# THE EFFECT OF PLAYING A SCIENCE CENTER-BASED MOBILE GAME: AFFECTIVE OUTCOMES AND GENDER DIFFERENCES

BY

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Abstract

Situated in a hands-on science center, The Great STEM Caper was a collaborative mobile game built on the ARIS platform that was designed to engage 5th-9th grade players in NGSS science and engineering practices while they interacted with various exhibits. Same gender partners sharing one iPad would search for QR codes placed at specific exhibits; scanning a code within the game would launch a challenge for that exhibit. The primary hypothesis was that in-game victories would be equivalent to "mastery experiences" as described by Bandura (1997) and would result in increased science self-efficacy. Gender differences in gameplay behaviors and perceptions were also studied. The study included two groups, one that played the game during their visit and one that explored the science center in the traditional way. The Motivation to Learn Science Questionnaire was administered to participants in both groups both before and after their visit to the science center. Participants wore head-mounted GoPro cameras to record their interactions within the physical and social environment. No differences in affective outcomes were found between the game and comparison groups or between boys and girls in the game group. The MLSQ was unable to measure any significant change in science self-efficacy, interest and enjoyment of science, or overall motivation to learn science in either group. However, girls outperformed boys on every measure of game achievement. Lazzaro's (2004) four types of fun were found to be a good fit for describing the gender differences in game perceptions and behaviors. Girls tended to enjoy hard fun and collaborative people fun while boys enjoyed easy fun and competitive people fun. While boys associated game achievement with enjoyment and victory, girls perceived their game achievement as difficult, rather than enjoyable or victorious.

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Contents

List of Tables

List of Figures

# CHAPTER 1: INTRODUCTION

In a recent report published by the National Research Council (2011), *Learning Science through Computer Games and Simulations*, games were described as "worthy of future investment and investigation as a means to improve science learning" (p. 2). The report advocates for research that furthers the field's understanding of the role that games can play in science education. A large portion of current research focuses on video games for learning, also known as "serious games" (Zyda, 2005). The development of extremely portable and location-aware devices with full internet access (i.e. smart phones and tablets) provides the opportunity to explore how serious games can support learning on location and outside the classroom. Introducing a mobile learning game focused on specific objectives to the typical science field trip may have an impact on the outcomes of that experience. Currently, little research exists to study this type of serious location-based game.

Teachers use science field trips to provide a real-world connection to the classroom curriculum, to expose students to new experiences, and to increase interest, motivation, and excitement toward science (Kisiel, 2005). The National Science Education Standards assert that good science programs require access to the world beyond the classroom and that museums and science centers "can contribute greatly to the understanding of science and encourage students to further their interests outside of school" (NRC, 1996). However, in this era of strict accountability, administrators and teachers often remain unsure of the educational value of field trips (Behrendt and Franklin, 2014). Their concerns are well-founded.

Typically, when students visit an informal educational institution, such as the science center, they are given the freedom to explore the center in a discovery-oriented fashion. They are not guided through the exhibits or given any explanations, other than what is provided by signage.

This type of experience contrasts sharply with in-school science learning, which is characterized by teacher-guided and objective-oriented lessons. Free-choice learning is highly valued by those in the field of informal education because learners are intrinsically motivated to make choices that are most meaningful to the individual (Falk & Dierking, 2000). However, what often happens when learners are given complete freedom to explore a novel environment (such as a science center) is that they bounce from exhibit to exhibit without engaging with the science in any meaningful way. This "novelty effect" or "ping pong effect" is a significant obstacle to a meaningful learning experience (Falk & Dierking, 2000). The design objective of this project was to create a game that preserved free-choice, was intrinsically motivating to play, and provided learners with a goal that effectively engaged them in science or engineering practices with the exhibits. The Great STEM Caper was designed to be a hybrid type of science learning experience that uses some of the best strategies that both formal and informal education have to offer.

Science City in Kansas City, MO was the site used in this study. Science City is located inside historic Union Station, includes over 120 hands-on displays, and welcomes over 200,000 visitors annually. On its website, Science City describes itself as, "an engaging environment ripe for exploration, experimentation and discovery… **Science City** is a place of wonder, where kids and adults can find something new with each visit. Throw the don't touch mindset out the window. There are no tests and no wrong or right answers, just a chance to explore with freedom and pure imagination" (http://www.unionstation.org/sciencecity/about) The Great STEM Caper included challenges for 15 of Science City's primary exhibits. Throughout the study, Science City is referred to as a hands-on science center, or simply a science center.

Fundamentally, this project is the first iteration of a personal design-based research agenda. It is my first attempt at creating a location-based mobile game designed to increase players' engagement with science and engineering practices in a science center. As a measure of effectiveness, this investigation explores how playing a challenge-based mobile game in an interactive science center can influence the affective outcomes of the participants. An open-source location-based game development platform for iOS devices called ARIS was used to design a mobile game for $5^{th}$-$8^{th}$ grade students who visit a hands-on science center on a group field trip.

Without some type of assessment of specific objectives, there is a lack of evidence to support the claim that field trips and informal learning experiences are indeed as valuable as we intrinsically know they are. However, it is a tricky endeavor to insert formal learning objectives into an informal learning experience. If the field trip becomes too much like school, there is the danger of diminishing the enjoyment, if not the effectiveness, of self-motivated and free-choice learning that typically takes place in such environments (Falk & Dierking, 2000). It was determined that assessing the effect playing The Great STEM Caper game by focusing on cognitive outcomes would be ill-aligned with the objectives of the project (i.e. to create a game that was genuinely fun to play in a free-choice environment that would engage students in science and engineering practices with the exhibits in the science center). It was therefore determined that measuring affective outcomes, such as interest, motivation, and self-efficacy, would be more appropriate.

There is a need in the research on science education for more studies that focus on affect. Despite the fact that it is widely accepted that emotions are central to learning (Alsop & Watts, 2003), less than 10% of the articles published between 2001 and 2011 in the Journal of Research on Science Teaching (JRST), Science Education (SciEd), and the International Journal of Science Education (IJSE) dealt with affective constructs (Fortus, 2014). Positive affect is not only necessary for learning to occur (Perrier & Nsengiyumva, 2003; Fortus, 2014), but it should be as much a desired outcome of school-sponsored learning as increasing cognitive understanding. Therefore, this study focuses on the affective outcomes for students who played The Great STEM Caper during their visit to the science center.

This study primarily explored two separate questions, “How does playing an exhibit-based mobile game during a group field trip to a hands-on science center affect students’ science self-efficacy, interest, and motivation to learn? And, “Are there gender differences in the affective outcomes, in perceptions of the game, or in the way students play the game? I chose to measure changes in affective outcomes, rather than conceptual change because doing research in an informal learning environment requires that my methods respect the free-choice and intrinsic motivation of the learner. To explain, I wanted to avoid using research techniques that felt too much like formal schooling, such as tests of conceptual knowledge. Research methods that could threaten self-esteem or feel critical or controlling can thwart both participation and learning (Shute, 2008). I hypothesized that a successful game experience would increase students’ self-efficacy, interest, and motivation toward science. A game that is fun to play while requiring players to use their science inquiry skills to be successful should result in higher affective outcomes toward science for students.

I used mixed-method data collection strategies that are well-aligned with my research purposes. The data, both qualitative and quantitative in nature, were used to create a well-informed description of students’ perceptions, behaviors, and affective outcomes as a result of playing a mobile, exhibit-based game during their science center field trip. Quantitative data included an in-game record of game performance and pre- and post-visit Likert-type survey (i.e. the Motivation to Learn Science Questionnaire) of participants’ self-efficacy, interest, and motivation toward science. In addition, after successfully completing a challenge, players were presented with a 3 question mini-survey that asked them to report how much they enjoyed the challenge, how difficult they thought it had been, and how victorious they felt after completing it. A qualitative analysis of post-visit interviews with a sample of participating students informed the interpretation of the survey data. The qualitative analysis also included the multi-media artifacts that players created within the mobile game itself. Players uploaded evidence and scientific explanations via text, image, audio or video in response to game prompts. In addition to the MLSQ, the post-survey also included some additional open-ended questions. Finally, during each trial, one female pair and one male pair wore a head mounted GoPro camera to capture high-definition video and audio of their first-person perspective. The video provided a clear window into how participants interacted with each other, with the game, with the exhibits, and with other people at the science center. I compared the results of two study groups: the experimental group of game-playing participants and a comparison group that visited the science center in the traditional way. In addition, I explored gender differences in the way participants played the game and their perceptions of the game.

Founded on social-constructivist theory, my pedagogical philosophy is that children learn best when they are intrinsically motivated, collaborating with others (both peers and experts), and engaged in a real-world experience. Social constructivism originated with Lev Vygotsky (1930) to describe how learning and the construction of knowledge occurs through discourse within a social context. More recently and more specific to my work with smart devices, computer-supported-collaborative-learning (CSCL) uses social constructivism to design technology-enhanced learning environments. The ARIS platform upon which The Great STEM Caper is built uses the Notebook feature to support communication and the social construction of knowledge between players. Additionally, Falk and Dierking's (2000) Contextual Model of Learning describes learning in informal environments such as science centers. The theoretical foundations of this study span several fields and the outcomes of this research should be of interest to those in diverse disciplines.

This dissertation includes five chapters: introduction, literature review, research design, results, and discussion. In Chapter 1, I have introduced the context of my research, Science City, as well as the rationale for my study, including how it fits in with existing research agendas in informal science education and games for learning. The literature review synthesizes important previous research on inquiry-based science learning, field trips, and game-based learning to create a coherent theoretical foundation for the study. I also briefly summarize the literature that explains why motivation, interest, and self-efficacy in science are important indicators for success in future science learning and how those affective constructs are best measured in informal learning contexts. In the third chapter, I provide a detailed rationale of both the qualitative and quantitative components of the research design. This chapter explains in detail how I used a unique method to collect data from within the game itself and the methods I used to analyze that data qualitatively. The fourth chapter includes all of the findings from the data: changes in self-efficacy, interest, and/or motivation toward science between the two groups and types of behavior and interactions typical. Finally, I discuss the implications of this research for informal education settings, designers of location-based games for learning, as well as for teachers who take their students on field trips. I conclude with a plan for future research as well as outline a strategy for using technology to support effective connections between informal and formal science education.

# CHAPTER 2: LITERATURE REVIEW

There are several bodies of research that are particularly pertinent to this study. The Great STEM Caper is designed to engage students in inquiry-based science practices; therefore the literature supporting inquiry as an effective method for science learning is discussed here. The effect of the playing the game is determined by measuring the change in participants' affective domain, specifically motivation to learn, interest and enjoyment, and self-efficacy. Literature describing these constructs, why they are meaningful measures for predicting science achievement, and evidence of gender differences is reviewed here, as well. In addition, I outline the research that explains why field trips and outside-the-classroom experiences are valuable for science learning. Finally, I discuss the research surrounding games for learning, including gender differences, mobile and location-based games, and augmented reality.

## Science Inquiry

Both in and out of school, learners develop an understanding of science through use of critical thinking skills applied in combination with science content knowledge and hands-on science inquiry practices. In other words, learning science requires that one actually "do science." Engaging students in the processes of science through hands-on investigations (i.e. active science inquiry), rather than reliance on more passive instructional techniques, is more likely to increase students' conceptual understandings (Minner 2010). Learning science through inquiry-based experiences also improves students' attitudes toward and motivation to learn science (Kanter & Konstantopoulos, 2010). The National Research Council's recent Framework for K-12 Science Education (2012), uses the term "science and engineering practices" instead of "inquiry" or "science process" skills specifically "to emphasize that engaging in scientific investigation requires not only skill but also knowledge that is specific to each practice" (NRC *Framework*, 2012, p. 30). However, the National Science Education Standards previously developed by the NRC in 1996 contained nearly identical constructs under the heading "Science as Inquiry". The science and engineering practices of the new Framework and the subsequent Next Generation Science Standards (2013) identified as essential for all students to know are:

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Throughout this research, the terms "inquiry", "inquiry skills", and "inquiry-based" are used synonymously with "science and engineering practices". A mobile game is a medium well-suited for crafting real-world challenges that require learners to apply both content knowledge and the processes of science. Such a game may be effective at encouraging students to engage in science and engineering practices during a visit to a hands-on science center.

## Affective Outcomes

Emotions are a central part of learning, but there is little contemporary science education research that explores affect (Alsop and Watts, 2003). In fact, during the decade from 2001 to 2011, only 51 articles (less than 10%) published by the Journal of Research in Science Teaching were on topics related to affect (Fortus, 2014). Topics related to affect include, but are not limited to, motivation, interest, and self-efficacy.

Motivation to learn is one of the most powerful predictors of academic success and can be described as the tendency to find academic activities meaningful and to derive the intended benefits from them (Brophy, 1987; Hidi & Harackiewicz, 2000). Koballa & Glynn (2007) note that intrinsic motivation is particularly desirable because it drives students to pursue interests and apply their knowledge and abilities. Intrinsic motivation is developed through arousal, interest, and curiosity and is influenced by learners' self-efficacy (Koballa & Glynn in Abell & Lederman, 2007). To design a learning environment that has the potential to increase learners' motivation to learn in a particular domain, one must attend to arousing learners' curiosity and interest and ultimately providing them with an experience that increases their self-efficacy in that domain.

Interest in a particular domain strongly influences how motivated one is to learn it (Koballa & Glynn in Abell & Lederman, 2007). Interest can be individual or situational (Hidi & Harackiewicz, 2000). Personal interest develops early in life, usually by age 14, and tends to be fairly stable over time (Reid in Saleh & Khine, 2011). Situational interest is elicited by engaging environmental factors in a particular context. Hidi and colleagues (2000) argue that situational interest can play an important role in learning for individuals who might not have pre-existing individual interest in a content area and could ultimately be used to increase motivation for academically unmotivated students. The Great STEM Caper is structured around a series of challenges designed to elicit student curiosity and situational interest in inquiry-based science activities. Increased interest in science inquiry, even situational interest during the game, can be correlated with increased motivation in the domain.

Higher self-efficacy also leads to increased motivation to learn and predicts performance. In other words, if one believes that he/she has the ability to be successful at a particular endeavor, one is more likely to be interested in learning more about it and to actually succeed at doing it. According to Bandura (1997), a learner's own successful experiences, "mastery experiences", are the most direct way to increase a person's sense of self-efficacy. For instance, if you want a student to believe that they are good at science and that they "can do science", make sure that students have mastery experiences in science. At the middle school age (i.e. grades 5-8), girls typically report higher science self-efficacy than boys (Britner & Pajares, 2001). However, it is not simply the mastery experience itself that increases self-efficacy, but more importantly, it is a person's interpretation of the experience that has the most influence (Bandura, 1997; Britner & Pajares, 2006). An individual must cognitively process every experience in the context of previously held-beliefs, perceived difficulty of the task, effort expended on the task, and help received to complete the task (Britner & Pajares, 2006).

