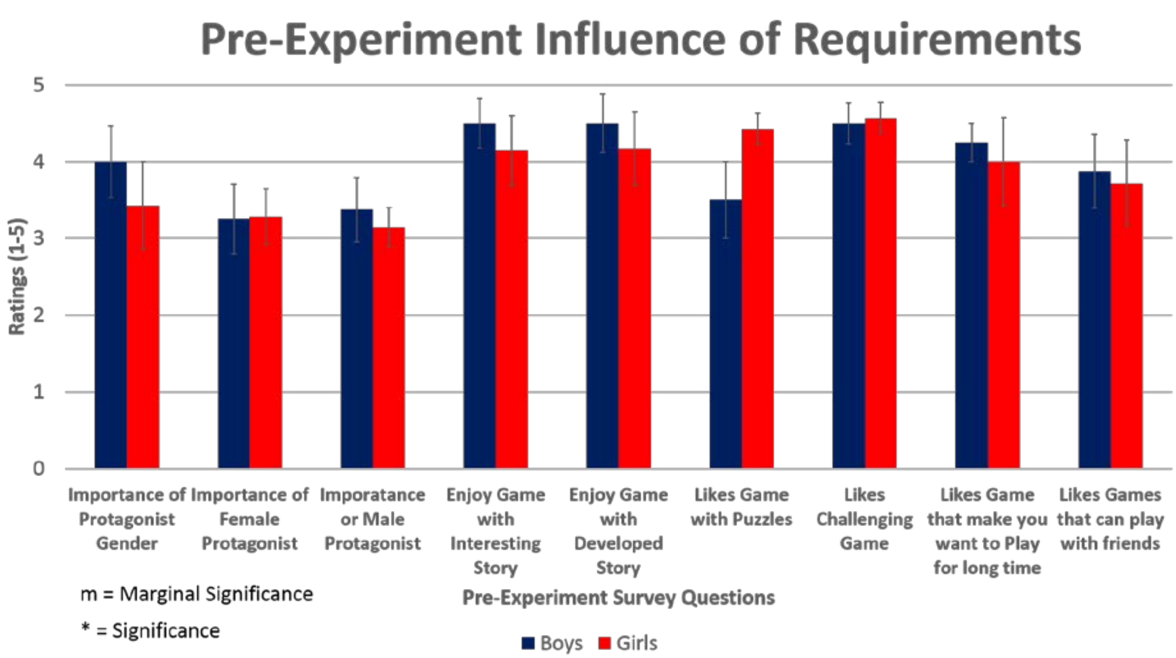

Figure 16: Pre-Experiment Influence of Requirements (n = 15). The error bars represent standard error.

Gender Requirement. The Gender of the main protagonist was relevant to the participants. The Likert scale scores showed that students across both genders had similar views reporting a high interest. Males did have an average of 4.0 (SE= 0.46) suggesting that the gender of the main character mattered; while females averaged a score of 3.42 (SE= 0.57) and the gender mattering as well. The questions regarding the importance of a female or male character were also relatively even. Both males and females rated the importance of a female protagonist similarly (males: M=3.25, SE=0.45; females: M=3.28, SE=0.35). However, males placed a slightly higher importance for having a male character (M= 3.37, SE=0.41) than females (M=3.14, SE=0.26).

Narrative Requirement. Participants were asked if they enjoyed a game with an interesting and developed story. Both gender averages were high for the story requirement with males posting a higher average than females in both categories. For interesting story males had an average of 4.5 (SE= 0.32) while females averaged 4.14 (SE =0.26). For a developed story, males averaged a 4.5 (SE= 0.37) while females had an average of 4.16 (SE= 0.47).

Uncertainty Requirement. The requirement of uncertainty addressed in the game is was assessed through questions about game aspects. Females post a higher average of 4.42 (SE= 0.2) for favoring games which had puzzles while males posted an average of 3.5 (SE= 0.5). For the question of preference with challenging games, both males (M= 4.5, SE= 0.26) and females (M= 4.57, SE= 0.2) posted relatively high averages.

Social Requirement. The social aspect was addressed in the question which asked about students' preferences for playing games with friends. The overall consensus leaned towards students agreeing as both males (M= 3.88, SE= 0.47) and females (M= 3.71, SE= 0.57) scored relatively the same.

Fun Experience Requirement. Both males (M= 4.25 SE=0.25) and females (M= 4 SE= 0.57) tended to agree with wanting games to encourage long periods of play. They also indicated liking games which they could play with friends (males: M= 3.88, SE= 0.48 and females: M=3.71, SE= 0.57).

Post-Game Influence of Requirements

Figure 17 depicts the Post-Game Influence of the requirements upon students. The main effect of design requirements was significant (t (11.96) = -2.18, p = .049) for the puzzles question. The effect of design requirements on gender was marginally significant (t (7.68) = -2.12, p = .068) for the desire to play with friends question. Marginal significance (t (12.87) = -0.99, p = .067) for the hints question.

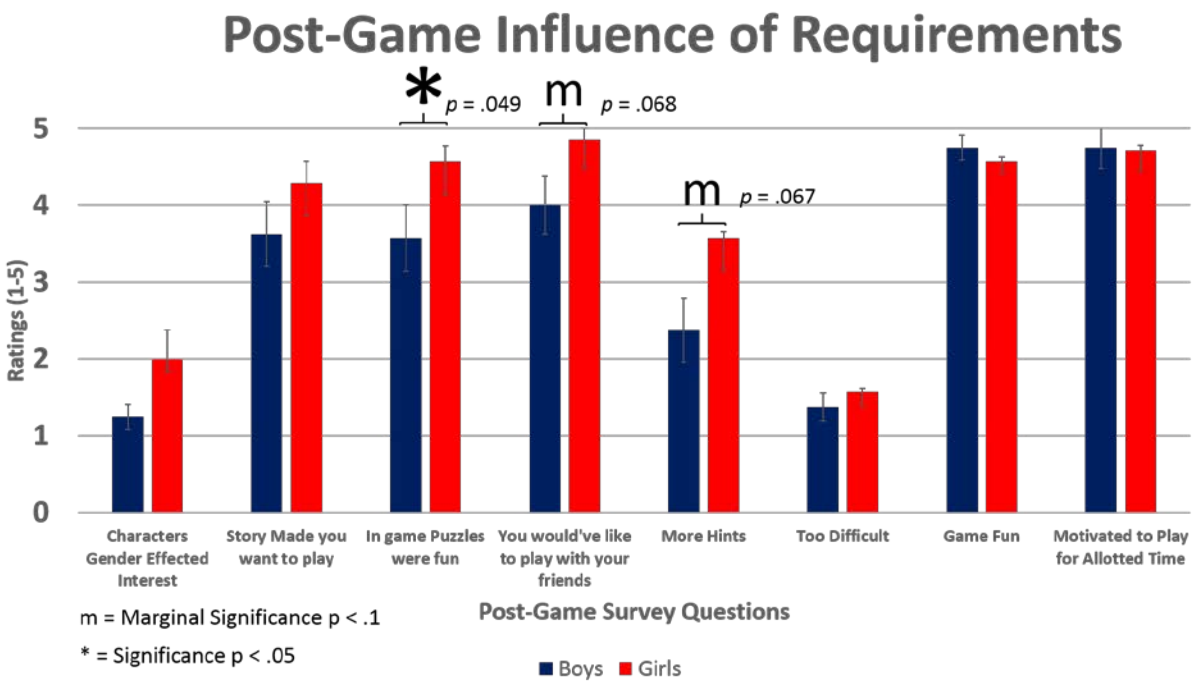

Figure 17: Post-Game Influence of Requirements (n = 15) .The error bars represent standard error.

Gender Requirement. The students indicated that the character's gender did not have an effect on their interest in playing the game with averages of 1.25 for males (SE = 0.16) and 2 for females (SE= 0.38).

Narrative Requirement. Females scored higher on a question about the story motivating them to play more (males: M = 3.63, SE = 0.42 and females: M = 4.29, SE = 0.29).

Uncertainty Requirement. Participants reported that the game was not too difficult with low averages on Likert scale responses (males: M= 3.57, SE= 0.41 and females: M= 4.57, SE= 0.2). However, students also responded to the game was challenging (males: M= 4.13, SE= 0.42 and females: M = 3.85, SE = 0.2).

Mechanics Requirement. To determine if mechanics were effective, a question about in-game hints was included. Males reported not needing hints while females indicated that more hints would be helpful (males: M = 2.38, SE = 0.41 and females: M = 3.57, SE = 0.08).

Social Requirement. In response to the wanting to play the game with friends, both males and females responses indicated agreement. Females responded with a higher preference towards playing the game with friends (males M = 4, SE = 0.26 and females: M = 4.43, SE = 0.07)

Fun Requirement. Females recorded high responses to the game's puzzles being fun (M= 4.57, SE = 0.2), while males also agreed but to a lower degree (M = 3.57, SE = 0.43). Both genders were motivated to play for the allotted time (males: M= 4.75, SE = 0.26 and females: M= 4.71, SE = 0.07) and found the game to be fun as they recorded high responses (males: M= 4.75, SE= 0.16 and females: M = 4.57, SE = 0.06).

Performance

Figure 18 presents results of performance on the surveys taken by all participants. Participants displayed the lowest level performance on the Pre-Experimental Survey. The highest level of performance was displayed on the Post-Game Survey. However, the highest increase was shown between the Pre-Experiment and the Post-Tutorial Survey.

Overall Performance

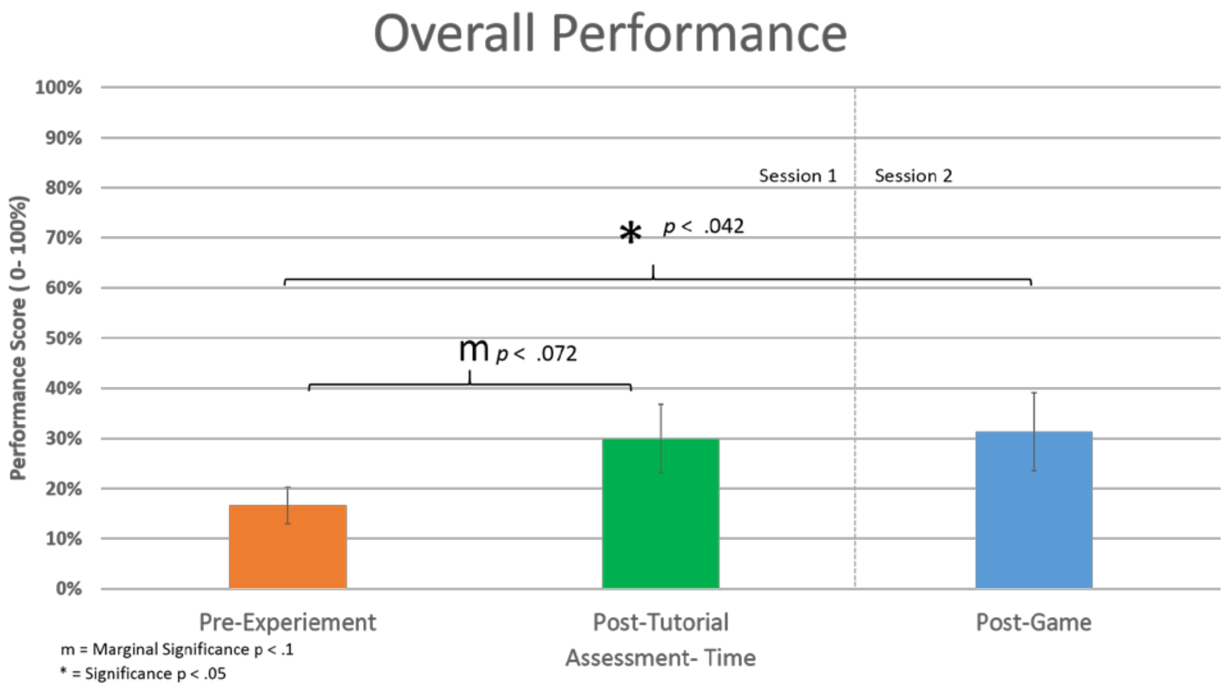

Figure 18: Overall Performance (n = 15) The error bars represent standard error.

Figure 19 displays performance across the 3 concepts. The main effect of the assessment-time was significant (F (2,26) = 3.7, p = .037).The Post-hoc analysis showed that there was a marginally significant increase (p = .072) in score from the Pre-Experiment (M=16, SE = 6.29) to the Post-Tutorial Survey (M =30, SE = 6.29). There was also a significant increase (p = .042) in performance from the Pre-Expierment (M = 16, SE = 6.29) to the Post-Game Survey (M = 31.33, SE = 6.21).

In contrast, the performance during the Post-Game tutorial is lower than the Post-Tutorial within Variables and Lists. If Statements follows the trend of increases in succession with the largest increase coming After the Post-Game Survey instead of the Post-Tutorial.

Performance was also measured across all three concepts. The main effect of the assessment-time was significant (F (2, 28) = 3.83, p = .033) for the variables concept. The Post-hoc analysis showed that there was a significant increase (p = .033) in score from the Pre-Experimental (M=19.8, SE = 7.64) to the Post Game Survey (M = 44.13, SE = 7.64). The main effect of assessment-time was significant (*F* (2, 28) = 5.09, p = .013) for the if statements concept. Post-hoc analysis showed that there was a marginally significant increase (p = .072) in score from the Pre-Experimental (M = 3.33, SE = 7.16) to the Post-game survey [M = 30, SE = 7.16]. No significance was found for the lists condition.

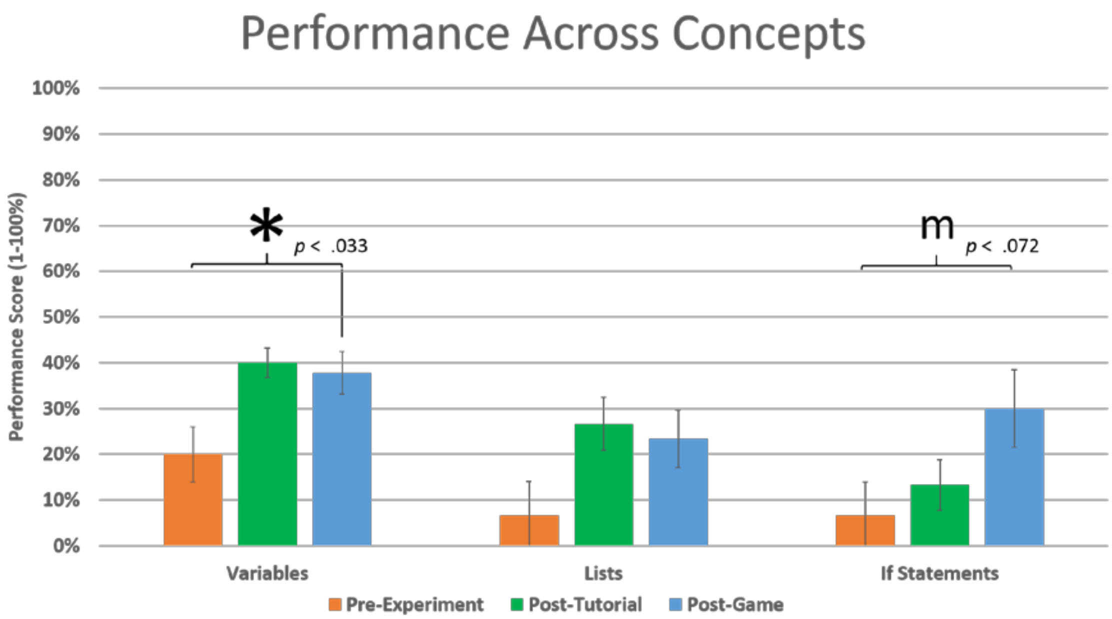

Figure 19: Performance across Concepts (n = 15). Error bars represent standard error.

Overall Performance by Gender

Figure 20 provides a comparison of overall performance by gender. There was not any significance for overall performance across gender. In the Pre-Experimental setting males scored 19% (SE= 0.03) while females scored 14% (SE = 0.06). However when participants were tested again during the Post-Tutorial Quiz, females scored 33% (SE = 0.11) out performing males who scored 28% (SE = 0.08). This trend held true once again during the Post-Game Survey as females scored 33% (SE = 0.12) while males scored 30% (SE = 0.1).