Within the context of a game, "winning" may be considered a mastery experience for the player. Victory has an emotional component known as "fiero" (McGonigal, 2011); fiero is what we feel when we triumph over adversity or challenge. By setting up challenges that require players to engage in science inquiry, one could expect increased science self-efficacy when players master a challenge and exhibit fiero. If the game requires that players use their science inquiry skills to be successful in the game, then winning the game should have a positive effect on players' science self-efficacy.

Barab and Dede (2007) explain how "game-like virtual learning experiences can provide a strong sense of engagement and opportunities to learn for all students, even helping learners with low self-efficacy start afresh with a new ‘identity’ not tagged as an academic loser.” They go further to say that “immersive, collaborative simulations may act as a catalyst for change in students’ self-efficacy and learning processes” (Barab & Dede, 2007). Although a place-based mobile game is not an “immersive simulation” as envisioned by Barab and Dede, it still includes a combination of activities in both the virtual and physical worlds. As such, a mastery experience within the game could increase the player’s self-efficacy for real-world science.

## Field Trips

A well-planned class field trip provides unique and valuable learning opportunities for students. The world outside of the classroom is rich with potential learning experiences still rooted in an authentic context. Field trips can also provide access to experts, tools, and materials typically unavailable in school classrooms. Indeed, the National Science Education Standards assert that good science programs require access to the world beyond the classroom and that museums and science centers “can contribute greatly to the understanding of science and encourage students to further their interests outside of school” (NRC, 1996). However, field trips are expensive and between 2006 and 2010 more than half of American school districts eliminated field trips from their budgets (Ellerson, 2010). Additionally, due to increased accountability requirements of No Child Left Behind, educators feel increased pressure to make certain that every moment of instructional time is used effectively to improve students’ academic performance (NCLB, 2008). If students are to experience the benefits that real-world learning experiences can provide, educators must demonstrate that field trips are not only an effective use of instructional time, but that they are essential for meaningful learning. Educational research that investigates the effects of different kinds of out-of-school learning may help teachers make an evidence-supported case for class field trips.

Teachers have many reasons for taking their students on field trips, particularly science field trips. Motivations for science field trips span cognitive and affective goals. Kiesel (2005) discovered that teachers are largely looking for a real-world experience that connects to the classroom curriculum, provides a general learning experience, exposes students to a new experience, or encourages life-long learning. Additionally, many teachers cite social-emotional motivations for field trips such as the desire to enhance students' interest and motivation in science, to increase student engagement through a change in setting or routine, or simply to provide an enjoyable experience (Kiesel, 2005). However, educational effectiveness of a field trip is determined by how well the experience is integrated into the school curriculum and if the teacher envisions the field trip as a "day out" or reward for school-based behavior or achievement, it generally falls short as a meaningful learning experience (Abell and Lederman, 2007). However, field trips can have a lasting impact on young learners, who are often able to recall strong memories of both cognitive and sociocultural contexts of field trips years later (Falk & Dierking, 2000). But mere memory of a field trip as an adult does not provide sufficient evidence that science field trips are fulfilling teachers' goals for students. Teachers need more empirical support to back up their conviction that field trips are a powerful component to children's education as well as researched-based guidance on how best to add educational value to the memorable nature of the field trip experience.

Despite teachers' intentions, science field trips, and field trips in general, often do not realize their potential as learning opportunities. Field trips bring the students out of the structured, formal learning environment of the classroom and into a less-structured, informal learning environment. Teachers may intend the field trip to provide concrete experiences that connect to the classroom curriculum (Kiesel, 2005), but they may find their objectives challenged by an unfamiliar physical environment designed for free-choice learning (Falk & Dierking, 2000). Free-choice environments offer the learner choice and control over the experience, which is prerequisite for eliciting intrinsic motivation. However, a high level of novelty in a free-choice environment can result in superficial engagement with the exhibits. This is sometimes referred to by museum staff as the "ping-pong effect" and can be characterized by visitors thoughtlessly pushing buttons, throwing levers, and bouncing from one exhibit to the next (Schaller & Flagg, 2013). Because of this "ping-pong" or "novelty effect", school visits to science centers often result in off-task behavior that inhibits student use of science practices and diminishes the educational value of a traditional visit to a museum or science center (Eshach, 2006; Falk and Dierking, 2000). As a result, it is standard museum evaluation practice to measure and try to increase the amount of time that visitors spend engaged with an exhibit (Falk and Dierking, 2000). "Humans just don't learn well when they are left entirely up to their own devices to operate within a complex environment about which they know very little," and good science teachers do not turn learners loose to engage in activities without any support or guidance (Gee, 2007, p.113). Classroom teachers and museum educators must develop strategies to overcome obstacles and support learning during a field trip. Providing focus and guidance without relinquishing free-choice and intrinsic motivation may help to minimize the novelty effect and facilitate a more powerful learning experience.

Current strategies for minimizing novelty and supporting learning require teachers to devote time and attention to the task before the field trip. Of course, teachers must first be aware that the novelty of the physical environment may impede their students' learning and also that the effect can be minimized. Using advance organizers and exposing students to some of what they will experience at the museum are effective ways to decrease the novelty effect (Gutwill and Allen, 2012). However, many teachers report a lack of time, resources, and/or sufficient overlap with curriculum to implement pre- or post- field trip activities (DeWitt & Osborne, 2007). Classroom teachers and museum educators might prefer a strategy that would address the novelty effect when students arrive at the museum. Innovative use of technology could minimize the novelty effect by focusing students' attention, encouraging engagement in science practices, and supporting collaborative problem solving.

## Games for Learning

Digital games are one innovative use of technology that could focus students' attention on a goal-oriented experience. People enjoy playing games because they are fun. Educationally, "fun" translates into an experience that is intrinsically motivating and inherently engaging to learners. A uniquely effective characteristic of digital games is that they provide an "ideological virtual world purposefully designed to instantiate and value particular ways of viewing and behaving" (Squire, 2011). In the case of The Great STEM Caper, the ideological world values engagement in scientific inquiry and engineering practices. The theory of "transformational play" explains how learners assume the role of the protagonist in the game world and employ conceptual understandings to make decisions that are consequential in a fictional context while simultaneously transforming the virtual world as well as the learner's own self-efficacy (Barab, Grasalfi, & Ingram-Goble, 2010). Thus, players assume character roles (e.g. scientist, detective, journalist, etc.) as they engage in educationally valued ways of thinking and make decisions that determine the fate of the virtual world. In this way, the virtual game experience can provide a meaningful and powerful learning experience.

Not all games are created equal, and for a period, much of the research on digital games for learning had been inconclusive (Honey & Hilton, 2011; Young, 2012). However, current design-based research has found that there are particular game-design features that support learning. Design elements that include player control, choice and consequential decision-making--a.k.a. personal agency—(Dede & Barab, 2009; Dickey, 2005; Denis & Jouvelot, 2005; Federation of American Scientists, 2006; Gee, 2007); complex, relevant, and engaging narratives (Gresalfi, Barab, Siyahhan, & Christensen, 2009); personalized and specific feedback (Barrett, 2011; Clark, Nelson, Sengupta, & DÁngelo, 2009; Honey & Hilton, 2011; Lee & Chen, 2009; Rup & Gustha, 2010); and intrinsic, rather than extrinsic, rewards (Charles, McNeill, McAlister, Black, Moore, Stringer, Kucklich, & Kerr, 2005; Habgood & Ainsworth, 2011; Sweetster & Wyeth, 2005; Tuzun, Yilmaz-Soylu, Karakus, & Kizilkaya, 2009) have emerged as effective strategies for creating a game that can have a significant positive impact on learning (Barab, Thomas, Dodge, Carteaux, & Tuzun, 2005; Kiili, 2005; Luckin, 2008). Additionally, Charsky and Ressler (2011) maintain that a game that is "fun to play" will have better outcomes than one that is focused too heavily on academic outcomes. When they integrated conceptual scaffolds (i.e. concept maps) into gameplay during a 9$^{th}$ grade history class, motivation to learn history through gameplay decreased compared to motivation to learn history during regular classroom instruction. But when the scaffolds were removed, motivation to learn through gameplay increased compared to regular classroom instruction (Charsky & Ressler, 2011). The game design principles that support learning are nearly identical to good game design principles in general. In other words, creating a fun and intrinsically motivating game which will keep players engaged until they "win" or master the game is a very similar task to creating a game that will keep learners engaged until they master the skill or content objectives. The primary difference is that in a learning game, game goals and objectives are designed based on the learning goals and objectives. For example, instead of sword-fighting an ogre to get the key to unlock the treasure chest, the player in a science learning game must design a block and tackle and then figure out how many 25 lb sacks of flour it will take to raise the 100 pound player to the top of the barn where the treasure is hidden.  Effective educational game design must prioritize fun, but do so in a way that integrates desired learning goals with game goals.

## Types of Fun

In the context of gameplay, Lazzaro (2004) identified four types of fun that motivate players.  Specifically, she identified types of fun that emotionally engage players in a game that does not have a strong narrative component.  Narrative necessarily requires sequence, and in a museum or science center setting, narrative in a game is difficult to employ without sacrificing a commitment to free-choice exploration and learning.  To be intrinsically engaging (and fun) a game in a free-choice learning environment must be emotionally engaging without narrative.  Hard fun, easy fun, serious fun, and people fun are all different kinds of fun that elicit emotion and motivate people to play and continue playing.  Hard fun elicits emotion by providing players a goal to pursue.  Easy fun is the sheer enjoyment that players experience through game activities (e.g.  exploring, using the controls, etc.) Serious fun engages players who seek a meaningful experience that has an effect on their real world condition.  Finally, people fun evokes emotions related to competition, cooperation, performance, and spectacle.  Players who are motivated by people fun see games as vehicles for social interaction.  Lazzaro's four types of fun provide a key to designing a game that will be fun to play within a free-choice learning environment.

Learning games can be effective in a variety of disciplinary subject areas, but science may be particularly well-served by a game-based instructional approach.  Several science learning goals are embedded in gameplay, such as the practices of inquiry, critical thinking, decision making, and problem solving (Klopfer, 2008; National Research Council, 1996).  Similar to a good science classroom, a game can exist within an ideological world in which particular ways of knowing are valued (Squire, 2011). In other words, a game can provide a virtual world where the player assumes the virtual or “projected” identity of a scientist (Gee, 2007). Learning in such an environment encourages “hypothesis testing, risk taking, persistence past failure, and seeing ‘mistakes’ as new opportunities for progress and learning” (Gee, 2007, p. 37). The very nature of gameplay provides practice in a scientific way of thinking and solving problems. To play a science game, the learner must behave like a scientist; and to play the game well (a.k.a. to win), the learner must master the skills of scientific practice.

## Gender Differences in Game-based Learning

There has been a significant amount of research dedicated to exploring gender differences in the effects of playing science education video games, however there have not been any published studies that look at mobile science learning games (Basham, et al). Although some are collaborative, video games immerse the player in a virtual world in which she/he interacts only with virtual objects and characters. In contrast, situated mobile games like The Great STEM Caper require players to traverse the physical world, interacting with physical objects and real people. This difference is very important because the results of previous studies about science learning through video games may not be directly applicable to this study. Nevertheless, it seems important to discuss the previous findings regarding gender differences in science learning video games.

In their review of the literature on girls’ gaming experience in science education, Basham et al concluded that girls generally had less experience playing video games than boys did and scored lower on measures of time spent playing video games (Bonanno & Kommers, 2008), interest in video games (Lucas & Sherry, 2004), and preferences for using video games for learning (Bourgonjon, Valcke, Soetaert, & Schellens, 2010). Because of their inexperience within the gaming environment, girls experienced more difficulty completing tasks, which led to lower perceptions of the game as helpful for learning (Lin, Tutwiler, & Chang, 2012). However, as girls gained more experience within the gaming environment, the differences began to disappear (Blumberg & Sokol, 2004; Carr, 2005; Jensen & de Castell, 2010; Yang & Chen, 2010 in Basham, ?). Girls tended to make more use of scaffolds and guidance systems built into games, which was correlated with gains in content knowledge (Nelson, 2007; Ketelhut, 2007). Finally, in five studies that looked at student engagement within a science-specific gaming environment, both males and females preferred gaming over traditional instruction (Annetta, Mangrum, Holmes, Collazo, & Cheng, 2009; Liu, 2004; Liu, Horton, Olmanson, & Toprac, 2011; Schifter, Ketelhut, & Nelson, 2012; Wrzesien & Alcaniz Raya, 2010)

## Location-based, Situated, and Augmented Reality Mobile Games

Technological progress has resulted in a highly portable and powerful new game platform: the internet-connected, or "smart", mobile device (think smart phone or tablet). Just as a real child is able to assume a virtual identity in digital game, a game that is played on a location-aware device (i.e. GPS and/or microwave cell phone enabled), is able to extend its virtual world into the real-world. The boundary between the real and the virtual can become fluid and permeable, and ideally, the player is able to move seamlessly between the two. Such an arrangement enables the educational game designer to situate game elements in the real world. For instance, a game played on a smart phone could facilitate face-to-face interaction between players and subject area experts. It could require players to conduct a hands-on experiment that uses the actual physical laws of the universe rather than simulated laws in a virtual world. Or it could support the player as she learns how to collect and calculate the DBH measurement (i.e. diameter at breast height) for an elm tree. The learning opportunities available in the real-world already exist, and they are infinite. However, without a guide or mediator such as a teacher or a game, those opportunities remain remote, inaccessible, or even invisible. Adding mobility and location-awareness to an educational game allows the educator/game-developer to design learning experiences that harness the potential of any specific physical environment.

Mobile technologies' unique combination of location-awareness and networking capabilities provide a platform that supports a pedagogical approach consistent with situated learning theory. To explain, learning can be described as "situated" within both physical and social contexts. Situated learning theory promotes the notion that learning takes place in the course of an activity and within appropriate and meaningful contexts (Lave & Wenger, 1991). "Appropriate and meaningful" contexts can also be described as "authentic," involving real-world problems or projects that are relevant and interesting to the learner (Ally, 2009). In addition to drawing upon the real-world context of a problem or project, situated learning engages the community that develops around the activity (Klopfer, 2008). By connecting the game and its players to one another over space and time, communication networks facilitate collaboration and the co-construction of knowledge and support a learning experience that is authentically situated in a community of practice (Sprake, 2012). These connections between the players, the problem or project activity, and the real, physical world are the key characteristics of situated learning (Klopfer, 2008). Location-based mobile learning games are designed experiences born out of the confluence of mobile technology and situated learning theory. Even so, mobile technology also lends itself to the effective application of other learning theories.