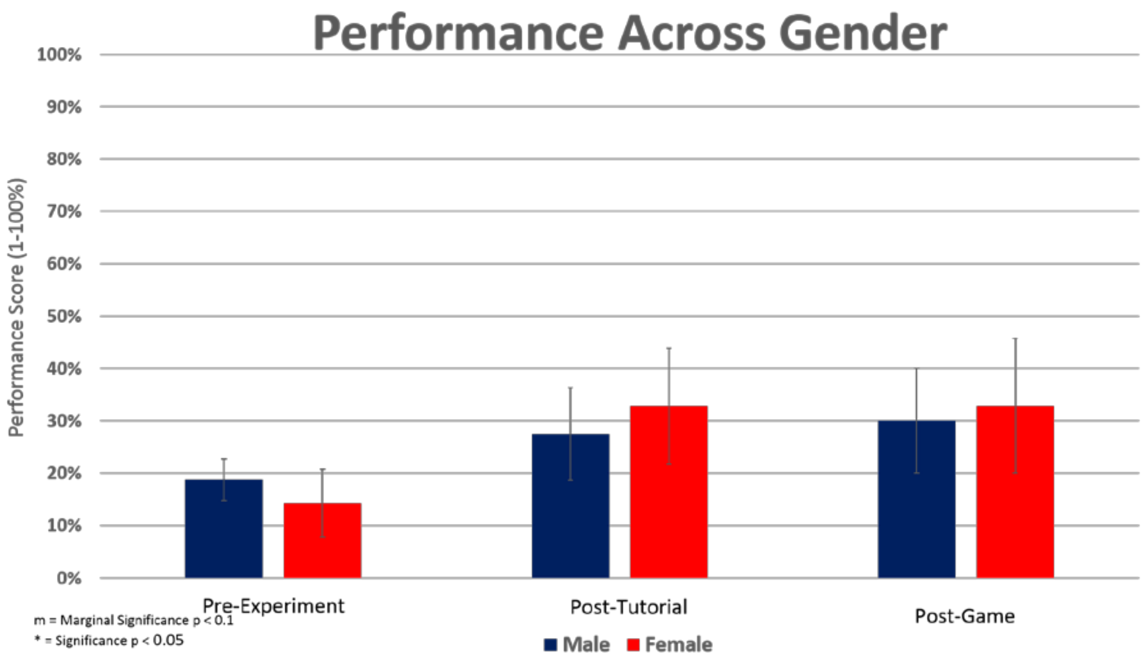

Figure 20: Performance across gender (n = 15) Error bars represent standard error.

Performance by Programming Concept

Figure 21 describes participants' performance in the concept of variables. There was not significance in the variables concept. Males scored 25% (SE = 0.9) while females scored 14% (SE = 0.07) during the Pre-Experiment. However, after the tutorial quiz, females performed higher at 52% (SE = 0.11) while males scored 29% (SE = 0.94). Although, in the Post-Game Survey performance was relatively the same with males scoring 38 % (SE = 0.1) and females scoring 38% (SE = 0.1). There was not any significant interaction between assessment-time and gender. Post-hoc analysis showed that there was a marginally significant increase (p = .081) from the pre-experimental (M = 19.45, SE = 7.68) to the post-tutorial survey ([M = 40.5, SE = 7.68) for female participants.

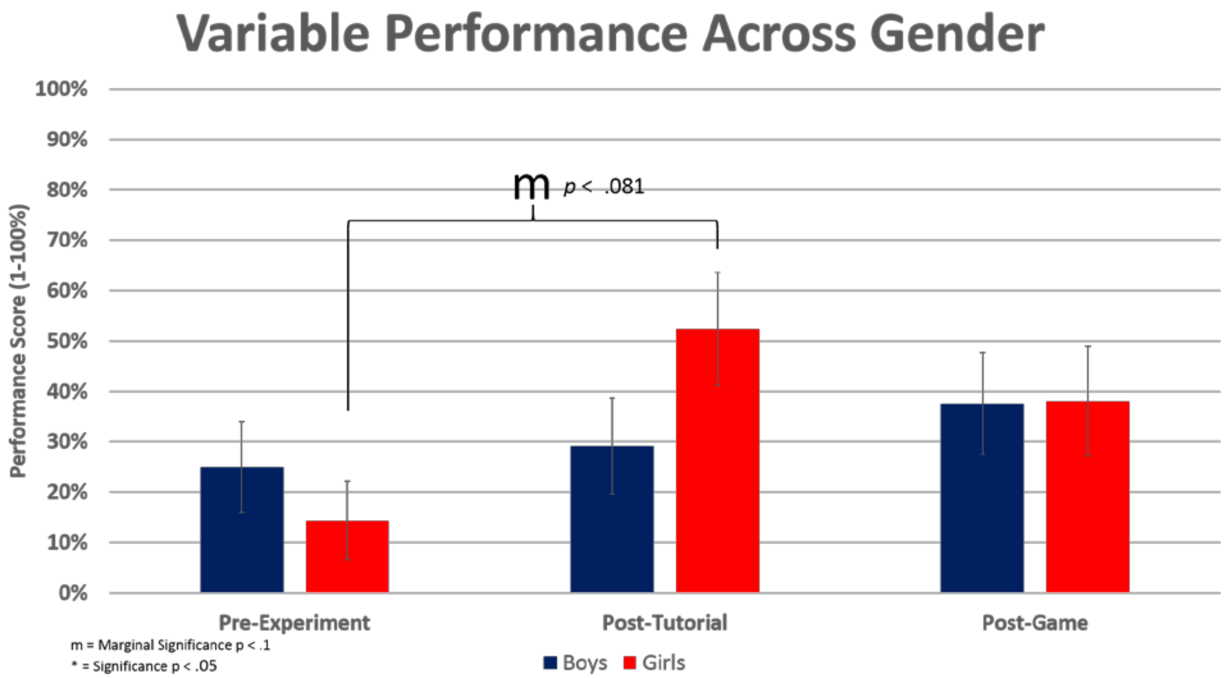

Figure 21: Performance across genders for Variables (n = 15) Error bars represent standard error.

Figure 22 describes the performance of lists through the three phases of the study. There was not any significance for this condition. In the Pre-Experimental Survey, students performed around the same level with males scoring 6% (SE = 0.5) and females scoring 7% (SE = 0.05). Like the Variables concept, females scored 36 % (SE = 0.09) and males 19% (SE = 0.07) during the tutorial quiz. After the Post-Game Survey, female students scored 29 % (SE = 0.08) compared to males who scored 19 % (SE = 0.07).

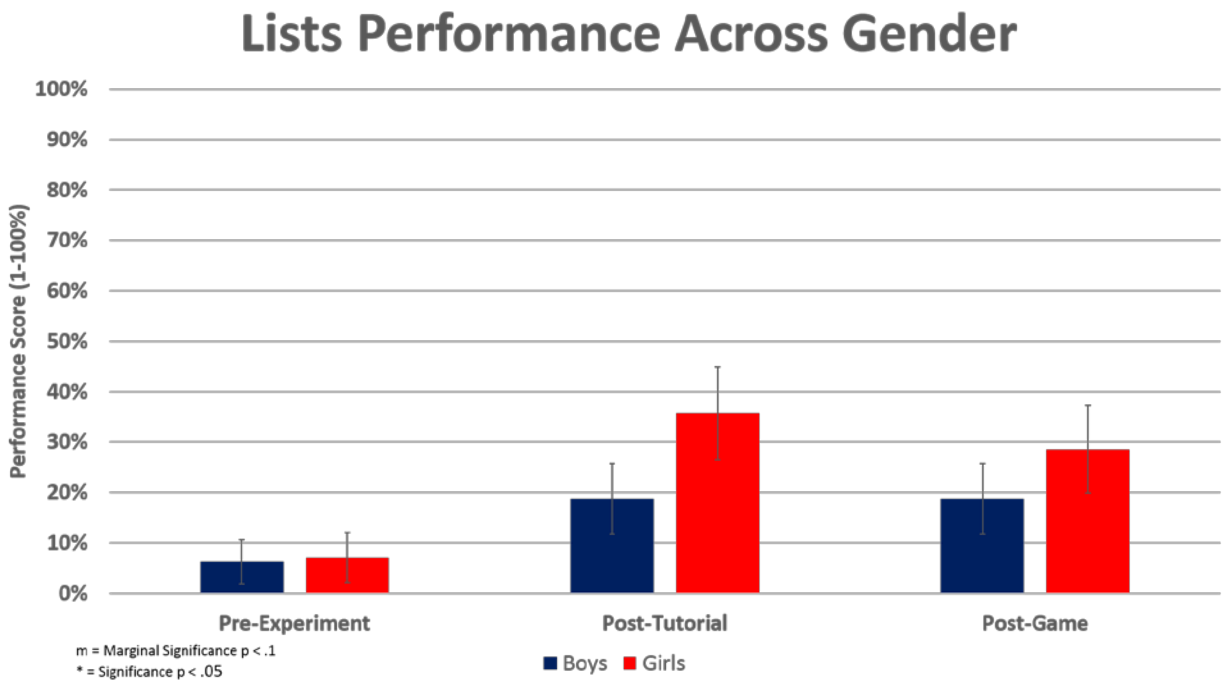

Figure 22: Performance across gender for Lists (n = 15) Error bars represent standard error.

Figure 23 focuses on the students' performance with if statements. There was not significance in this condition. Females scored 14% (SE= 0.09) while males scored 0 % (SE= 0) during the Pre-Experiment Survey. Males scored 13 % (SE= 0.09) performing slightly below females who scored 14 % (SE= 0.09) during the post-tutorial. Males scored 31 % (SE= 0.12) and performed better than females who scored 29 % (SE=0.13) during the Post-Game. Significance was not found within the lists or if statements condition.