Mobile games are also well suited for constructivist learning, which is often used in combination with situated learning. Constructivist learning theory explains how learners construct new knowledge by connecting current experiences to previous life experiences. The active, lived experience of the learner is central to constructivist theory. While playing a location-based mobile game learners are not passive, but are "action oriented" (Ally, 2009, p.37); both cognitively and physically they pursue information, evaluating evidence as they construct an understanding of both the real and game worlds. By incorporating natural laws of the physical environment into the mechanics of gameplay, the educator/game designer can provide an authentic experience, rather than a simulation, upon which the learner can construct those new understandings. As Eric Klopfer (2008, xii) explains, "The synthesis of the constructivist and situated learning paradigms lead us to design activities that are inherently social, authentic and meaningful, connected to the real word, open-ended so they contain multiple pathways, intrinsically motivating, and filled with feedback." Furthermore, feedback and game challenges can be customized based on choices the player makes within the game that identify her prior knowledge, preconceptions, or misconceptions. Especially when designed to be collaborative, a location-based mobile learning game is an example of an activity created in response to the synthesis of situated and constructivist learning theory.

Currently, the technology that enables location-awareness works well outdoors, but does not lend itself to indoor use. Furthermore, the iPads that will be used in this study will be connected to the internet through a wi-fi network, not a cellular network. Although a device can be located in physical space through a wi-fi network, the results are not accurate or responsive enough to be useful in a location-based mobile game. Therefore, because this study focuses on the indoor environment of the science center, it relies on the use of quick response or QR codes that the player must scan with the mobile device in order to identify their location within the science center. The QR code provides information on the player's location at the moment of scanning, but is a weak substitute for true location-awareness. Essentially, the use of QR codes requires players to perform an action (i.e. find and scan the codes) to move the game forward, whereas location-awareness would allow the game to automatically move forward based on the player's physical location. The distinction is significant, but for the Great STEM Caper, gameplay would not be meaningfully altered with GPS or cell network. Due to this distinction, perhaps the term "situated mobile game" should be used to describe both location-based games as well as games such as The Great STEM Caper that are situated in the real world but do not make use of location-awareness.

A situated mobile game is closely related to an "augmented reality" game. Augmented reality games create a virtual context for the physical world by placing a virtual "game layer" over the physical environment. In contrast to virtual reality, which aims to replace the real world by immersing the player in a digital world, augmented reality supplements the real world with digital information (Sprake, 2012). Successful augmented reality games require players to solve complex problems that use a combination of real collected evidence and virtual information (Klopfer and Squire, 2007). For example, an augmented reality game for a science museum might require players to assume the role of scientist as it guides them to engage in inquiry-based interactions with the museum's hands-on exhibits in order to discover evidence needed to solve a mystery. Ideally, an augmented reality game uses mobile technology to engage, motivate and guide the learner through experiences situated in the real world.

Bridging the boundaries between formal school learning and informal out-of-school learning, situated mobile learning games bring virtually guided learning into the real world. Such games can be described as an informal learning opportunity because they are intrinsically motivating to play (i.e. they are fun) and they are situated outside of the formal school environment. However, informal learning is also characterized by being incidental, spontaneous, and lacking an authority figure or mediator: it occurs during reading, viewing, or listening, and the educational path is determined by the learner alone (Csikszentmihalyi & Hermanson, 1995; Tamir, 1990). In contrast, situated learning games exhibit some characteristics more descriptive of formal learning experiences: they serve as a guide or mediator between the learner and the experience, they incorporate explicit goals and rules, and they provide feedback on the player's progress (Honey & Hilton, 2011). Hence, situated mobile learning games synthesize both formal and informal learning characteristics to create a unique kind of learning experience. A hybrid between formal and informal, the "non-formal" learning experience occurs outside of school during mediated, planned experiences that appeal intrinsically to the learner (Eshach, 2006). The situated mobile learning game is a prime example of a non-formal learning experience because it is an intrinsically motivating activity existing outside of school that also introduces goals, rules, and individualized feedback to the player/learner. Situated mobile learning games literally represent "the best of both worlds" as they not only bridge the virtual and the physical, but also formal and informal education.

# CHAPTER 3: RESEARCH DESIGN/METHODS

This project used a challenge-based mobile game for 5th through 8th grade students to guide and mediate their experience at a hands-on science center during a group field trip. The primary objective of the game design was to create an inquiry-based science learning game that is engaging and genuinely fun to play. An open-source, location-based game platform called ARIS (i.e. Augmented Reality and Interactive Storytelling) was used to create the game. ARIS is developed at the University of Wisconsin as part of Games+Learning+Society (GLS, 2015).

The mobile game, The Great STEM Caper, uses a challenge-based game structure to encourage engagement in science and engineering practices at specific exhibits and creates opportunities for student collaboration. To win the game, players must solve challenges in the domains of science, technology, engineering, and mathematics. The game is designed to be collaborative, rather than competitive, and all players have the opportunity to successfully complete the game and experience mastery during their visit to the science center. This research is aimed at exploring whether victories in-game – a.k.a. "fiero" experiences (McGonigal, 2011) – translate to real world mastery experiences (Bandura, 1997) which could reinforce students' beliefs that they can do science and therefore increase their science self-efficacy more than a traditional, less goal-oriented science center experience.

The study was conducted in three phases, employed a quasi-experimental, design-based methodology, and utilized a mixed-methods approach to data collection. The first phase began with the design and development of The Great STEM Caper, playtesting the game with small groups of 2-3 students, and making adjustments to the game and the research protocol based on player feedback. The second phase included large group pilot-testing of the Great STEM Caper and the research protocols. The third and final phase of the study included 10 groups of 5-25 students in the target demographic visiting the science center and either playing the game in all female or all male pairs or exploring the center with a partner in the traditional discovery-oriented way.

## Sample

Participants were recruited from organizations that offer out-of-school educational programming to typically underserved or at-risk youth (e.g. Boys and Girls Club, Girl Scouts). The study sample included 79 students in the game group and 42 students in the comparison group. Originally, the research design focused on recruiting classes of students from schools that serve a majority of students with low socio-economic status. Logistically, recruiting classes of participants directly from schools proved impossible; therefore, the research design was adjusted to focus on recruiting student groups from non-profit organizations outside of schools, but within the same target demographic. Ultimately, there were ten intact groups that participated in Phase 3 of this study: eight intact game groups with 79 participants, and two intact comparison groups with 42 participants. On the Pre-survey, participants shared their current school grade level, the name of the school they attended, and their gender. Based on this data, the game group study sample is described as 43% female (n=34) and 57% male (n=45) while the comparison group sample is described as 48% female (n=20) and 52% male (n=22). The mean grade level of the game group was 6.97, meaning that on average the game group participants were $7^{th}$ graders. The mean grade level for the comparison group was 8.18, meaning that on average, the participants in the comparison group were $8^{th}$ graders. The percent of students in each group labeled as “economically disadvantaged” was determined by averaging the percentage of students eligible for free and reduced lunch at the participants’ schools. In the game group, 79% of the participants attended schools where over 50% of the student population was eligible for free or reduced lunch. The average percentage of students eligible for free or reduced lunch at those schools was 72%. In the comparison group, 48% of the participants attended schools where over 50% of the student population was eligible for free or reduced lunch. The average percentage of students eligible for free or reduced lunch at those schools was 58%.

| **Grade Level** | **5th** | **6th** | **7th** | **8th** | **9th** | **Other** | **Mean** |
|---|---|---|---|---|---|---|---|
| Comparison (42) | 0 | 0 | 0 | 76% (32) | 17% (7) | 7% (3) | 8.18 |
| Game (75) | 7% (5) | 29% (22) | 24% (18) | 40% (30) | 0 | 0 | 6.97 |

| **SocioEconomics** | **Disadvantaged** | **Non-disadvantaged** | **% Free Lunch** | **Home-school** | **Private** | **Not reported** |
|---|---|---|---|---|---|---|
| Comparison (42) | 48% (20) | 50% (21) | 58% | 0 | 2% (1) | 0 |
| Game (76) | 79% (60) | 9% (7) | 72% | 4% (3) | 5% (4) | 3%(2) |

## Phase 1

### Game Design and Development

The Great STEM Caper is a free-choice, challenge-based game that is designed to engage players in science and engineering practices with the exhibits at a hands-on science center. There are 15 possible challenges in the game that have different characteristics in terms of content area (i.e. S.T.E.M.), level of difficulty (i.e. easy, medium, hard), and type of game mechanic involved *(See Appendix:* Table *).* Players must find and scan QR codes at exhibits throughout the science center to launch each Challenge in the game *(See Appendix: Figure 3 and Figure 5).* There is not a singular linear path through the game and players are free to choose which challenges to do and the order in which to do them. Originally, players were to earn a badge in each disciplinary area: Science, Technology, Engineering, and Mathematics in order to win the game *(See Appendix: Figure 4)*. Each badge requires players to achieve 3 skill units in that specific discipline. For example, a player must earn 3 science units to achieve science mastery and the accompanying badge. Skill units are tabulated in the Player Attribute Tab *(See Appendix: Figure 7)*. However, after the GSC was pilot tested, the requirements for winning were decreased to 7 skill units in any combination. Technically, players can now win the game without earning any badges at all.

Challenges are worth 1, 2, or 3 skill units. There are 8 challenges that are worth one unit in a single discipline and are considered "easy" challenges. Solving an easy challenge results in a "small victory" experience. A "small victory" occurs in the game as a static visual, text, and auditory indicator that a disciplinary unit has been earned. Two and three unit challenges are worth units in more than one discipline and there is one challenge that is worth two units in a single discipline. The 5 challenges that are worth two units are categorized as "medium" level challenges and result in a "medium victory" experience upon successful completion of those challenges. A "medium victory" occurs in the game as lightly animated visual, text, and auditory indicator that two units have been earned. Two challenges are worth 3 units of experience and are categorized as "difficult" challenges which result in a "large victory" experience upon successful completion. A "large victory" occurs in the game as a more animated visual and text component along with a more exciting auditory component to indicate that the player has earned 3 units. Victory experiences increase in intensity as players earn units, then badges, and eventually win the game. See Table 1 for a matrix of the challenges, disciplinary areas, difficulty levels, and game elements.

The game includes challenges that use four different game elements or mechanics: collaboration, narrative/story, surprise, and tool use.  Each of these elements provides a novel experience during gameplay and is designed to add to the player's perception of fun and enjoyment of the individual challenges and the overall game.

The game is intended to be played by two partners sharing the iPad and standing shoulder-to-shoulder for discussion and collaborative gameplay.  There are also seven challenges which require collaboration among more than one pair or sharing challenge solutions with the whole group.  Players use the Notebook feature in ARIS to take pictures, record audio or video, and create text notes which can then be shared with the whole group, tagged, "liked", and commented on.  These collaborative challenges are designed to give players an experience that mimics participation in the "big S" scientific community: sharing work and receiving feedback from peers.  Such collaboration and sharing also provides players the opportunity to experience in-game emotions that can be described as "people fun", or amusement that comes from communicating, collaborating, or competing with others (Lazzaro, 2004).

Three challenges involve a narrative or story-based game element.  Narrative is an effective way to emotionally engage players (Schell, 2008).  Players will strive to succeed in a game to find out what happens or to influence how the story moves forward.  All three narrative challenges involve solving a mystery that has supposedly occurred at the science center.  The Crime Lab and Dino Lab challenges are connected by the mystery of a missing dinosaur skull; players collect evidence in the Dino Lab and take it to the Crime Lab for analysis and to solve the mystery.  The third narrative challenge involves a mysterious bird call heard by the Animal Keeper in the Nature Center that players are asked to help identify.  Players must collect a recording of the mysterious bird call in the Nature Center and move to the Bird Treehouse on the other side of the science center to use the computer database that will allow them to identify the mystery bird by its call. Not only do these three challenges involve a storyline, but they also require players to move from one part of the science center to another to solve the challenge.

Three challenges do not appear on the game map. These three are designed as bonus or surprise challenges that a player may or may not ever find. QR codes were hidden at The Giant Maze, Mr. E Hotel, and Brain Puzzles to be discovered by the most observant players. Jesse Schell (2008) defines fun as “pleasure with surprises”, and the bonus challenges are designed to provide an element of surprise along with giving players further options on their unique path to winning the game.

Another three challenges are designed to be aided by use of a physical tool, such as a compass, measuring tape, stopwatch, magnifying glass, or calculator. Virtual versions of the tools were hidden around the science center like “easter eggs” for players to find. Finding a virtual tool is another type of pleasurable surprise for the player and should add more fun to the game. Virtual tools that are found can be traded for the actual physical tool at The Great STEM Caper headquarters during gameplay. The measuring tape and stopwatch can be used to solve the Ball Ramp Challenge; the compass is required for solving the hardest challenge at the Unplugged exhibit; the calculator is quite helpful for solving the Sky Bike Challenge; and the magnifying glass can aid players in identifying the fingerprint at the Crime Lab. Figuring out how a physical tool might be used to solve a challenge may be equated with a mastery experience that should lead to increased self-efficacy.

This study was designed to explore the relationships between a player’s perception of challenge difficulty, their enjoyment of the challenges and the overall game, the level of victory experienced within the game, the intensity of their fiero experiences, and their change in science self-efficacy after playing the game. According to Jane McGonigal (2011) “fiero” is the Italian word for “*…what we feel after we triumph over adversity. You know it when you feel it – and when you see it. That’s because we almost all express fiero in exactly the same way: we throw our arms over our head and yell.”* To collect the most reliable feedback from players regarding their perceptions of difficulty, enjoyment, and fiero associated with individual challenges, the data collection device was embedded within the game itself. After each victory within the game, players were immediately taken to a three-item questionnaire that asks them to rate the difficulty of the challenge, how much “fun” the challenge was to complete, and how intensely they experienced “fiero” upon completing the challenge. All three constructs were measured on a 5-point Likert scale using a digital survey viewed within the game. It is important to note that data from the in-game surveys will reflect the responses of the pairs and not of individual students. For statistical analysis, each individual student will be assigned the responses selected by the pair. This is a trade-off to maintain the collaborative intent of using one iPad per pair of students while still gathering temporally more reliable in-game data.