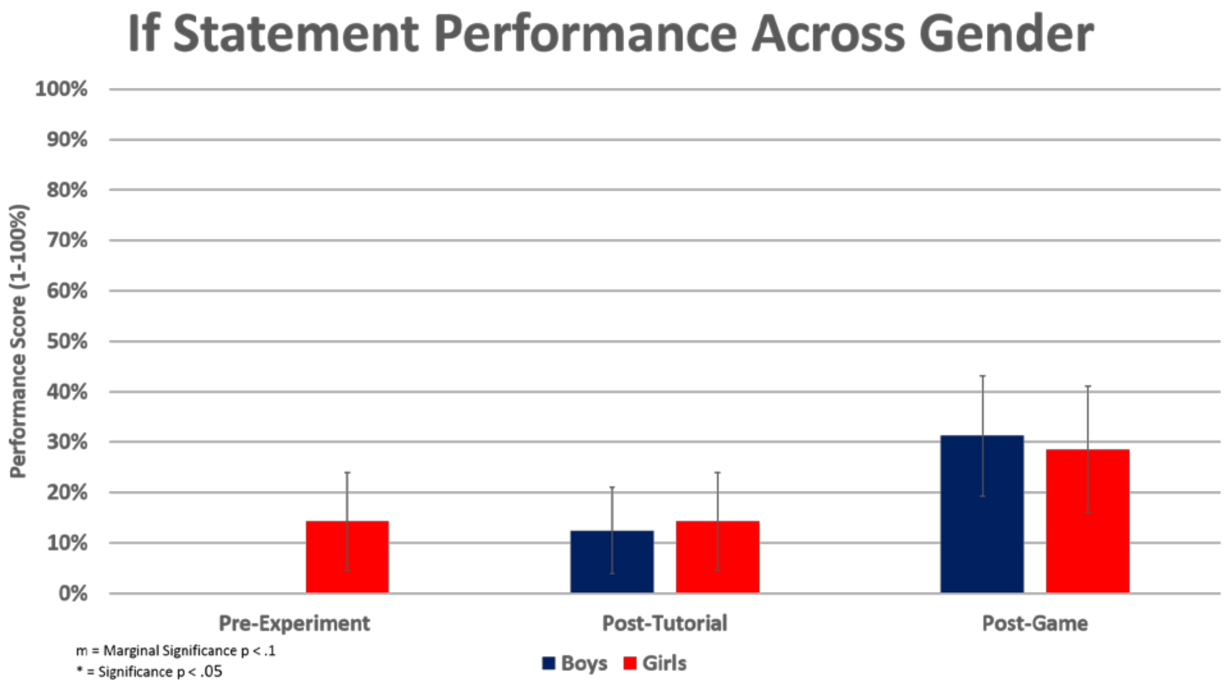

Figure 23: Performance across gender for If Statements (n = 15) Error bars represent standard error.

Workload

Figure 24 describes results from the NASA Task load Index Survey (TLX) immediately after the end of gameplay. Significance was not found for workload. Their perceived workload is visualized in Figure 23. Students indicated levels of mental (M = 10.5, SE =0.37), temporal (M = 9.14, SE = 0.43), and effort (M = 12.8, SE = 0.41) as requiring the most workload while playing the game. Physical (M= 3.21, SE= 0.19), performance (M= 7.21, SE= 0.29), and frustration (M= 6.4, SE=0.39) were lower than those. The average of scores was 8.21 (SE = 0.69) for all of the participants.

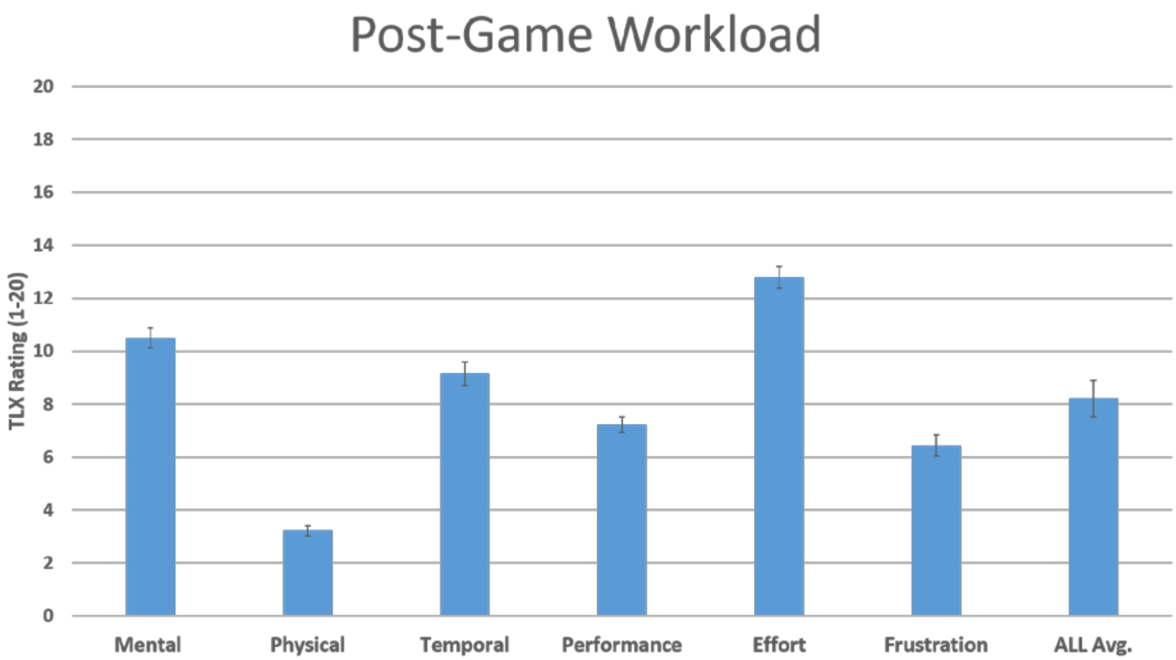

Figure 24: Post-Game Workload Ratings with Averages (n = 15) Error bars represent standard error.

STEM Attitudes

Change in opinion after Game experience

Figure 25 displays students' responses about whether or not their preexisting opinions about CS related careers changed and if they were more likely to enter into a STEM field such as CS after having played the game. Students, indicated that their opinions had changed (M= 3.36, SE= 0.29). Also, students indicated that they were more likely to consider a career in CS or a related field (M= 3.71, SE= 0.3).

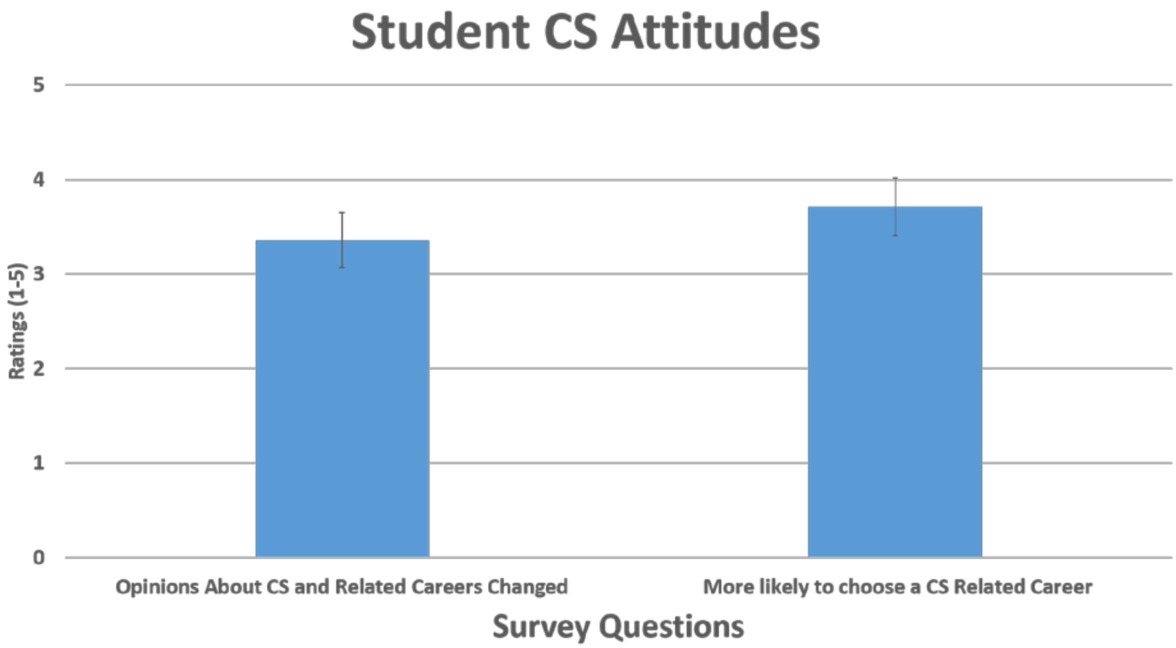

Figure 25: STEM & CS Attitudes (n = 15) Error bars represent standard error.

Figure 26 compares these findings between males and females. Female students had a higher response (M= 3.5, SE = 0) of opinions changing about CS and related fields compared to males (M= 3.25, SE = 0.37). Females (M= 4.17, SE= 0.08) also indicated that they were more likely to choose a CS related career field which was greater than males (M = 3.38, SE = 0.41). There was not significance for these survey questions.

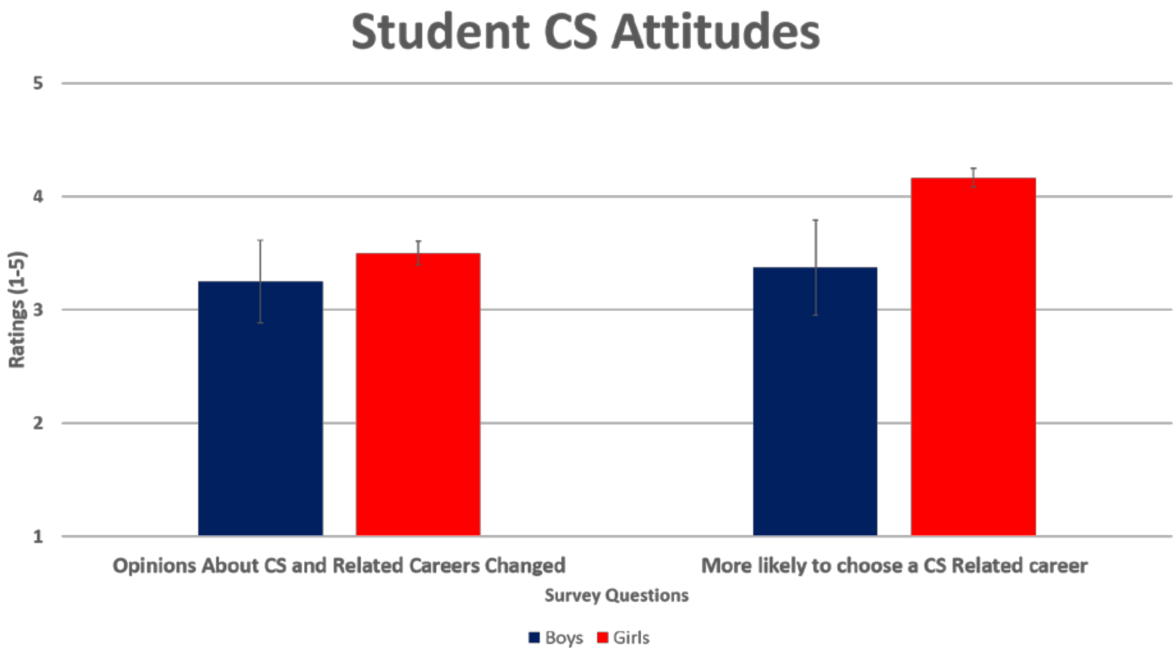

Figure 26: Post-Game Gender STEM & CS Attitudes (n = 15) Error bars represent standard error.

Desire to Learn about Programming

Figure 27 presents results about students desire to learn about programming. Students presented a strong desire to learn about programming from the start with males and females rating their desire very similarly (males: M=5, SE=0 and females: M=4.71, SE= 0.06). Students left still maintaining a high desire to learn about programming (males: M= 4.88, SE= 0.13 and females: M=4.71, SE= 0.04). Specifically females had higher responses about having a desire to change career fields in CS. There was no significance between genders for the desire to learn about programming.

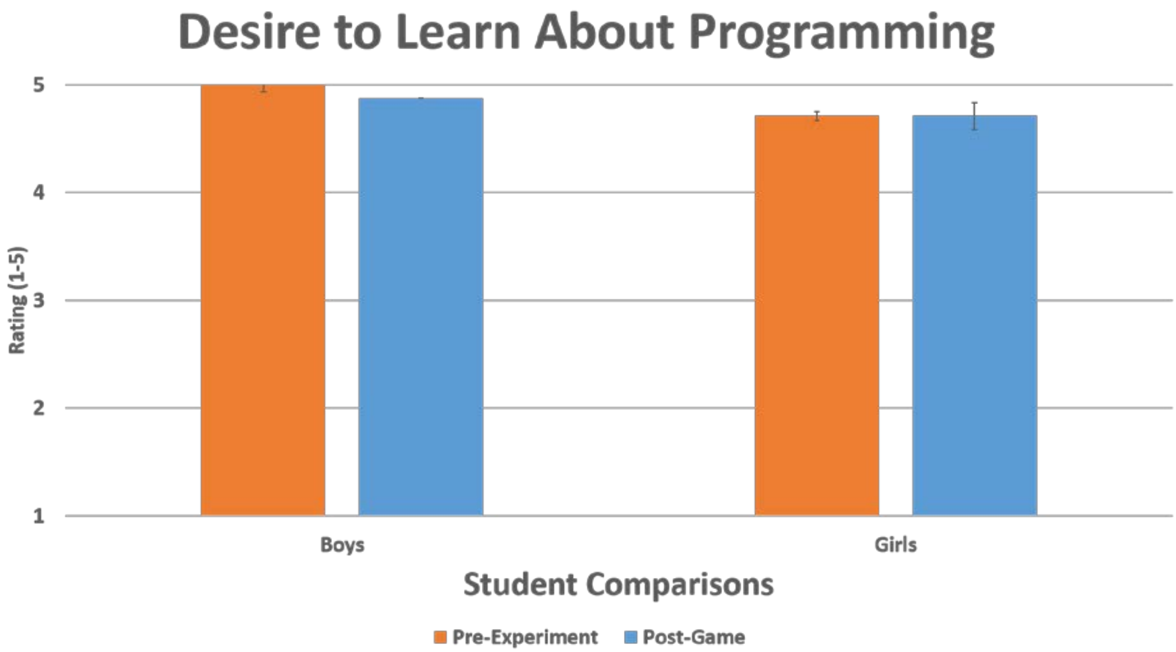

Figure 27: Desire to Learn About Programming (n = 15) Error bars represent standard error.

Feedback on Game

Figure 28 shows feedback which students provided about the game and the tutorials. Both males and females seemed to be near consensus in agreeing that the game helped them learn about programming (males: M= 4.5, SE = 0.19 and females: M = 4.14, SE = 0.08). Additionally, students reported that they understood the tutorials (males: M = 4.38, SE = 0.26 and females: M= 4.14, SE = 0.05) and the tutorials helped with learning programming (males: M = 4.38, SE = 0.26 and females: M = 4.29, SE = 0.03).

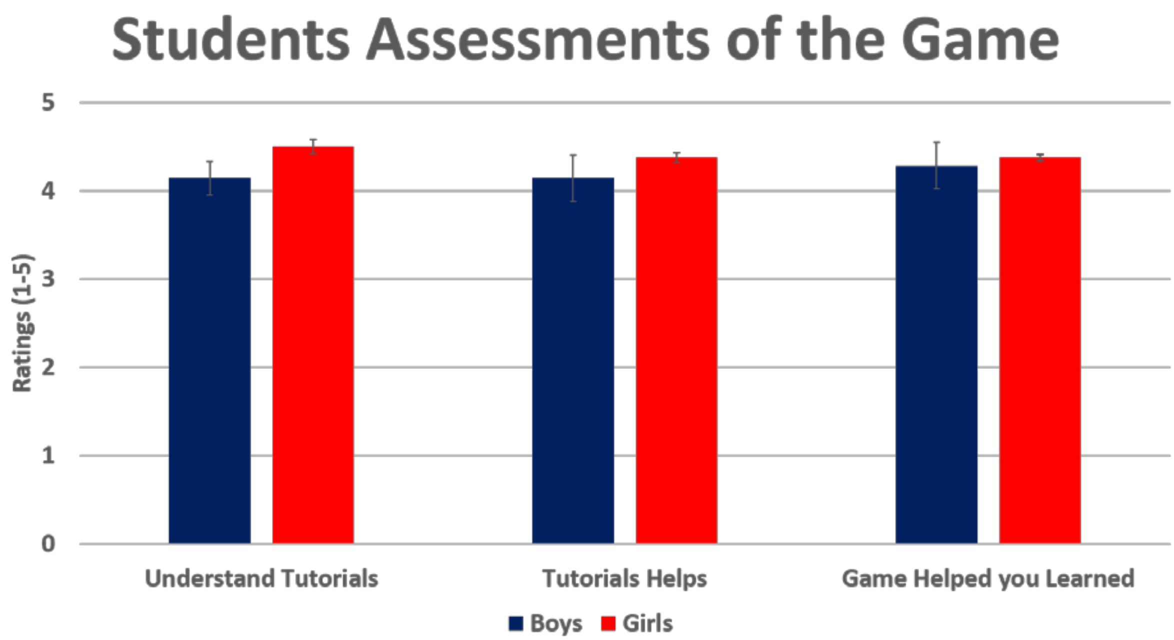

Figure 28: Students Assessments of the Game (n = 15) Error bars represent standard error.