**Playtesting**

During Phase 1 playtesting, one child in a game-pair wore a “Go-Pro” camera on his/her forehead to record high-definition video of the player perspective throughout gameplay. The GoPro affords the researcher a view of the player’s interaction with the game on the iPad, their interactions with the exhibits, as well as interactions with their partner and other players. The purpose of playtesting was to ensure that the game functions as intended and to gather children’s perceptions of the overall game and the individual challenges within the game. Playtesting was also important to confirm that the game could be successfully completed in less than two hours, the average length of a school field trip to the science center. Informal interviews following the playtesting sessions asked players to reflect on the level of fun and difficulty that they experienced during the game as well as their suggestions for improvement.

## Phase 2

### Pilot-testing, and Adjustments to Game and Research Protocol

After several rounds of small-group playtesting and game adjustments, the game was pilot-tested with a school group of seventeen 8th grade students. The pilot-test focused on the feasibility of large group gameplay; the social, collaborative components of the game; and digital survey data collection. The school group pilot-test included both pre- and post- surveys administered on-site via the iPads. The pre-game survey was the Motivation to Learn Science Questionnaire (Glynn & Koballa, 2006). Post-game surveys included the MLSQ as well as items asking players to rate the level of difficulty and enjoyment they experienced during the overall game. The post-survey also included open-ended items that asked students to share what they liked about the game, what they didn't like, what they thought they learned through playing the game, and their suggestions for improving the game. Although gameplay occurs with two students sharing one iPad, each student completed the surveys individually on separate iPads. As per the research protocol, one male pair and one female pair of players wore the Go-Pro camera during the school group pilot test to record high-resolution video and audio of the player perspective. Three stationary video cameras were also installed to record player interaction with specific exhibits: 1) CityPark/ Unplugged, 2) Giant Lever, and 3) Crime Lab. Pilot-test data was used to make final adjustments to the game and the research design before launching the quasi-experimental phase of the study.

As a result of the pilot-test, the stationary video cameras were removed from the research design. Due to the noisy nature of the science center, the stationary cameras were unable to record meaningful audio. Furthermore, the cameras had to be securely positioned in safe areas that could not provide highly valuable video footage, either. Most footage contained nothing relevant: e.g. many long stretches of no action or other science center visitors hamming for the camera. It was determined that the stationary cameras were not contributing valuable data and their use was discontinued.

It became clear during the pilot test that participants had difficulty figuring out how to play the game without instruction. Although an animated video at the beginning of the game explains the game's objectives, it did not explain the game's mechanics. Furthermore, the noise level in the science center made it difficult for participants to hear the video running on their iPad. As a result, not one team during the pilot test solved a challenge. To remedy this discouraging situation, an orientation was introduced during the quasi-experimental phase of the study. The orientation began with the whole group watching the introductory video projected on a large screen with audio amplified. Afterward, the researcher explained the mechanics of the game and projected a qr code for an Introductory Challenge. Players scanned the code to launch the challenge which asked players to take a picture of their team, give themselves a team name, and share the picture with the group. Completed with or without support, this challenge allowed all participants to interact with the game mechanics (i.e. scanning a code, reading a challenge, using the Notebook to solve the challenge, etc) and successfully earn a Technology Skill Unit before venturing out into the science center with their partners to play the game. This simple adjustment to the research protocol resulted in many phase 3 teams successfully completing the game.

### Phase 3

After final adjustments to the game design and research protocol, eleven separate student groups were brought to the science center to participant in the final mixed-methods, quasi-experimental phase of this study. Both quantitative and qualitative types of data were collected to support triangulation of conclusions to the research questions. Quantitative data were collected via the Likert-type pre/post survey of participants' affective beliefs about learning science (i.e. the MLSQ) as well as through in-game rating of the difficulty, fun, and fiero experienced with individual challenges. In addition, quantitative data were collected from each pair's game performance: number of challenges completed, number of skill units earned, number of badges achieved, and whether the pair won the overall game or not. Data included post-visit interviews with a sample of students from both the game and comparison groups; open-ended items on the post-survey; and video data from the GoPro cameras worn by one male pair and one female pair during each trial. Data from Phase 3 were used to compare outcomes between the game group and the comparison group. The game group played The Great STEM Caper during their visit and the comparison group explored the science center in the traditional manner.

**Research Protocol**

Both the game and comparison groups were instructed to complete the pre-visit MLSQ 1-2 weeks before their scheduled visit to the science center. Upon arriving at the science center, participants in a game group were given a whole-group orientation to the game. This orientation included an animated introductory video, overview of the rules for visiting the science center, assignment of a same-sex partner, assignment of an iPad to each pair, and an introductory challenge designed to familiarize the participants with the nature of the game and its mechanics. Participants in comparison groups were also oriented to the rules for visiting the science center and paired with same-sex partners before being released to explore. Both groups completed the post-visit survey on-site before departing from the science center at the conclusion of their visit.

Students in both groups were asked to volunteer to wear the Go-Pro camera during their science center visit.  One male pair and one female pair wore the Go-Pro and were told that they could switch the camera from one partner to the other after one hour (a.k.a.  the halfway point). In reality, participants often gave the camera to another participant who was not their partner, but as requested, they always gave it to another of the same sex.  The Go-Pro recorded the individual student's perspective as they interact with the exhibits, the game, and other people (i.e.  players, teachers, or science center staff).  Because players collaborated in same-sex pairs, the video also provides a window into gender differences in gameplay and interactions.  This first-person data is especially useful for observing players' problem solving strategies as well as their immediate reactions to in-game frustrations or victories.  Finally, from a design perspective, video of the player's perspective while interacting with the game itself can be used to identify strengths and shortcomings of the game's user experience.  Such data provides evidence that will be used to improve future game design.

One to two weeks following their visit to the science center, a sample of boys and girls from every group were individually interviewed at the students' schools or meeting sites about their visit experience.  Interview questions focus on students' perceptions of the science center visit and the game (if participant was part of a game group).  Questions ask specifically about what they particularly liked or disliked and how the visit and/or the game could be made more enjoyable or educational.  Finally, interviewees were asked if they would like to visit the science center again, and if so, if they would prefer to play a game or to explore on their own.  Both comparison and game group interview protocols are included in the appendix.

**Instrument**

To measure potential change in students' science interest, self-efficacy, and motivation to learn, pre- and post-visit surveys will be given to both groups. The Motivation to Learn Science Questionnaire (MLSQ) includes 20 1-to-5 Likert-type items divided into four categories: self-efficacy, interest and enjoyment, connection to daily life, and importance to the student (Barak, Ashkar, & Dori, 2011). The integrity of the instrument was maintained, but for this study only the subscales for self-efficacy and interest as well as the overall motivation score was analyzed. Barak et al (2011) adapted the Science Motivation Questionnaire (SMQ) (Glynn & Koballa, 2006) to create the MLSQ for elementary students because the original SMQ targeted college students. When administered to 1,335 4$^{th}$ and 5$^{th}$ grade students, the MLSQ exhibited a Cronbach's Alpha coefficient for internal consistency of 0.88, a very good indicator of the instrument's ability to collect data reliably (Barak et al, 2011). Cronbach's Alpha coefficient for this study's sample of 120 5$^{th}$-9$^{th}$ grade students was 0.94, a highly reliable instrument in this case as well. Furthermore, a digital version of the Likert-type survey was easily administered using the touchscreen interface of the iPad. The MLSQ is a proven instrument for quantitatively measuring students' science interest, self-efficacy and motivation to learn.

## Quantitative Analysis

An analysis of covariance between the pre- and post MLSQ scores was conducted to determine if playing The Great STEM Caper had an effect on students' science self-efficacy, interest, or motivation to learn. The game and comparison groups were intact, non-randomized groups coming to the science center. In addition, the two groups' scores on the pretest were significantly different. To take these pretest differences into account, change scores from pre- to post- were used to determine if the groups experienced different outcomes from their visit to the science center. Change scores of the overall MLSQ and the subscales of self-efficacy and interest/enjoyment were analyzed using independent sample t-tests. Likewise, independent sample t-tests were also used to compare change scores between boys and girls in the game group.

A comparison of means was conducted for the two groups' perceptions of how much they thought they learned during the visit and how much they enjoyed it. Game group participants were also asked how much they enjoyed the game. Gender differences were explored through a comparison of means between boys' and girls' responses. A test of correlation was conducted between players' in-game report of challenge enjoyment, difficulty, level of victory experienced, and their change in self-efficacy from pre- to post-visit as measured by the MLSQ. These correlations were also analyzed by gender.

Players' level of achievement in the game and was determined by the number of challenges completed, number of skill units earned, number of badges achieved, and whether the player won the game or not (a.k.a. earned 7 skill units). Girls' and boys' game performance were compared using statistical means and modes.

## Qualitative Analyses

In addition to the quantitative survey and game-performance data, this study also included several types of data that were analyzed qualitatively. The data included GoPro video, responses to open-ended questions on the post-survey, and follow-up interviews with a sample of participants. Still photographs taken by the researcher, as well as those taken on the iPad by participants, are also included in the data available for qualitative analysis. During each group's visit to the science center, one male pair and one female pair volunteered to wear the GoPro camera for the duration of the visit. This resulted in approximately 40 hours of high-definition, first-person video and audio footage that served as a window into the behaviors of boys and girls as they played the game and/or explored the science center. In addition, a total of 28 participants from both the comparison and game groups, were individually interviewed within 2 weeks of their visit to the science center.  Finally, open-ended post-survey questions were used to collect qualitative responses from every participant immediately before each group departed the science center.

The data were analyzed qualitatively to deepen understanding of the quantitative results. The video data allowed the researcher to observe first-hand how participants played the game. For the most part, participants appeared to act naturally while wearing the GoPro camera and did not seem to behave as though anyone were observing them.  There were many incidents of camera-wearing participants running through the science center after being instructed to walk, or uttering mild obscenities when there was not an adult physically present in the near vicinity. Some participants also made faces in the camera when it was first used, but these behaviors stopped as students engaged in the museum.  It appears that a researcher can use these small body-mounted cameras to observe a subject without much interference with natural behavior. The video allows the researcher to interpret behavior directly, rather than rely solely on self-reported perspectives from interviews and survey questions.  The video was a valuable data source for observing how participants actually experienced aspects of the game that were of research interest: How do participants perceive the game?  What are their experiences of fun, learning, difficulty, and victory within the game?  Do boys and girls experience or perceive the game differently?  Do boys and girls perceive their game performance differently (i.e.  self-efficacy)?  The video was the primary source of data for observing players' victory experiences, and allowed the researcher to observe participants' reactions first-hand.

The open-ended questions on the post-survey provided more insight into the perspectives of participants than the quantitative data allowed.  One of the key affordances of the open-ended questions was that they were asked of each and every participant, providing corroboration for more lengthy and detailed responses received during the sample of interviews. Both the open-ended survey responses and the interviews were the primary source of data for answering the research questions focused on participants' perceptions of gameplay – specifically fun, learning, and difficulty.

## General Inductive Analysis Approach

All of the video data were analyzed using a general inductive approach. Specifically, I followed the approach described and outlined by Thomas (2003). The purpose of general inductive analysis, as described by Thomas, is to 1) condense extensive and varied raw data into a brief summary format, 2) to establish clear, transparent , and defensible links between the research objectives and the finds derived from the raw data, and 3) to develop a model or theory about the underlying structure of experiences which are evident in the raw data (p. 2). According to Thomas, "most inductive studies report a model that has between three and eight main categories in the findings" (p. 5).I used this as a guide in determining how many categories I should end up with. The general inductive approach includes some underlying assumptions. The primary assumption is that data analysis is determined by both the research objectives as well as findings arising directly from multiple readings and interpretations of the raw data. To quote Thomas (2003), "The primary mode of analysis is the development of categories from the raw data into a model or framework that captures key themes and processes judged to be important by the researcher" (p. 3). Furthermore, Thomas explains that establishing the trustworthiness of the findings can be done through triangulation within the project. The next paragraph describes the features of categories developed during general inductive analysis and the process of inductive coding.

General inductive analysis results in the development of categories into a framework that summarizes the raw data and conveys key themes. The core of inductive analysis are the categories that result from the coding. These categories have four key features: a label for the category, a description of the category, text or data associated with the category, and links between categories (such as a hierarchical system) (Thomas, 2003). The process of inductive coding includes the following procedures: 1) preparation/cleaning of the raw data, 2) close reading of the textual data, 3) creation of categories, 4) overlapping coded and uncoded text, and 5) continued revision and refinement of the category system (Thomas, 2003). The "creation of categories" requires a bit more explanation. According to Thomas, it is the research objectives that determine the categories. The upper level categories are usually derived from the research aims, while the specific lower level categories, which I refer to as "codes" in this project, are derived from multiple readings of the raw data, also known as "in vivo" coding. I used a hierarchical organization scheme in which codes were organized under the upper level categories, as well as sometimes being "sub-codes" of other codes. As Thomas explains, "The intended outcome of the process is to create three to eight categories which, in the coder's view, captures the key aspects of the themes in the raw data and which are assessed to be the most important themes given the research objectives" (p. 5). Based on this explanation, I determined that I should be working toward developing three to eight key themes that captured the essence of the data as represented by the upper level categories and their lower level codes.

In qualitatively analyzing the data in this project, I followed the general inductive analysis procedures outlined by Thomas. Data were prepared for analysis in stage one. During stage two, interview transcripts were read once and initial categories and codes created. Multiple close readings of all data were conducted during stage three, which continued until analysis ceased to render anynew codes. During stage four, codes were examined for redundancy and overlap. Many codes were combined with others during stage four and new categories were formed for codes that seemed related. Major themes began to emerge through analysis during stage four. During the fifth and final stage, codes, categories, and themes were compared by frequency of reference to determine what findings and major themes the data suggest. Table 1 provides a brief outline of the five stages, which are described in detail in the next section.