CHAPTER VII

DISCUSSION

Hypothesis Assessment

The hypothesis of the evaluation stated that "*Interest in STEM will increase when comparing before and after opinions of Middle School students after they play an educational game designed with their preferences in mind which teaches concepts of python programming.*" The hypothesis was partially supported by the evaluation result.

Results generally show that the game had a positive effect on students' interest and attitudes towards programming. The participants showed a strong initial desire to learn about programming before the entered the study, and after the experience with the game, students indicated a desire to learn more about programming. Furthermore, students provided positive feedback about the game, reporting they felt they had learned about programming and the tutorials were effective. Students indicated that their opinions about CS and related careers had changed after playing the game, and they were more likely to choose a CS career as a result.

The second hypothesis stated that "*Female students' attitudes and interests in CS will increase greater than male students after playing the game Sorceress of Seasons*". This hypothesis was partially supported by the results. Female students reported a higher likelihood on the questions about CS opinions and careers related to programming than males. This lends support to the effectiveness of the requirements.

Game Requirements

The effectiveness of the requirements for design of the game Sorceress of Seasons was partially supported by the results of the evaluation.

The mechanics of programming presented in the game are simple enough to where students could grasp after a short explanation in the tutorial and immediately at the beginning of the second session. Though some players had difficulty with typing in commands exactly as needed for the teleportation blocks and list section. Students displayed a grasp of the concepts but the specificity of the programming commands may have been a barrier to overcome.

The requirement of a female protagonist was not as important as initially believed as some self-reported information suggested that the gender of the character was ambiguous. While students did report on surveys that to a degree the gender of a character matter, what SOS and the character design were able to accomplish was to not serve as a distraction to users. One participant however openly reported a dislike of the character and elements of the game. They indicated that the aesthetic of graphics was “too blocky.” Another participant did not like the design of the blue robots, but did not specify why.

Results of the study support the inclusion of uncertainty in the game as a majority of students reported to like the puzzles, find the game challenging but not too difficult and being motivated to play the game. The games puzzles or challenges were met with high response from females which was significant. This suggests that the method in which the requirement of uncertainty was incorporated in the game was successful However, female students indicated that they would have liked to receive additional help within the game. Furthermore the requirement of engagement throughout the activity was clear through students in person feedback. A majority of participants indicated disappointment when the allotted gameplay was complete as they wanted to continue playing. Meanwhile during the collection of materials, one of the participants inquired when they could the game would be available to download.

Previous work has shown that strategies such as pair programming and storytelling have been methods for encouraging social interactions for female middle school students to work with programming. Within the environment of the study, social interactions within the game are limited to players talking about their achievements and unlocking abilities such as statements of excitement when figuring out the ammo coin abilities or successfully breaking a wall. Female and male students indicated in the Post-Game Survey that they would've liked to have played the game with their friends. This suggests that the inclusion of collaborative play or further interaction within the game would be well received. This also follows previous work which indicates the benefits of teamwork within GBL (Martín-Sanjos et al., 2015; Stewart-Gardiner, Carmichael, Latham, Lozano, & Greene, 2013; Werner & Denning, 2009).

Performance

Students also found the game to be manageable and interesting. They identified that effort was the factor which required the most workload in NASA TLX survey. Performance scores were low at the conclusion of the study, given the short amount of time the study allowed to learn three major programming concepts. However, students did show learning gains from the pre-experiment survey to the post-game survey. The highest learning gains were seen for the variables concept. While males outperformed females in the pre-survey, after the game females outperformed the males, demonstrating a larger learning game. Overall the learning gains across the three concepts were similar for both genders. Although, females out performed males in the most of the assessments after the pre-survey. In the variables and lists concepts, students performed better in the post-tutorial survey than the post-game, perhaps due to the one week break between sessions. The findings between the Pre-Experiment and the Post-Tutorial such as female performance significantly increasing suggests that for the variables concept, the tutorial was effective.

Participants' score reflected that they had not yet achieved mastery. It may also reflect the short amount of time which they had with the subject material. Students had approximately 30 minutes of game play to practice the concepts. Additionally, since the concepts were introduced one by one, students may have only been able to practice with the variables concept in the game. Thus if a student does advance through the entire game, while they may have been exposed to 30 minutes of variables, they will only have 20 minutes with lists and about 10 minutes with if statements as each level builds takes a concept and builds upon it. Also, students were required to adapt abstract concepts and apply it within a real world example which may require practice beyond the allotted 30 minutes.

CHAPTER VIII

CONCLUSION

The purpose of this work was to determine if a game-based learning application that was designed with female middle school students in mind could increase interest in computer science. The hope was that in doing so, female students would be more interested in possibly pursuing a career in a STEM field such as computer science (CS) which in turn would increase representation of women in STEM. Additionally, it was the hope of the study to that all students, not just the female, who played the game would become more interested in CS. The evaluation presented here is a first step towards this goal. Specific design requirements were developed to address some of the barriers females experience in early education.

Students at a private middle school in Des Moines, IA participated in the two-hour experiment. Findings show that students' performance on the programming concept assessment question improved from the Pre-Experimental Survey to the Post-Game Survey.

Regarding the design requirements, a majority of students found the game to be challenging but not too difficult which is in line with the requirement of uncertainty. Most indicated that the game was fun to play and would like to play the game with their friends in some capacity. A couple of students indicated that the game was too difficult to understand; however, most did not indicate that. After playing the game, students indicated that the gender of the character did not matter compared to a higher importance held before in the Pre-Experimental Survey.

While students initially indicated a strong desire to learn more about programming, they also exited the experiment report that they had an increased desire to pursue a career in a CS related field. What these findings suggest is that the game was somewhat successful in increasing interest in STEM.

Several adaptations would need to be made to this study for a more concrete analysis. This study would need to be expanded to a longitudinal study in order to confirm effectiveness over time. Students would need to use the game over a longer period of time to poetically reach mastery of the programming concepts. Additionally, the participant population would need to be more reflective of middle school students; the demographics of the private school were not diverse and were not reflective of different ethnic and socio-economic backgrounds.

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APPENDIX A:

EXPERIMENTAL SURVEYS

Pre-Experiment Survey

1. **Gender**:

- ☐ Female
- ☐ Male

2. **Ethnicity**: (You may check more than one, as appropriate).

- ☐ African/Black
- ☐ Native American/Alaskan Native
- ☐ Asian/Pacific Islander
- ☐ Latina/Latino/Hispanic
- ☐ White
- ☐ Other: ______________________________

3. **Education**: Check the grade that you are in now or, if it is summer, check the grade you will enter next fall.
Check only one.

☐ 6th ☐ 7th ☐ 8th ☐ 9th

4. From the list below, check the classes you are currently taking in school this year OR if you are not currently in school, list the classes for which you are registered for your next school year. **Check all that apply**.

- ☐ Pre-Algebra
- ☐ Algebra I
- ☐ Algebra II
- ☐ Computer Applications
- ☐ Computer Science
- ☐ Drafting or CAD (Computer-Aided Drawing)
- ☐ Earth or Physical Science
- ☐ Engineering
- ☐ English
- ☐ Foreign Language
- ☐ General Math
- ☐ Geometry
- ☐ History/Social Studies
- ☐ Music
- ☐ Physics
- ☐ Pre-Calculus
- ☐ Technology Education
- ☐ Other math, engineering or science courses: ______________________

		Yes	No	Not Available
4a.	Are you currently enrolled in honors or advanced classes?	☐	☐	☐
4b.	Have you been encouraged to enroll in honors or advanced classes?	☐	☐	☐
4c.	Are you enrolled in a special engineering or science curriculum?	☐	☐	☐
4d.	Do you plan to enroll in honors or advanced classes next year?	☐	☐	☐

5. What do you plan to do when you graduate from high school? **Check only one.**

- ☐ Go to a college or university
- ☐ Attend a technical school (for example: business school, beauty school, technology school, etc.)
- ☐ Get a full-time job
- ☐ Join the military
- ☐ Don't know
- ☐ Other: ______________________________________

6. Have either of your parents attended college or university after high school?
☐ Yes ☐ No ☐ Don't Know

7. What do you think computer scientists and computer engineers do?

Tell us about your goals

8. The following statements describe work or jobs you might do in the future. Tell us how important each of the items below is to you in your future work.

How important is it to you to do . . .	***Not Important***	***Somewhat Important***	***Very Important***
a) Work that makes me think	☐	☐	☐
b) Work that allows me to make lots of money	☐	☐	☐
c) Work that allows me to use math, computer, engineering or science skills	☐	☐	☐
d) Work that allows me to tell other people what to do	☐	☐	☐
e) Work that allows me to help solve problems and create solutions	☐	☐	☐
f) Work that is fun to do	☐	☐	☐
g) Work that allows me to have time with family	☐	☐	☐
h) Work that allows me to help my community and/or society	☐	☐	☐
i) Work that makes people think highly of me	☐	☐	☐
j) Work that is satisfying to me	☐	☐	☐

9. Do you have any other the following devices (Check all that apply):

☐ Smart Phone (iPhone, Android, Windows, other)
☐ Lap Top
☐ Desk Top PC
☐ Tablet
☐ Gaming Console (XBOX One, PS4, Wii, Other)
☐ Hand Held Gaming Console (3DS, PSP, other)
☐ MP3 Device (iPod etc.)
☐ Other (write out) _______________

A. Do you play games on any of the devices that you have?

☐ Yes ☐ No

B. What is your favorite game and why:

C. Check all game types that you like:

- ☐ **Arcade Game** (similar to Dance Dance Revolution, Guitar Hero)
- ☐ **Action Game** (similar to Golden Eye, Destiny)
- ☐ **Action-Adventure** (similar to Zelda Series, God of War, Uncharted, Gears of War)
- ☐ **Adventure Game** (similar to The Walking Dead Game)
- ☐ **Racing/Vehicle Games** (similar to Mario Kart, Need for Speed, Ace Combat)
- ☐ **Strategy/Tactics Games** (similar to Pokémon, Pikmin, Brain Age, Scribblenauts)
- ☐ **Fantasy Game** (similar to Diablo, Final Fantasy, Fire Emblem)
- ☐ **First Person Shooter** (similar to Call of Duty, Halo, Splatoon, Metal Gear Solid)
- ☐ **Massive Multiplayer Online RPG** (similar to World of War Craft, League of Legends)
- ☐ **Mini-Game** (similar to Wii/Mario Party)
- ☐ **Sandbox Game** (similar to Minecraft)
- ☐ **Social Game** (similar to Farmville, Mob Wars, 3DS Street Pass)
- ☐ **Other**__________

10. The following statements describe preferences for game aspects. Tell us to what extent you do agree or disagree with each:

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
The Gender of the protagonist does not matter.	○	○	○	○	○
It is important to have a Female protagonist in a game	○	○	○	○	○
It is important to have a Male protagonist in a game.	○	○	○	○	○
I enjoy a game that has an interesting story/narrative.	○	○	○	○	○
I enjoy a game with a developed plotline/story.	○	○	○	○	○
I like games that have puzzles	○	○	○	○	○
I like games that are challenging	○	○	○	○	○
The best games make me want to play for long periods of time.	○	○	○	○	○
I like games which I can interact with friends/other players	○	○	○	○	○

11. *To the best of your ability, describe what this is and how you think it is used in programming?*

a = [1,2,3,4,5,6,7,8,9,10]

Check the box below that best describes your ability to learn to answer this question?
Check one only.

- ☐ I can solve this question now
- ☐ I can teach myself to answer this question
- ☐ I will be able to learn the answer once I take the right classes.
- ☐ Even if I took the right class, I wouldn't be able to answer this question.
- ☐ I don't think I will ever take a class that has concepts this hard.
- ☐ Other: ______________________________

12. Describe what programming languages are used for:

13. Have you ever programmed before?

☐ Yes ☐ No

14. Pleas rate your programming skill level:

None	Beginner	Intermediate	Expert	Master
○	○	○	○	○

15. To the best of your ability, define the following programming concepts and provide at least 1 example:

    a. Variables:

    b. Lists:

    B. If statements:

16. How would you define the following programming statement?

    Eggs = 3

    a. A String with data
    b. A List with data
    c. A Variable with data
    d. An If Statement with data

17. Given the following statement, how would you reference “Eggs” in a program?

    Breakfast = [Bacon, Eggs, Orange Juice, Milk, Oatmeal]

    a. 2nd Breakfast item
    b. Breakfast[1:3]
    c. Breakfast[1]
    d. Breakfast[2]

18. Using the following statement, write a variable, list, and if statement:

    On Fridays, we have pizza for lunch. Mondays and Tuesdays we have hot dogs. On Wednesdays we have either Tacos or Burritos. On Thursdays we have soup.

19. To what extent to do either agree or disagree with this statement

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I want to learn more about programming	○	○	○	○	○

Post-Tutorial Survey

1. *To the best of your ability, describe what this is and how you think it is used in programming?*

   a = [1,2,3,4,5,6,7,8,9,10]

   Check the box below that best describes your ability to learn to answer this question?
   Check one only.

   - ☐ I can solve this question now
   - ☐ I can teach myself to answer this question
   - ☐ I will be able to learn the answer once I take the right classes.
   - ☐ Even if I took the right class, I wouldn't be able to answer this question.
   - ☐ I don't think I will ever take a class that has concepts this hard.
   - ☐ Other: ____________________________

2. Describe what you think programming languages are used for:

3. To the best of your ability, describe the following concepts:

   a. Variables:

   b. Lists:

   c. IF statement:

4. How would you define the following programming statement?

   Shoe Brand = Nike

   a. A String with data
   b. A List with data
   c. A Variable with data
   d. An If Statement with data

5. Given the following statement, how would you reference “Fire” in a program?

   Elements = [Wind, Water, Fire, Lightning]

   a. 3rd Element in group
   b. Elements[1:4]
   c. Elements[2]
   d. Elements[3]

6. Using the following statement, write a variable, list, and if statement:

Mike plays baseball, basketball, football and tennis. He plays team sports (basketball, football and baseball) throughout the year. Mike plays Football in fall, basketball in winter, and baseball in the spring. He only plays tennis in the summer.

NASA Task Load Index (TLX) Survey

Mental Demand — How mentally demanding was the task?

Very Low — Very High

Physical Demand — How physically demanding was the task?

Very Low — Very High

Temporal Demand — How hurried or rushed was the pace of the task?

Very Low — Very High

Performance — How successful were you in accomplishing what you were asked to do?

Perfect — Failure

Effort — How hard did you have to work to accomplish your level of performance?

Very Low — Very High

Frustration — How insecure, discouraged, irritated, stressed, and annoyed wereyou?

Very Low — Very High

Post-Game Survey

1. The following statements describe preferences. To what extent you do agree or disagree with each:

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
The game's programming tutorials were easy to understand.	○	○	○	○	○
The programming tutorials helped you learn about programming.	○	○	○	○	○
The game helped you to learn about programming.	○	○	○	○	○
Your character's gender affected your level of interest in the game.	○	○	○	○	○
The game's story made you want to play the game.	○	○	○	○	○
The game had puzzles which were fun to figure out.	○	○	○	○	○
You found the Game to be challenging, but not too hard.	○	○	○	○	○
You were interested in playing the game for most of the allotted time	○	○	○	○	○
You were interested in playing the game for the allotted time.	○	○	○	○	○
You would have liked to play with your friends.	○	○	○	○	○
You would have liked more hints or help within the game.	○	○	○	○	○
The game was too difficult to understand.	○	○	○	○	○
You would consider this game enjoyable to play.	○	○	○	○	○
I would recommend this game to my friends.	○	○	○	○	○
I would like to learn more about programming	○	○	○	○	○

2. *To the best of your ability, describe what this is and how you think it is used in programming?*

   a = [1,2,3,4,5,6,7,8,9,10]

   Check the box below that best describes your ability to learn to answer this question?
   Check one only.

   - ☐ I can solve this question now
   - ☐ I can teach myself to answer this question
   - ☐ I will be able to learn the answer once I take the right classes.
   - ☐ Even if I took the right class, I wouldn't be able to answer this question.
   - ☐ I don't think I will ever take a class that has concepts this hard.
   - ☐ Other: ______________________________

3. Describe what you think programming languages are used for:

4. To the best of your ability, describe the following concepts:

   a. Variables:

   b. Lists:

   c. IF statement:

5. How would you define the following programming statement?

   Eggs = 3

   a. A String with data
   b. A List with data
   c. A Variable with data
   d. An If Statement with data

6. Given the following statement, how you reference "Milk" in a program?

   Breakfast = [Bacon, Eggs, Orange Juice, Milk, Oatmeal]

   a. 4t Breakfast item
   b. Breakfast[1:4]
   c. Breakfast[2]
   d. Breakfast[3

7. Using the following statement, write a variable, list, and if statement:

On Fridays, we have pizza for lunch. Mondays and Tuesdays we have hot dogs. On Wednesdays we have either Tacos or Burritos. On Thursdays we have soup.