Table 1

*Overview of Qualitative Coding Process*

| **Stage 1:** **Raw Data Prepared for Analysis** | **Stage 2A:** **Every Interview Source Assigned Two Classification Codes** | **Stage 2B:** **Initial Read-through of Interviews** | **Stage 3:** **Multiple and Close Readings of ALL Data** | **Stage 4:** **Reduce Overlap and Redundancy Among the Categories** | **Stage 5:** **Examine Frequencies, Decide what is Most Important** |
|---|---|---|---|---|---|
| 1. Interviews transcribed, uploaded to NVIVO;<br>2. videos uploaded to NVIVO, then summar-ized;<br>3. open-ended survey responses uploaded to NVIVO | 1. Male or Female<br>2. Game or Comparison | 1. 15 codes for exhibit challenges<br>2. Creation of upper level categories derived from research aims. ≈7 (fun, engagement, learning, difficulty, science & engineering practices, iPad, and GoPro) | 1. Additional 7 codes for exhibits without challenges<br>2. Lower level codes emerge from data. ≈60<br>3. Introduction of Lazzaro's 4 Keys to Fun as subcategories of the upper level fun category | 1. Combine similar codes and categories<br>2. Further organize codes into categories. | 1. Lazzaro's 4 Keys are identified as a good fit framework for the most important themes that emerged from the data.<br>2. A total of 45 codes and categories are combined under the 4 Keys framework. |

## Five Stages of the Coding Process

**Stage One.** The first stage may be better described as pre-analysis. During this stage, the raw data from interviews, open-ended survey questions, and video footage were prepared for analysis. All interviews had been digitally recorded and uploaded into NVIVO. Interviews were transcribed verbatim in NVIVO so text and audio were linked. Video footage was dealt with in a similar manner. Video files were uploaded into NVIVO and were then summarized, with interactions particularly relevant to the research questions also being transcribed verbatim. Still photographs taken by the researcher, as well as those taken by participants with the iPad during gameplay, were uploaded into NVIVO. Online survey data were exported from Survey Monkey and uploaded into NVIVO. After all data had been imported into NVIVO and properly prepared, the analysis moved into stage two.

**Stage Two.** During stage two, the interview transcripts were the first data to be given an initial read-through. As a result, four tasks developed during stage two. The first two tasks were to classify every interview source as either game or comparison, and male or female. The third task was to create codes for each of the 15 exhibit challenges were created: Ball Ramp, Bird I.D., Brain Puzzles, Crime Lab, Dino Lab, Giant Lever, Giant Maze, Mr. E Hotel, Maker Bridge, Music Park, Nature Center, Rocket Launch, Sky Bike, Unplugged, and Water Table Although the research questions for this particular study do not focus on interactions with specific exhibits, it is important for future analysis that the data be tied to the exhibit at which it took place. By coding every reference, interaction, or behavior to the corresponding exhibit, future analysis may be able to uncover trends in behavior related to specific exhibits or challenges.

After the initial read-through of the interview transcripts, the fourth and final task of stage two was to create upper level categories derived from the research objectives as well as the data. The original upper level categories that were identified included fun, engagement, learning, difficulty, science & engineering practices, iPad, and GoPro. “Fun” refers to something—such as an exhibit, activity, situation, or interaction--that was perceived as enjoyable, amusing, or entertaining. The upper level category of “engagement” was used to group data that describe to what and how participants allocate their attention. Any data that referenced the acquisition of new knowledge, skills, or understandings was put under the category of “learning”. The category of “difficulty” was used for instances that referred to perceived obstacles to success within the game. “Science and engineering practices” was the category for data that referenced behaviors that aligned with any of the eight NGSS science and engineering practices. The two technology categories were included to afford a focus on a design element of the study (i.e. the use of iPads to deliver a collaborative, exhibit-based game) and the research methods (i.e. use of the head-mounted GoPro to collect video data from $5^{th}$-$8^{th}$ graders in a museum setting). Any data that concerned perceptions or functionality of the iPads was put under the “iPad” category. And finally, any data that concerned the perceptions or functionality of the GoPro camera was put under the “GoPro” category. These first codes and categories were in place after the initial reading of the interview transcripts. Table 2 outlines these initial upper level categories, descriptions for each, and examples of coded text that illustrate the meanings and perspectives associated with the category.

Table 2

*Initial Upper Level Categories*

| **Upper Category Label** | **Description** | **Example from Data**<br>**Red=survey, blue=interview, green=video** |
|---|---|---|
| Fun | A reference to something—such as an exhibit, activity, situation, or interaction--that was perceived as enjoyable, amusing, or entertaining. | *It was the most fun I've had out of all my visits*.<br>*It was fun; I like that we got to pick our own groups.*<br>*I don't care, this isn't about winning, this is about having fun! [gasp] This is so cool! [looking at water table]* |
| Engagement | Data that describe to what and how participants allocate their attention; including comments from participants about how engagement could be improved | *[I liked] finding the QR codes and scanning the codes to get quests.*<br>*I like how it involved technology and science and how you got to go around all of science city and explore everything and do quests and solve problems with real things.*<br>*Boy 1: I'm making this puzzle. This is for extra points. Boy 2: You mean we don't even have to do this? Then let's go! You guys wasted about 5 minutes!* |
| Learning | A reference to the act or state of acquiring new knowledge, skills, or understanding | [In response to survey question, "What would have made the visit to the science center more educational?]<br>*Actually paying attention to stuff*.<br>*Oh you know the thing with the solar, it had those bulbs that you had to wind, there was this whole thing of houses and stuff in the middle, and I learned that the city gets powered more if the solar panels are faced a certain direction.*<br>No instances of "learning" coded in video |
| Difficulty | A reference to encountering particular obstacles to successfully playing the game. Subcategories were identified immediately. | *[I liked] that there where different things to do on the game, but sometimes it was hard to scan some of the scanners. And it was fun to find the quests but also difficult.*<br>*It was really long, and some of the questions were confusing, even though I scanned the codes.*<br>*Ugh! This is hard! Is there any other instrument besides these?* [She tries the xylophone again. Then back to the hand pipes.] *I can't do it.* [She reads the entire Music of Learning sign in the Music Park. Then back to the drums. Partner is not doing anything except holding the iPad.] *Oh my goodness! It's hard! You wanna skip this and come back? Yes!* |

| Upper Category Label | Description | **Example from Data**<br>**Red=survey, blue=interview, green=video** |
|---|---|---|
| Science & Engineering Practices | Any behavior (or reference to a behavior) that is described by the NGSS dimension Science & Engineering Practices, specifically:<br>1. Asking questions (for science) and defining problems (for engineering)<br>2. Developing and using models<br>3. Planning and carrying out investigations<br>4. Analyzing and interpreting data<br>5. Using mathematics and computational thinking<br>6. Constructing explanations (for science) and designing solutions (for engineering)<br>7. Engaging in argument from evidence<br>8. Obtaining, evaluating, and communicating information | No instances of "science and engineering practices" coded in survey responses<br>*I like that, uh, water thing! Where you got to create more paths and everything. And build...* (Tell me why you like that the most.) *Cause it's more thinking and you have to think to where to get it to go how you want it. You get to make your own ideas, how to control stuff, and build water pressure.*<br>*Boy 1: Hey, let me start the race, give me two objects!...here, a boat and a dolphin...alright, I'm gonna start them right here...oh, the boat sunk!...Boy 2: Try the one that he made and the one I made to see which one goes faster...Boy 1: Okay, okay...and this boat goes with mine because it's probably bigger than that other boat...okay, 1, 2, 3...mine's gonna go faster...Boy 2: hey you pushed it!...Nooo! We need more power! Oh, yours is smaller, that's why it goes faster.* |
| iPad | An explicit reference to or interaction with the iPad; especially those that were not neutral | *The game was okay, but I kept having issues with the iPad, that was kinda boring*.<br>*I liked the iPads and how you got to run around and try to figure out the mysteries.*<br>*Ah, the iPad gets kind of heavy, after a while...* |
| GoPro | An explicit reference to or interaction with the GoPro camera; especially those that were not neutral. | *I liked that you could take pictures and videos. I also liked the camera on my head. I wonder if I could see the video.*<br>[In response to, "What did you enjoy most about your visit to the science center?] *Where you get to wear the camera on your head and record everything.*<br>*Aw, let me wear it, let me wear it!* (Boys trade camera and adjust the fit.) *Does this look okay?* (Takes the camera back off again and holds it at arm's length for a selfie smile. Holds the camera in his hands and plays with it for a minute, then gives camera back to first boy who puts it back on. Second boy helps him adjust the angle.) |

**Stage Three.** During stage three, all of the data, including interview transcripts, video summaries, and open-ended responses were subjected to multiple close readings, with data chunks being assigned to one or more of the initial categories. Consistent with general inductive analysis, there were sections of text that did not contain any data to categorize or code, as well as sections of text that were assigned to more than one category and/or code. Many new codes emerged during this process, as well.

Seven additional codes emerged for exhibits that did not have a corresponding challenge in the game and were categorized as "Outside the Game" exhibits. These exhibits included a real helicopter, Science on a Sphere, checkers/chess, shuttle simulator, whisper dishes, trains in the KC Rail Experience, and the Maker Space. The Maker Space was actually off-limits to participants during the study, but a few wandered in or looked at it through the window. Otherwise, most of the "Outside the Game" exhibits were excluded from the game because they did not lend themselves to engagement through science and engineering practices. At the end of stage three analysis, there were 22 exhibit codes: the 15 exhibits with corresponding challenges within the GSC game, and 7 additional exhibits that were not associated with game challenges. Table 3 outlines the Challenge Exhibits and the "Outside the Game" exhibits, as well as the frequency with which they were referenced in the data.

Table 3

*Science Center Exhibit References*

| Challenge Exhibits | References | Outside the Game Exhibits | References |
|---|---|---|---|
| Nature Center | 109 | Helicopter | 30 |
| Giant Lever | 74 | Science on a Sphere | 18 |
| Dino Lab | 71 | checkers/chess | 7 |
| Mr. E Hotel | 62 | shuttle simulator | 6 |
| Sky Bike | 61 | whisper dishes | 3 |
| Unplugged | 53 | trains (KC Rail Experience) | 3 |
| Music Park | 50 | Maker Space | 2 |
| Water Table | 39 | | |
| Bird ID Treehouse | 37 | | |
| Crime Lab | 31 | | |
| Rocket Launch | 26 | | |
| Ball Ramp | 16 | | |
| Brain Puzzles | 15 | | |
| Giant Maze | 11 | | |
| Maker Bridge | 4 | | |

Approximately 60 additional perception and/or behavior codes were also identified during this phase. Read-throughs continued until all significant codes had been identified. All emergent codes and categories are described in detail in the paragraphs that follow, as well as in Tables 4-9. Throughout stage three, it became apparent that the original upper level categories of fun, engagement, learning, and difficulty would need to be further divided into sub-categories that would more meaningfully reflect the content of the data. It was at this time that Lazzaro's 4

Keys to Fun (2004) were first recognized as a probable good fit for describing players' motivations, behaviors, and perceptions of the game. Together, these four types of fun (i.e. hard fun, easy fun, serious fun, people fun) became the first important theme to emerge as chunks of data were being grouped under the original category of "fun" [see Table 4].

Soon after the categories for fun had been determined, codes under each type of fun began to emerge. As part of this study's hypothesis, "fiero" was a construct that immediately became a code under the category of hard fun. Similarly, the ping-pong effect had been predicted, and was included as a code under the category of easy fun. Unique to this project, however, was a phenomenon that can be described as "code scanners". Code scanners are game group participants who enjoyed finding and scanning the QR codes without solving the corresponding challenges. "Code scanners" fell under the category of easy fun, as well. Social interaction, collaboration, and competition were all codes that emerged early on in the analysis process and were classified under the category of people fun. Serious fun remained without any codes until stage four of the analysis. Table 4 lists the four primary categories of fun, their initial corresponding codes, provides a description of each construct, gives examples from the data as well as the number of references associated with each subcategory. Reference numbers for the primary categories of hard fun, easy fun, people fun, and serious fun are not given because those primary categories ultimately included many more codes than those initially listed at this early stage of analysis.

Table 4

*Lazzaro's Four Types of Fun Theme*

| Subcategories for Fun | Description | Example from Data<br>**Red=survey, blue=interview, green=video** | References |
|---|---|---|---|
| **Hard Fun** | Enjoying the pursuit of challenge, mastery, or sense of goal accomplishment. | *I liked that we got to go around and try new challenges involving science....I actually had a lot of fun. I also thought it was cool to try to figure out some of the challenges, like the musical game. It was fun but hard at the same time.* | N/A |
| ● Fiero | An instance of exultation as a result of accomplishment. | *"See, I did it, I did it...The maze! I made it!*<br>*Oh, oh, oh, I got it! I got it! You made it! Got it! Oh, oh, oh,"* doing a victory dance, then, *"Go all the way on the outside...naw, I'm just joking, see you made it. Ta da! We're awesome!"* (high five) | 65 |
| **Easy Fun** | Enjoying exploration, fantasy, imagination, and role play. Enjoying the controls of a game: a.k.a. scanning codes | [What would have made your visit to the science center more fun?] *Food! Glow in the dark. Hide & Seek. Scavenger Hunt.* | N/A |
| ● Ping-pong effect | Bouncing from one exhibit to another without engaging in meaningful interaction. | Stops at scarf hurricane tube, and then pushes buttons at model train set, *"Look! look! Hey let's go in here! Have you been in the tunnel with the little slide? We crawled up in here, dude! Come on, let's go! Let's go!" "Wait, hold up!* Looking at iPad, then boys crawl into tunnel. | 117 |
| ● Code scanners | Enjoying searching for, finding, and scanning QR codes without engaging in the challenge that follows. | What was your favorite thing about your visit to the science center? *Finding the QR codes and scanning the codes to get quests.* | 92 |
| **People Fun** | Enjoyment of being with friends, building social bonds, and teamwork. | *It was actually pretty fun, I got to spend some time with some friends. Like this kid that I didn't really know, he's basically in like 3 or 4 of my hours, but I don't really talk to him very much, because you know, he's somewhat like, not very good sometimes? Um, I got to, he was my partner, but he was actually pretty good.* | N/A |

| Subcategories for Fun | Description | Example from Data<br>Red=survey, blue=interview, green=video | References |
|---|---|---|---|
| • Social interaction | General enjoyment of being with friends. | *I think just being with my friends was the most fun part, and then going into the Nature center area and seeing the staff hold different animals.* | 213 |
| • Collabor-ation | Enjoyment of working together with others to achieve a goal. | *Girl 1 brings the QR code to the group and offers it for scanning before she has to go put it back at Melody Park. Girls 2 and 3 scan it.* | 256 |
| • Competit-ion | Enjoyment of being better at something than someone else. | *I liked how the QR codes were hidden, cause some people were like, "Where are they?" and I was like, "Nope, you have to find them yourself!"* [So you weren't going to help them?] laughs, *Cause we were competing!* | 94 |
| **Serious Fun** | Enjoying something that changes the way one thinks, feels, or behaves in the real world. | *It was fun because you got to learn about science more.* | N/A |

Codes within the learning category (7) emerged through data analysis without any pre-existing framework. The Great STEM Caper was purposefully designed to encourage player engagement in science and engineering practices, rather than to study, measure, or increase content knowledge. Likewise, the science center describes itself as an "engaging environment ripe for exploration, experimentation and discovery" (http://www.unionstation.org /sciencecity/ about). Most participants reported having learned during their visit to the science center. Participants cited the hands-on nature of the exhibits as contributing to both fun and learning. When asked for suggestions about what might make the experience more educational, many participants suggested that there be more expert guides (i.e. docents) to talk to them about each exhibit. Some participants took note that the game encouraged them to pay closer attention to the exhibits, and that they had learned more as a result. Finally, there were a few suggestions to include more mathematics in the game. Table 5 describes the subcategories for learning, provides examples from the data, and lists the number of references within the data.