8. After playing the game, what do you think computer scientists and computer engineers might make or invent that could make a difference in your life (either good or bad)? Make a list in the space below. (Please write in whole sentences)

9. List three things that you liked about the game?

10. List three things that you did not like about the game?

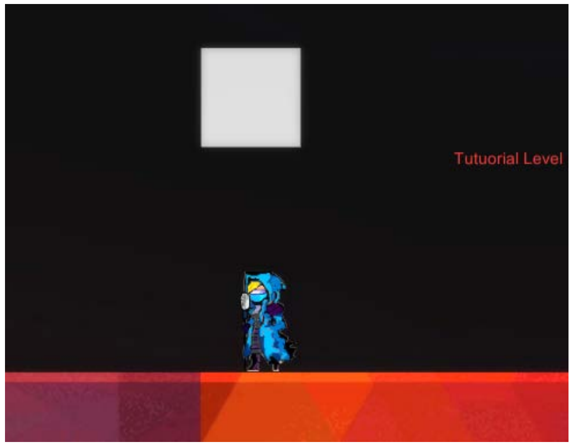
11. To what extent do you agree with the following statements:

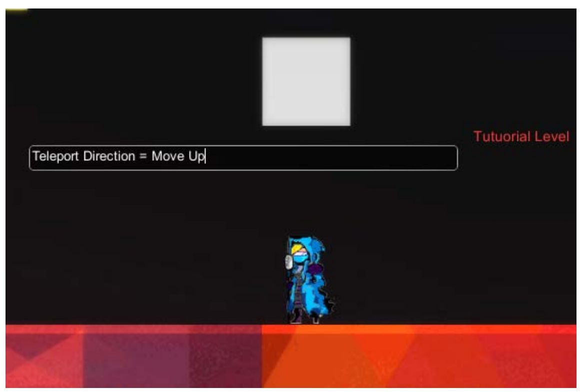
	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Your opinions about Computer Science, Computer Engineering, or Programming changed after playing the game	○	○	○	○	○
After playing the game, you more likely to consider a career which uses programming	○	○	○	○	○

APPENDIX B

GAME IMAGES

Figure 8 Images





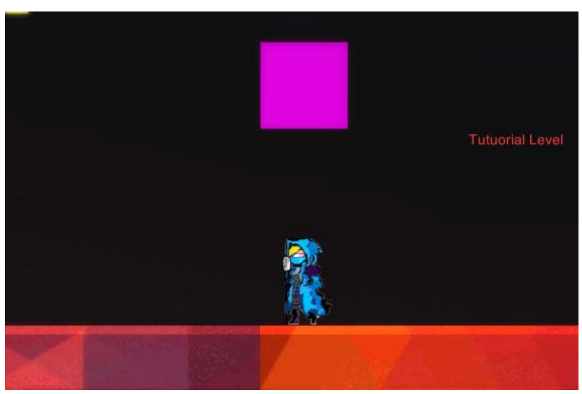
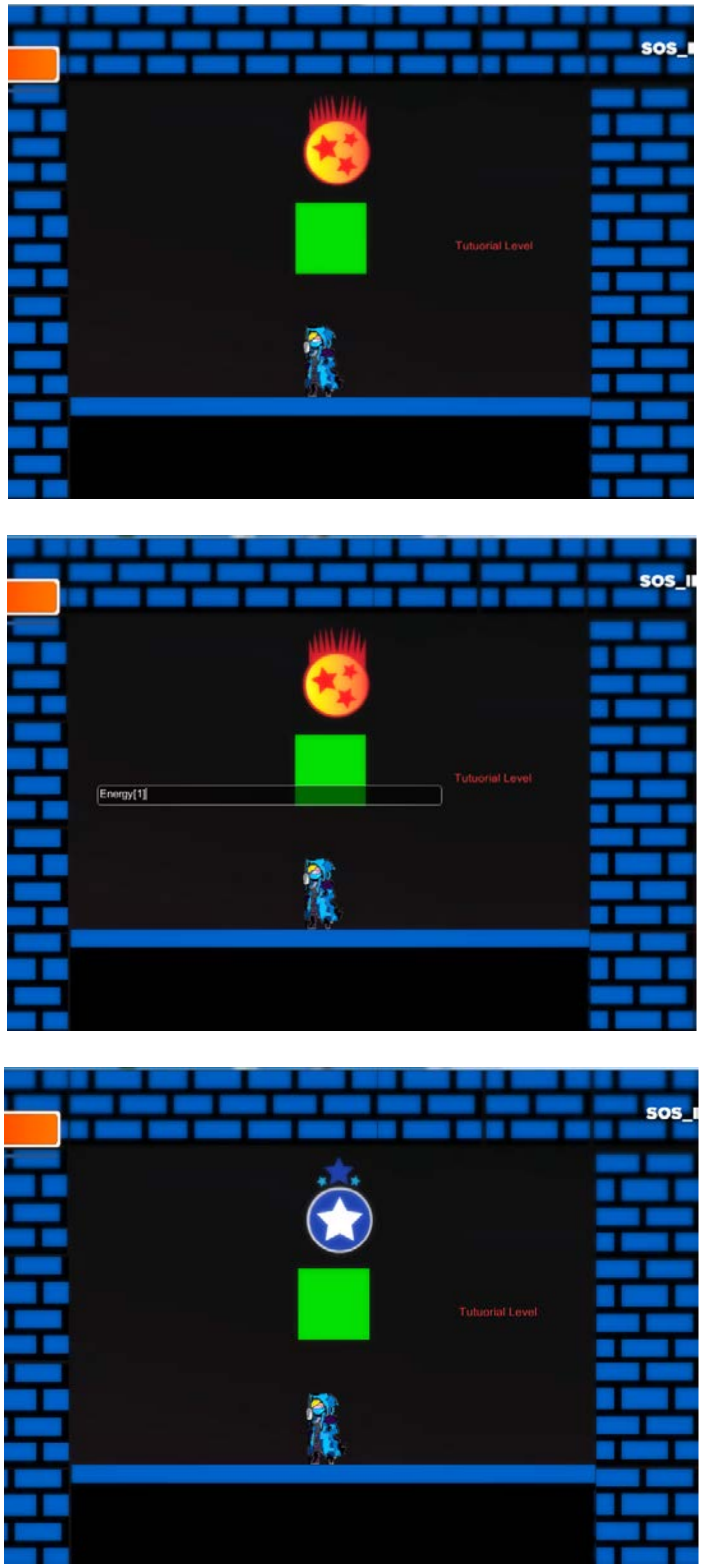


Figure 10 Images



APPENDIX C

INSTITUTIONAL REVIEW BOARD APPROVAL

IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

Institutional Review Board
Office for Responsible Research
Vice President for Research
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Date: 3/12/2015

To: Desmond Bonner
5212 Lincoln Way, Unit 1
Ames, IA 50014

CC: Dr. Michael Dorneich
3018 Black Engineering Bldg

From: Office for Responsible Research

Title: Game-Based Learning for Middle School Students

IRB ID: 15-081

Approval Date: 3/12/2015 **Date for Continuing Review:** 3/11/2017

Submission Type: New **Review Type:** Expedited

The project referenced above has received approval from the Institutional Review Board (IRB) at Iowa State University according to the dates shown above. Please refer to the IRB ID number shown above in all correspondence regarding this study.

To ensure compliance with federal regulations (45 CFR 46 & 21 CFR 56), please be sure to:

- **Use only the approved study materials** in your research, **including the recruitment materials and informed consent documents that have the IRB approval stamp.**
- **Retain signed informed consent documents for 3 years after the close of the study,** when documented consent is required.
- **Obtain IRB approval prior to implementing any changes** to the study by submitting a Modification Form for Non-Exempt Research or Amendment for Personnel Changes form, as necessary.
- **Immediately inform the IRB of** (1) **all serious and/or unexpected adverse experiences** involving risks to subjects or others; and (2) **any other unanticipated problems involving risks** to subjects or others.
- **Stop all research activity if IRB approval lapses,** unless continuation is necessary to prevent harm to research participants. Research activity can resume once IRB approval is reestablished.
- **Complete a new continuing review form** at least three to four weeks prior to the **date for continuing review** as noted above to provide sufficient time for the IRB to review and approve continuation of the study. We will send a courtesy reminder as this date approaches.

Please be aware that IRB approval means that you have met the requirements of federal regulations and ISU policies governing human subjects research. **Approval from other entities may also be needed.** For example, access to data from private records (e.g. student, medical, or employment records, etc.) that are protected by FERPA, HIPAA, or other confidentiality policies requires permission from the holders of those records. Similarly, for research conducted in institutions other than ISU (e.g., schools, other colleges or universities, medical facilities, companies, etc.), investigators must obtain permission from the institution(s) as required by their policies. **IRB approval in no way implies or guarantees that permission from these other entities will be granted.**

Upon completion of the project, please submit a Project Closure Form to the Office for Responsible Research, 1138 Pearson Hall, to officially close the project.

Please don't hesitate to contact us if you have questions or concerns at 515-294-4566 or IRB@iastate.edu.