Table 5

*Emergent Codes Under the Learning Category*

| **Parent Category** | **Learning Codes** | **Description** | **Example from Data** **Red=survey**, **blue=interview**, **green=video** | **References** |
|---|---|---|---|---|
| All Learning Subcategories subsumed by Serious Fun | +learning | A positive reference to the act or outcome of acquiring new knowledge, skills, or understanding during the visit to the science center. | *It was fun because you got to learn about science more.* | 66 |
| | -learning | A negative reference to the act or outcome of acquiring new knowledge, skills, or understanding during the visit to the science center. | *Sometimes I didn't get what I was supposed to be learning from the exact activity.* | 11 |
| | +docent/tour guide | A suggestion that including more explicit, verbal explanations of the exhibits given by an expert would result in more learning. | [What could make your visit to the science center more educational?] *More people to tell us what things are about.* | 17 |
| | paying close attention | An explanation that having one's attention focused on a particular aspect of an exhibit supports learning. | *If you're sitting in a room, you can notice some things, but if you pay closer attention you can notice more.* | 6 |
| | +hands on | An explanation that engaging with the exhibits in a physical way supports learning. | *I just liked the stuff I could goof around with, like play with and goof around with.* | 5 |
| | more math | A suggestion that including more mathematics related problems would result in more learning. | *There wasn't a lot of mathematics in it, it was mostly like science and tech, so I think it would be a lot cooler if there were more mathematics.* | 4 |

Codes began being assigned to the "difficulty" category almost immediately. There were many references to the game being "too hard" and players often described themselves as feeling "frustrated" at particular points during the game. Sometimes the game was described as "too easy", but even these instances seemed to reflect the general feeling that the game was not aimed at the right skill level for several participants. Some participants described the game as having too many challenges. Finally, a few participants suggested that the game could take players' self-reported skill level into account and offer a customized play experience. This aligned with the suggestions from players who wanted to be able to access hints, manuals, and more scaffolding. Table 6 displays the codes that were grouped under "difficulty", their descriptions, an example, and the number of references found in the data.

Table 6

*Difficulty Codes Categorized Under Hard Fun*

| Parent Category | Difficulty Subcategories | Description | Example | References |
|---|---|---|---|---|
| All Difficulty Subcategories Subsumed by Hard Fun | Frustration | Reference to reaching a point of no discernable progress when attempting to solve a problem or challenge. | *It would get boring, at some time, or I mean, frustrating and confusing.* | 101 |
| | too hard | Reference to challenges or the game overall is as being beyond the skill level of the participant to complete successfully. | *Make the quests a little bit easier, like easier to understand and stuff.* | 56 |
| | too easy | Reference to the challenges or game overall as not being challenging enough to the participant. | *The quests could be a little more challenging.* | 8 |
| | too many | Reference to the suggestion that players be required to complete fewer challenges as a way to make the game more engaging. | [What could make the game more fun?] *If the game was a little easier, or had one less problem.* | 8 |
| | customization | Reference to the suggestion that players be able to request hints or choose to play at different predetermined levels. | *If you had a button that said your age, like if you have certain ages, like 8 and under, 8-12, 12 and up, like for certain grades, cause we already know half of you're explaining.* | 3 |

By far, the largest initial upper level category was "engagement." No fewer than 29 codes were classified under engagement when they were first identified. In fact, the category of engagement essentially became a catch-all for many new codes before the trend was noticed. After the issue was identified, though, it was evident that many of these codes would need to be reassigned under other categories or might coalesce into new codes through further analysis. Table 7 lists the subcategories for engagement with a description, examples from the data, and the number of references that occurred. The left-most column designates to which category the theme was ultimately assigned during stage four.

Table 7

*The Catch-All Engagement Category, with Ultimate Parent Category Assignments*

| **Parent Category** | **Subcategories for Engagement** | **Description** | **Example from Data** **Red=survey, blue=interview, green=video** | **References** |
|---|---|---|---|---|
| Serious Fun | +reading | An instance of or positive reference to reading the challenges or exhibit signage. | *It could be more educational if every student read the descriptions on the area they're at.* | 51 |
| Easy Fun | +moving around | A reference to enjoying the highly mobile nature of the game and/or the visit. | *I enjoyed the game, how you got to walk around and do it, like you actually got to get up and walk around and take pictures with it and stuff like that. It had you into it, cause if you sit there and you're just doing it, it don't {?} cause you're just sitting there doing it, but as you're walking around and being active with it, you stay into it.* | 48 |
| Easy Fun | +QR code scanning | An instance of or reference to enjoying scanning the QR codes. | *I liked how the game was interactive, and you had to go to the QR scanner to actually scan the codes, and there were a lot of them, so if you just scanned as many as you could and then went to do the quests, I don't think you would get it done.* | 46 |
| Hard Fun | adult help | An instance of receiving adult help during gameplay. | They head back over to Cecelia, who says *"I found it! It was Becky!" How did you know it was Becky? "Because* | 45 |

| Parent Category | Subcategories for Engagement | Description | Example from Data<br>Red=survey, blue=interview, green=video | References |
|---|---|---|---|---|
| | | | *her fingerprint matches."* How did you match it? *"Because a teacher helped me!"* | |
| Hard Fun | Confusing | A reference to being confused by the game. | *The only thing I didn't like about this is that the quests were sometimes confusing and I didn't understand what do.* | 40 |
| Easy Fun | -QR code scanning | An instance of or reference to difficulty finding and/or scanning the QR codes. | *I did not like the fact that the barcodes were hard to find I never found the one in the astronaut center and that bugged me a whole lot.* | 37 |
| Hard Fun | more codes/challenges | A suggestion for improving the game by providing more codes and challenges. | [What would have made the game more fun?] *Maybe just a few more of the codes and a few more quests in other places, because there wasn't one in every place we went to.* | 35 |
| Serious Fun | +science | A reference to liking/enjoying science. | *I enjoyed a lot of things; I've always liked science, so I found a lot of things there very interesting.* | 20 |
| Hard Fun | more time | A suggestion to provide more time to improve the game and/or visit experience. | [What would have made your visit to the science center more fun?] *More time to be here playing.* | 18 |
| Easy Fun | Distraction | An instance of or reference to a participant being distracted from engaging in a challenge or exhibit. | Boy1 has iPad, leads Boy2 to Periodic Table, *"We need a calculator."* One of the other teams has it. They run to the tree, but get sidetracked by Science on a Sphere. They leave quickly toward animal skins and echo cave, *"I'm hungry! So am I."* | 17 |
| Easy Fun | Novelty | A reference to enjoying the novelty of the experience. | *It was very exciting and surprising because you never knew what was next.* | 16 |

| Parent Category | Subcategories for Engagement | Description | Example from Data<br>Red=survey, blue=interview, green=video | References |
|---|---|---|---|---|
| Serious Fun | Interactive | A reference to enjoying the interactive nature of the experience. | *I liked the solar energy exhibit. It was just really cool because it was really interactive and you got to mess with like the sun and the solar panels and stuff.* | 15 |
| Hard Fun | Badges | An instance of or reference to earning badges as a motivating or enjoyable experience. | *We earned the math badge! We only need three more to earn all the badges. Yeah, we're on a roll!* | 14 |
| Meta-Research | food | A suggestion to improve the visit by providing access to food | [What could make your visit to the science center more fun?] *To be able to eat here and have like some more slides with rides.* | 13 |
| Easy Fun | Autonomy | A reference to enjoying the autonomy of the experience. | *I liked that I had the freedom to explore around.* | 12 |
| Hard Fun | +interesting | A positive reference to the experience being interesting. | *It was pretty cool; it was a lot more interesting with the game because I'd already done everything there a lot of times, so it gave something else to do, so that made it more fun.* | 12 |
| Easy Fun | Enjoyment | A reference to enjoying the experience. | *It was a very active/fun game so I enjoyed it a lot.* | 10 |
| Hard Fun | -interesting/boring | A negative reference to the experience being boring or not interesting. | *I like that we got to pick our own groups. But I've been there so many times before that it gets boring doing the same thing over and over again.* | 10 |
| Easy Fun | rides-n-slides | A instance of or reference to engaging with an exhibit solely for the purpose of physical interaction. | *The helicopter was fun; I liked the slide, but everybody else wants to go down it while there's people sitting at the bottom, just standing there and I got stuck in there.* | 10 |

| Parent Category | Subcategories for Engagement | Description | Example from Data<br>**Red=survey**, **blue=interview**, **green=video** | References |
|---|---|---|---|---|
| Serious Fun | -reading | An instance of or reference to NOT wanting to read challenges or exhibit signage. | Boy scans a code, barely reads the challenge and says *"blah blah blah"*; Girl grabs the iPad, *"Whoa!"* she reads the challenge and says "*We'll need the magnifying glass for this because we need to find evidence*." She hands the iPad back to Boy. | 8 |
| Easy Fun | scavenger hunt | A reference to a game that's objective is searching for and finding hidden items | *I liked searching for the scanner tags, it was like a hunting game.* | 7 |
| Meta-Research | broken exhibits | An instance of or reference to broken exhibits hindering engagement. | *There were some things that were broken that weren't working, cause the science center has been there for a long time. So if those things got fixed up, I think it would be more fun.* | 7 |
| Hard Fun | Narrative | A reference to enjoying the challenges that included a narrative element. | *I like the sort of questish feel. Like with the detective thing, I felt like I was really a detective.* | 7 |
| Meta-Research | too crowded | A reference to the science center being so crowded that engagement was hindered. | The stairs are too crowded to head back up to Crime Lab, so the girls head through rocket launch area. iPad partner goes up the stairs to take the picture, while camera partner waits for turn at the rocket launch. Other boys (not game) push in front. | 6 |
| Easy Fun | more exhibits | A suggestion to include more exhibits to improve the experience. | *I think I had a lot of fun but it would have been more funner [sic] if there was more things to do.* | 6 |
| Meta-Research | bugs/glitches | An instance of or reference to experiencing frustrating bugs or glitches during gameplay. | *Sometimes the scanner would not work.* | 5 |

| Parent Category | Subcategories for Engagement | Description | Example from Data<br>Red=survey, blue=interview, green=video | References |
|---|---|---|---|---|
| Serious Fun | +math | A demonstration of or reference to doing and/or liking mathematics. | *I learned different mathematics and how to understand a question that you don't really understand. Like, the solar question, it was like, use the equation that we gave you to figure out the direction of the solar panels, and we couldn't figure that out until finally we went back and looked at the quest.* | 5 |
| Easy Fun | Discovery | A reference to enjoying the opportunity for discovery provided by the experience. | *It was adventurous; we had lots of fun and we discovered lots. I would love to do it again and it was kind of hard but fun at the same time; I loved it.* | 5 |
| Easy Fun | scary things | A reference to enjoying scary things. | They exit the elevator on level two looking for the Music Park. They head the wrong direction toward the heliport and get inside. They laugh and enjoy it, thinking it was scary. | 4 |
| Serious Fun | more depth | A suggestion for improvement by going into more depth regarding the exhibits and the science. | *What would have made my visit more educational would be to actually get to know the pets.* | 4 |
| Hard Fun | Prizes | An instance of or reference to winning prizes as a motivating element. | *You know what happens if we finish 3? We can get a pass back here for free! I wanna come back here, so let's go! You are unfocused!* | 2 |

Not all new codes that were identified from the data were initially categorized under one of the original categories, however. Some new codes stood alone, at least at first. Entitled “emergent stand-alone codes”, Table 8 lists the codes that emerged that were not immediately classified within a category. The leftmost column in the table identifies the category to which each of the standalone codes was ultimately assigned during stage four.

Table 8

*Emergent Stand-Alone Categories, with Ultimate Parent Category Assignments*

| **Parent Category** | **Emergent Stand-Alone Categories** | **Description** | **Example** | **References** |
|---|---|---|---|---|
| Meta-Research | +nothing | No suggestions for improvement. | *Nothing could make this more fun here!* | 94 |
| Meta-Research | +game | A positive reference to the game or games in general. | *I like how the game involved technology and science and how you got to go around all of science city and explore everything and do quests and solve problems with real things.* | 88 |
| Meta-Research | -game | A negative reference to the game or games in general. | [What could have made your visit to the science center more educational?] *More science, talking, instead of letting us play games like that.* | 83 |
| Hard Fun | Map | Interaction focused on the in-game map, or reference to a/the map. | *You have to go to the map. We have to go the stars...Where are we now?... Kinderlab... sooo, okay...let’s go to the Nature Center...it’s right there!* | 62 |
| People Fun | +notebook | An instance of or reference to enjoying the use of the ARIS notebook feature within the game. | *Well, it was fun that you got to take pictures and videos with it and that you got to type.* | 43 |

| Parent Category | Emergent Stand-Alone Categories | Description | Example | References |
|---|---|---|---|---|
| Hard Fun | goal orientation | A demonstration of or reference to being goal oriented during the visit to the science center. | *Didn't we do that like 5 times already? Yes, but we don't know what we did wrong. We want to get this thing done! We're gonna get it done if takes us all day!* | 36 |
| Meta-research | in-game survey | Instance of participant encountering one of the in-game surveys. | Girl 1 is doing a mini-survey: *"How vIvacious did it make you feel to complete the...How what? ...Vivacious...Victorious!.. How victorious did it make you feel to complete the Giant Lever?...Extremely?...Quite a bit...How difficult was it...Extremely!...quite a bit.."*(she defers to her partner). | 19 |
| Hard Fun | hints/manuals/ support | A suggestion for game improvement that includes providing hints, manuals, or other kinds of scaffolding support. | *I think that the creator should give some more details or hints to make it a bit easier.* | 11 |
| Easy Fun | Playing | A reference to enjoying the act of playing. | *What I liked about the game was you got to learn and still play.* | 4 |
| Serious Fun | locative nature | A reference to enjoying the fact that the game involved the physical surrounding. | *I liked how [the game] uses the area around you to solve things.* | 2 |
| Easy Fun | adventure/ exploring | A reference to enjoying the experience as an opportunity to explore and go adventuring. | *[I liked] the adventure and the partnership.* | 2 |
| Serious Fun | Presentations | A suggestion that providing more content oriented presentations would result in more learning. | [What would make the visit more educational?] *To have presentations.* | 1 |

**Stage Four.** Eventually, after multiple close readings of the data, there came the point at which no new codes emerged. When new codes ceased to emerge, the analysis entered stage four. At this time, the existing categories, codes, and data references were critically examined to reduce overlap and redundancy among coded concepts. Similar and related codes were grouped together in categories. For example, data chunks that referenced an appreciation for the adventure of the science center experience (Adventure) and those that referenced an appreciation for exploring the science center (Exploring) were combined to form a single Adventure/Exploring code. Furthermore, Adventure/Exploring was then grouped under the category of Easy Fun with other codes such as QR Codes, which referenced enjoyment of searching for and scanning QR codes. The ultimate goal of stage four was to determine how categories and codes might fit together to create a model or framework consisting of 3-8 of the most important themes.

During stage four, it suddenly became apparent that many of the codes under engagement, as well as several of those new codes that were standing alone, could be considered various facets of one of the four types of fun. For example, the drive to achieve a goal and the desire for hints, manuals, and support can be viewed as facets of hard fun. Taking pictures, videos, and audio recordings with the ARIS notebook to share with the group and/or responding to others' posts in the notebook with a "like" or "comment" can be seen as facets of social interaction and people fun. Enjoying the adventure of exploring and moving around the science center with relative autonomy can be seen as facets of easy fun. This was the beginning of the idea that the four types of fun might be the major themes to emerge from the data that could describe participants' behaviors during the visit to the science center and their perceptions of the experience.

The most enlightening moment occurred when two of the original upper level categories were entirely subsumed into the four types of fun matrix.  First, it was realized that the entire category of learning dealt with facets of Lazzaro's serious fun (i.e.  fun with a real-world purpose).  "Learning" and all of its codes were recoded under serious fun.  Serious fun is described as purposeful play.  Serious fun results in changing the way players think, feel, or behave.  Serious fun makes a difference in the real world, the world outside of the game.  When a player recognizes that learning is an objective of a game, they are enjoying serious fun.  In this study, participants recognized that the hands-on activities and challenges facilitated their learning and they cited that specific characteristic of the experience as fun.

> *On the whole, everything was fun.  I got to enhance my math, science, and tech skills.  I really enjoyed it and I wish I will be able to do it again.  (interview, Damon, 6$^{th}$ grade boy, 4/14)*
>
> *It was fun because you got to learn about science more.  (post-survey, Heather, 6$^{th}$ grade girl, 9/14)*

Similarly, suggesting that more mathematics challenges would make the game more fun is a recommendation for more learning experiences in the service of fun, a.k.a.  serious fun. When a game makes you pay closer attention to the details of your surroundings and you learn more as a result, that is also serious fun.  Rather than a game designed purely for entertainment, The Great STEM Caper is designed to engage players in science and engineering practices, thus making it a "serious game".  It makes sense that a serious game would result in serious fun.

The second original category to be subsumed in its entirety by one of the four types of fun was the "difficulty" category.  All of the codes under the difficulty category only make sense if the participant is focused on achieving a goal, which is the foundation of hard fun.  All of the codes that emerged under the original category of “difficulty” are related to a hard fun approach to playing the game. Hard fun is characterized by being goal-oriented and seizing the opportunity to experience achievement or mastery. One only feels frustrated when experiencing limited success toward reaching a particular goal. Likewise, describing the experience as too hard, too easy, or having too many challenges is a result of engaging in a hard fun approach to playing the game. The codes described by the difficulty category are obstacles to success that actually make the experience fun because it is hard. Although, admittedly, the experience may have been too difficult for some participants, thus diminishing the fun they experienced. Suggesting that the game be customized for varying levels of player skill speaks to developing a more satisfying gameplay experience from a hard fun perspective. The final organizational structure of all the codes included under the four types of fun thematic framework is displayed in Table 9.

After codes were combined and reorganized to eliminate overlap and redundancy, there still remained some codes that stood alone and were important, but were not integrated into the four types of fun framework. All but one of these remaining codes were eventually organized under the new theme of “meta-research”. Codes that dealt with research methods and those that facilitated the research process were included under this category. The GoPro and iPad codes belonged under the meta-research theme. Nearly all negative references to using the iPad were centered on problems with the technology not working properly; therefore, it was determined that the code of bugs and glitches was redundant, and was thus subsequently merged with the – iPad code. Segments of video that showed players interacting with the in-game surveys or the introductory quest were sections that needed to be coded for analysis of those specific research elements. A few codes emerged that were relevant to the overall research site and design;

crowds, broken exhibits, and participant hunger were hindrances to full engagement in the science center experience. Finally, two codes were created to facilitate the process of conducting and writing up the research: "important video clips" and "great quotes." [See Table 10]

Table 9

*Final Distribution of Themes into the Four Types of Fun*

| **Final Distribution of Themes Into the Four Types of Fun (+Number of References for Each)** | | | |
|---|---|---|---|
| **Hard Fun** | **# of Ref 533** | **Easy Fun** | **# of Ref 390** |
| ● Fiero | 65 | ● QR Codes/Code scanners | 138 |
| ● Map | 62 | ● Ping-pong effect | 117 |
| ● Goal orientation | 36 | ● Adventure/exploration/moving around | 50 |
| ● More codes/challenges | 35 | ● Distraction | 17 |
| ● Badges | 14 | ● Novelty | 16 |
| ● +Interesting | 12 | ● Autonomy | 12 |
| ● -Interesting/Boring | 10 | ● Rides-n-slides | 10 |
| ● Narrative | 7 | ● Enjoyment | 10 |
| ● Prizes | 2 | ● Scavenger/treasure hunt | 7 |
| (Difficulty) | | ● Discovery | 5 |
| ● Frustration | 101 | ● Scary things | 4 |
| ● too hard | 56 | ● Playing | 4 |
| ● adult help | 45 | | |
| ● confusion | 40 | **Serious Fun (Fun from Learning)** | **126** |
| ● more time | 18 | ● +Reading | 51 |

| Final Distribution of Themes Into the Four Types of Fun (+Number of References for Each) | | | |
|---|---|---|---|
| ● hints/manuals/support | 11 | ● +Science/more science | 20 |
| ● too easy | 8 | ● Docent/guide | 17 |
| ● too many | 8 | ● Interactive | 15 |
| ● Customization | 3 | ● -Reading | 8 |
| **People Fun** | **641** | ● Hands-on | 5 |
| Social interaction | 213 | ● +Math/more math | 4 |
| ● Notebook | 43 | ● More depth | 4 |
| Collaboration | 256 | ● Locative Nature | 2 |
| ● Everyone can win | 3 | | |
| Competition | 94 | | |
| ● Showing off sharing knowledge | 32 | | |

Table 10

*Meta-Research Codes*

| Codes | Description | Example from Data | References |
|---|---|---|---|
| +nothing | No suggestions for improvement. | *Nothing could make this more fun here!* | 94 |
| +game | A positive reference toward the concept of playing a (or the) game during a visit to the science center. | *I liked that we had to find different things and work in teams. We got to play games and it was a fun little game.* | 75 |
| -game | A negative reference toward the concept of playing a (or the) game during a visit to the science center. | *I like just looking around and stuff. I'd rather walk around and look instead of on the ipad or do a game.* | 70 |

| Codes | Description | Example from Data | References |
|---|---|---|---|
| +GoPro | A positive reference toward wearing a GoPro camera during the visit to the science center. | *Aw, let me wear it, let me wear it!* (Boys trade camera and adjust the fit.) *Does this look okay?* (Takes the camera back off again and holds it at arm's length for a selfie smile. Holds the camera in his hands and plays with it for a minute, then gives camera back to first boy who puts it back on. Second boy helps him adjust the angle.) | 67 |
| -GoPro | A negative reference toward wearing a GoPro camera during the visit to the science center | *The only thing I disliked was that camera! It was annoying! It kept on bobbing and like, I kept on hitting the ceiling to one of the places, I was like UGH, and it fell off once but I got it back on.* | 46 |
| great quote | A quote from any data source that could be used as an exemplar of an important theme. | *I liked that you could walk around; you had something to look for instead of looking around for something to do. And also this was fun; you can't always learn and have fun so I really enjoyed this.* | 35 |
| important video clip | A segment of video that captures an instance of an important theme. | Great video of scanning the quest, getting it, reading it, looking at map, deciding how to get to Dino Lab. | 32 |
| -iPad<br>bugs/glitches | A negative reference toward using an iPad during the visit to the science center. | *The game was okay, but I kept having issues with the iPad. It was kinda boring.* | 30 |
| +iPad | A positive reference toward using an iPad during the visit to the science center. | *I liked the fact that it's on an iPad, and I also like the technology quests.* | 19 |
| in-game survey | A segment of video that shows players interacting with the in-game surveys. | Girl 1 is doing a mini-survey: *"How vIvacious did it make you feel to complete the...How what?... Vivacious... Victorious!...How victorious did it make you feel to complete the Giant Lever?...Extremely?...Quite a bit...How difficult was it...Extremely!...quite a bit.."*(she defers to her partner). | 19 |
| +food | A suggestion to improve the visit by providing access to food | [What could make your visit to the science center more fun?] *To be able to eat here and have like some more slides with rides.* | 13 |

| Codes | Description | Example from Data | References |
|---|---|---|---|
| broken exhibits | An instance of or reference to broken exhibits hindering engagement. | *There were some things that were broken that weren't working, cause the science center has been there for a long time. So if those things got fixed up, I think it would be more fun.* | 7 |
| introductory quest | A segment of video that shows players interacting with the introductory quest. | This is the beginning for the other pair. Orientation and introductory quest. These girls tell the other pair not to follow them. They scan the stopwatch. They figure out how to see the info by clicking detail. They read the description aloud, but are still a little confused about it. I walk over to mention the 3-question surveys and help them understand what the tools are for. | 7 |
| too crowded | A reference to the science center being so crowded that engagement was hindered. | The stairs are too crowded to head back up to Crime Lab, so the girls head through rocket launch area. iPad partner goes up the stairs to take the picture, while camera partner waits for turn at the rocket launch. | 6 |
| doesn't watch video | An instance in which a video is triggered within the game but the player clicks through it without viewing. | Girl 1 goes to do the rocket and Girl 2 is going to take a picture, but the win screen for Rocket Launch pops up (she clicks through it, without watching the video) and the in-game survey pops up, which she clicks through | 5 |

After all of the other codes had been assigned under one of the major themes, one last code remained standing alone, not incorporated under any other category. The "elevator" code emerged from the data as it became evident from video footage that participants enjoyed riding and being inside the glass elevator at the science center. However, the elevator could not be categorized under "rides and slides" under the easy fun theme, because participants' behavior inside the elevator changed markedly compared to their behavior in the science center at large. Inside the elevator was much quieter than outside in the noisy science center. Participants' behavior and conversations changed when they stepped inside the elevator and the door closed. These surprising observations required that the elevator be designated as a minor, standalone theme [see Table 11].

Table 11

*The Unexpected Elevator Theme*

| Theme | Description | Examples | References |
|---|---|---|---|
| elevator | A video clip that captured interesting participant behavior while riding the glass elevator. | *Elevator!  We're going to 1, hurry up get in here!  Okay, so, we have three points right now! (looking at attributes) Do you want to hold the iPad?  You want me to?  I don't care, I'm just asking if you want to. Oooo, that was scary!  (the elevator)* | 19 |

**Stage Five.** During stage five, frequencies of references were examined, and as a result, Lazzaro's framework was confirmed as a good model to explain the most important themes that had emerged.  A total of 45 codes were ultimately categorized under one of the four types of fun. These 45 codes made up approximately 75% of all data references.  Table 9 shows the final organization of codes into the four types of fun theme and the number of references included in each code.

Frequencies of occurrence between game/comparison and male/female were compared for each major theme.  Specifically, the game and comparison groups were compared based on the percentage of references in each category of fun.  Likewise, males and females in the game group were compared using the percentage of references in each category of fun.  Because the number of sources or cases in the different groups was not equal, the number of coding references had to be converted to a percentage in order to do a fair comparison.  For example, from the game group, there were fourteen interviews with female participants and eight interviews with male participants.  Due to the unequal number of interviews for each gender when comparing perceptions of the game between males and females, it was necessary to have NVIVO compare percentages of a certain response within each group, rather than the actual number of coded references. Data were queried using a coding matrices approach, which allowed the comparison of how common a particular response was between the two groups, regardless of how many cases were included in each group.

# CHAPTER 4: RESULTS

## Quantitative Findings

*Primary Research Question: How does playing an exhibit-based mobile game during a group field trip to a hands-on science center affect students' science self-efficacy, interest, and motivation to learn? Are there gender differences within the group that plays the game?*

To examine the impact the game has on students' affective outcomes, the game group and the comparison group were compared using the change in scores from pre- to post- on the overall MLSQ as well as the subscales of science self-efficacy and interest and enjoyment of science. The game group was further divided by gender to determine if there are gender differences in the affective outcomes of those who played the game.

Both the comparison (n=35) and the game group (n=74) completed the MLSQ pre-survey within the two weeks prior to visiting the science center. All participants took the post-survey before departing the science center. The MLSQ produces five separate affective measurements including the overall motivation to learn science and the four subscales: interest and enjoyment of science (IE), science self-efficacy (SE), connection to daily life (CL), and importance to the student (IS). The subscales of connection to daily life and importance to the student were considered irrelevant to the research questions and therefore were not considered separately. Only the overall MLSQ along with the two subscales of self-efficacy, and interest and enjoyment are relevant to the research questions. Table 12 and Table 13 below include the pre- and post-results of the overall MLSQ and all four subscales for each group.

Table 12

*Comparison Group Descriptive Statistics*

| **Measure** | **N** | **Mean** | **Std. Deviation** |
|---|---|---|---|
| MLSQPre | 35 | 64.46 | 12.431 |
| MLSQPost | 38 | 65.53 | 16.306 |
| IEPRE | 36 | 16.57 | 4.257 |
| IEPOST | 38 | 16.76 | 5.268 |
| SEPRE | 35 | 15.86 | 3.515 |
| SEPOST | 38 | 16.37 | 4.214 |
| CLPRE | 36 | 15.57 | 3.013 |
| CLPOST | 38 | 15.89 | 3.992 |
| ISPRE | 36 | 16.18 | 3.292 |
| ISPOST | 38 | 16.50 | 4.490 |

Table 13

*Game Group Descriptive Statistics*

| Measure | N | Mean | Std. Deviation |
|---|---|---|---|
| **MLSQPre** | 74 | 71.41 | 11.223 |
| **MLSQPost** | 79 | 71.14 | 11.347 |
| **IEPRE** | 74 | 18.84 | 3.220 |
| **IEPOST** | 78 | 19.00 | 3.767 |
| **SEPRE** | 74 | 17.71 | 3.680 |
| **SEPOST** | 79 | 17.74 | 3.585 |
| **CLPRE** | 74 | 17.25 | 2.954 |
| **CLPOST** | 79 | 17.05 | 3.195 |
| **ISPRE** | 74 | 17.60 | 3.616 |
| **ISPOST** | 79 | 17.36 | 3.306 |

There were no differences between genders on any of the MLSQ measures within the comparison group [See Table 14]. However, girls within the game group scored significantly higher on the overall MLSQPre ($M$ = 74.79, $SD$ = 3.21) than did the boys in the game group ($M$ = 68.83, $SD$ = 3.16), $t(72)$ = 2.34, $p$ = .02 . Of particular importance to this study is that the girls within the game group also scored significantly higher on the science self-efficacy subscale, SEPre, ($M$ = 18.76, $SD$ = 3.42) than did the boys in the game group ($M$ = 16.92, $SD$ = 3.71), $t(72)$ = 2.19, $p$ = .03. There were no differences between the genders on any of the post-measures. [See Table 15]

Table 14

*Comparison Group Results Compared by Gender*

| | | N | Mean | Std. Deviation | t | df | Sig. | Mean Difference |
|---|---|---|---|---|---|---|---|---|
| MLSQPre | Girls | 19 | 64.27 | 12.265 | -.093 | 33 | .926 | -.4001 |
| | Boys | 16 | 64.67 | 13.025 | | | | |
| MLSQPost | Girls | 19 | 64.69 | 17.561 | -.312 | 36 | .757 | -1.6711 |
| | Boys | 19 | 66.36 | 15.384 | | | | |
| IEPre | Girls | 19 | 15.96 | 4.053 | -.912 | 34 | .368 | -1.2986 |
| | Boys | 17 | 17.26 | 4.497 | | | | |
| IEPost | Girls | 19 | 15.84 | 5.530 | -1.080 | 36 | .287 | -1.8421 |
| | Boys | 19 | 17.68 | 4.967 | | | | |
| SEPre | Girls | 19 | 16.47 | 3.583 | 1.104 | 34 | .277 | 1.2914 |
| | Boys | 17 | 15.18 | 3.414 | | | | |
| SEPost | Girls | 19 | 17.01 | 4.509 | .928 | 36 | .360 | 1.2705 |
| | Boys | 19 | 15.74 | 3.914 | | | | |
| CLPre | Girls | 18 | 15.56 | 3.110 | -.028 | 33 | .978 | -.0286 |
| | Boys | 17 | 15.58 | 3.002 | | | | |
| CLPost | Girls | 19 | 15.74 | 4.520 | -.241 | 36 | .811 | -.3158 |
| | Boys | 19 | 16.05 | 3.504 | | | | |
| ISPre | Girls | 19 | 16.30 | 3.030 | .220 | 34 | .827 | .2451 |
| | Boys | 17 | 16.05 | 3.653 | | | | |
| ISPost | Girls | 19 | 16.11 | 4.653 | -.533 | 36 | .598 | -.7837 |
| | Boys | 19 | 16.89 | 4.412 | | | | |

Table 15

*Game Group Results Compared by Gender*

| | | N | Mean | Std. Deviation | t | df | Sig. | Mean Difference |
|---|---|---|---|---|---|---|---|---|
| MLSQPre | Girls | 32 | 74.79 | 3.213 | 2.335 | 72 | .022* | 5.9687 |
| | Boys | 42 | 68.83 | 3.162 | | | | |
| MLSQPost | Girls | 34 | 72.08 | 3.821 | .637 | 77 | .526 | 1.6477 |
| | Boys | 45 | 70.43 | 3.769 | | | | |
| IEPre | Girls | 32 | 19.53 | 10.525 | 1.636 | 72 | .106 | 1.2222 |
| | Boys | 42 | 18.31 | 11.167 | | | | |
| IEPost | Girls | 33 | 19.05 | 10.467 | .085 | 76 | .932 | .0741 |
| | Boys | 45 | 18.97 | 12.037 | | | | |
| SEPre | Girls | 32 | 18.76 | 3.415 | 2.187 | 72 | .032* | 1.8419 |
| | Boys | 42 | 16.92 | 3.714 | | | | |
| SEPost | Girls | 34 | 18.22 | 3.712 | 1.033 | 77 | .305 | .8408 |
| | Boys | 45 | 17.38 | 3.483 | | | | |
| CLPre | Girls | 32 | 18.20 | 3.287 | 2.496 | 72 | .015* | 1.6715 |
| | Boys | 42 | 16.53 | 2.476 | | | | |
| CLPost | Girls | 34 | 17.15 | 3.002 | .236 | 77 | .814 | .1726 |
| | Boys | 45 | 16.98 | 3.364 | | | | |
| ISPre | Girls | 32 | 18.30 | 2.958 | 1.465 | 72 | .147 | 1.2336 |
| | Boys | 42 | 17.07 | 3.999 | | | | |
| ISPost | Girls | 34 | 17.69 | 2.990 | .774 | 77 | .441 | .5834 |
| | Boys | 45 | 17.10 | 3.539 | | | | |

The comparison group (n=35) and the game group (n=74) had different sample sizes and in an independent samples t-test, the comparison group scored lower on the MLSQPre ($M$ = 64.46, $SD$ = 12.43) than the game group ($M$ = 71.41, $SD$ = 11.22), $t(107) = 2.92$, $p = .004$. [See Table 16]

Table 16

*Pretest Differences Between Game and Comparison*

| | | N | Mean | Std. Deviation | t | df | Sig. | Mean Difference |
|---|---|---|---|---|---|---|---|---|
| MLSQPre | Comparison | 35 | 64.46 | 12.43 | 2.92 | 107 | .004** | 6.95 |
| | Game | 74 | 71.41 | 11.22 | | | | |

Due to the differences between the two groups, change scores from pre- to post- were used to compare outcomes between them. Independent samples t-tests revealed no significance differences between the game ($M$ = .65, $SD$ = 14.16) and comparison groups ($M$ = .30, $SD$ = 9.12), $t(106) = .133$, $p = .894$ on the change from pre- to post- on the overall MLSQ. Neither were there any differences in change scores from pre- to post- on any of the subscales. Finally, there were no significant differences in the change from pre- to post- between girls and boys who played the game. Playing The Great STEM Caper did not have a measurable effect on participants' science self-efficacy, interest, or motivation to learn when compared to outcomes for participants who explored the science center in the traditional way and did not play the game. [See Table 17 and Table 18]

Table 17

*Game vs Comparison Change Scores*

| | | N | Mean | Std. Deviation | T | df | Sig. | Mean Difference |
|---|---|---|---|---|---|---|---|---|
| MLSQChange | Game | 75 | .65 | 14.164 | .133 | 106 | .894 | .35777 |
| | Comparison | 33 | .30 | 9.120 | | | | |
| IEChange | Game | 74 | .10 | 3.538 | .925 | 104 | .357 | .69660 |
| | Comparison | 33 | -.60 | 3.706 | | | | |
| SEChange | Game | 74 | .03 | 3.579 | -.452 | 105 | .652 | -.30929 |
| | Comparison | 33 | .34 | 2.408 | | | | |
| CLChange | Game | 74 | -.15 | 3.466 | -.158 | 105 | .875 | -.10978 |
| | Comparison | 33 | -.04 | 2.947 | | | | |
| ISChange | Game | 73 | -.15 | 4.230 | -.278 | 105 | .782 | -.22267 |
| | Comparison | 33 | .07 | 2.717 | | | | |

Table 18

*Gender Differences in Game Group Change Scores*

| | | N | Mean | Std. Deviation | T | df | Sig. | Mean Difference |
|---|---|---|---|---|---|---|---|---|
| MLSQChange | Girls | 33 | -.38 | 13.792 | -.560 | 73 | .577 | -1.8553 |
| | Boys | 42 | 1.47 | 14.562 | | | | |
| IEChange | Girls | 31 | -.48 | 2.595 | -1.190 | 71 | .238 | -.99382 |
| | Boys | 42 | .52 | 4.077 | | | | |
| SEChange | Girls | 32 | -.53 | 2.692 | -1.183 | 72 | .241 | -.99062 |
| | Boys | 42 | .46 | 4.11 | | | | |
| CLChange | Girls | 32 | -.95 | 2.687 | -1.738 | 72 | .087 | -1.3942 |
| | Boys | 42 | .45 | 3.883 | | | | |
| ISChange | Girls | 32 | -.41 | 2.583 | -.459 | 72 | .647 | -.45842 |
| | Boys | 42 | .04 | 5.17 | | | | |

*Sub-question #1: What are the relationships between students' perceptions of enjoyment (fun), learning, game difficulty, "victory" experiences, and his/her self-efficacy?*

*Sub-question #2: How does gender relate to perceptions of the game and self-efficacy?*

## Fun and Learning

On the post-survey, participants were asked to use a four point Likert-type scale to rate how much fun they had and how much they thought they learned during the visit. The four choices were "none", "a little", "some", and "a lot". The game group reported having significantly more fun ($M$ = 3.72, $SD$ = .58) than the comparison group ($M$ = 3.22, $SD$ = 1.15), $t$(118) = 2.63, $p$ = .011 and also reported learning significantly more ($M$ = 3.28, $SD$ = .70) than the comparison group (M = 2.54, *SD* = 1.27), $t(117) = 3.50$, $p = .001$ [see Table 19]. No significant gender differences in overall fun, learning, or enjoyment of the game were found in the game group [see Table 20]. It is important to note that these are only two individual items on the survey and do not constitute a valid or reliable measure of "fun" or "learning" for the groups.

Table 19

*Fun and Learning, Self-reported, Game vs Comparison*

| | | N | Mean | Std Deviation | t | df | Sig. | Mean Difference |
|---|---|---|---|---|---|---|---|---|
| **Fun** | **Game** | 79 | 3.72 | .576 | 2.627 | 118 | .011* | .502 |
| | **Comparison** | 41 | 3.22 | 1.151 | | | | |
| **Learn** | **Game** | 78 | 3.28 | .701 | 3.497 | 117 | .001** | .7454 |
| | **Comparison** | 41 | 2.54 | 1.267 | | | | |

Table 20

*Game Group Fun, Learning, Enjoy Game by Gender*

| | | N | Mean | Std Deviation | t | df | Sig. | Mean Difference |
|---|---|---|---|---|---|---|---|---|
| **Fun** | **Girls** | 34 | 3.74 | .567 | .184 | 77 | .855 | .0242 |
| | **Boys** | 45 | 3.71 | .589 | | | | |
| **Learn** | **Girls** | 34 | 3.26 | .751 | -.191 | 76 | .849 | -.0308 |
| | **Boys** | 44 | 3.30 | .668 | | | | |
| **Enjoy Game** | **Girls** | 34 | 3.56 | .860 | 1.102 | 77 | .274 | .2255 |
| | **Boys** | 45 | 3.33 | .929 | | | | |

Fun and learning scores were correlated with change scores on the MLSQ and the subscales of self-efficacy and interest and enjoyment to determine if there were relationships between perceptions of fun and learning during the science center visit and change in these affective outcomes related to science. In the comparison group, there was a strong positive correlation between how much fun they had during the visit to the science center and the change in their "interest and enjoyment of science", $r(31) = .421$, $p = .015$. Likewise, the comparison group also displayed a strong positive correlation between how much they thought they learned during their visit and the change in the "interest and enjoyment of science", $r(31) = .49$, $p = .004$. The comparison group had a low correlation between perceptions of fun or learning with other MLSQ or subscale scores, pre or post [see Table 21].

Table 21

*Comparison Group Correlations*

| | | MLSQ PRE | MLSQ POST | MLSQ CHANGE | SE PRE | SE POST | SE CHANGE | IE PRE | IE POST | IE CHANGE |
|---|---|---|---|---|---|---|---|---|---|---|
| Fun | Pearson Correlation | .133 | .082 | -.033 | .066 | .021 | .080 | .154 | .062 | .421* |
| | Sig. | .447 | .625 | .857 | .702 | .899 | .657 | .371 | .710 | .015 |
| | N | 35 | 38 | 33 | 36 | 38 | 33 | 36 | 39 | 33 |
| Learn | Pearson Correlation | .183 | .258 | .302 | .229 | .276 | .272 | .140 | .163 | .490** |
| | Sig. | .293 | .117 | .088 | .178 | .093 | .125 | .417 | .328 | .004 |
| | N | 35 | 38 | 33 | 36 | 38 | 33 | 36 | 38 | 33 |

Like the comparison group, the game group also displayed a positive correlation between how much fun they had, *r*(71) = .382, *p* = .001, as well as how much they thought they learned, *r*(70) = .271, *p* = .021, and change in interest and enjoyment of science. Furthermore, for the game group, perceptions of fun, learning, and enjoyment of the game correlated positively with the post-measure of self-efficacy, although none of them correlated with change in self-efficacy [see Table 22].

Table 22

*Game Group Correlations*

| | | MLSQ PRE | MLSQ POST | MLSQ CHANGE | SE PRE | SE POST | SE CHANGE | IE PRE | IE POST | IE CHANGE |
|---|---|---|---|---|---|---|---|---|---|---|
| Fun | Pearson Correlation | .245* | .554** | .078 | .264* | .415* | .194 | .253* | .553** | .382** |
| | Sig. | .035 | .000 | .506 | .023 | .000 | .098 | .030 | .000 | .001 |
| | N | 74 | 79 | 75 | 74 | 79 | 74 | 74 | 78 | 73 |
| Learn | Pearson Correlation | .297* | .561** | .133 | .270* | .348** | .139 | .353** | .542** | .271* |
| | Sig. | .011 | .000 | .258 | .021 | .002 | .242 | .002 | .000 | .021 |
| | N | 73 | 78 | 74 | 73 | 78 | 73 | 73 | 77 | 72 |
| Enjoy Game | Pearson Correlation | .254* | .415** | .112 | .215 | .292** | .088 | .232* | .405** | .224 |
| | Sig. | .029 | .000 | .341 | .066 | .009 | .454 | .047 | .000 | .057 |
| | N | 74 | 79 | 75 | 74 | 79 | 74 | 74 | 78 | 73 |

When analyzed by gender, some differences appear between the girls and the boys in game group. Girls showed significant positive correlations between both the pre- and post-self-efficacy measures with their perceptions of how much fun they had as well as how much they learned. Perceptions of fun and learning were both strongly correlated (r = .4 to .69) with self-efficacy for girls; whereas for boys, only the perception of fun showed moderate correlation (r = .3 to .39) with self-efficacy. Both boys and girls showed a strong correlation between how much fun they had and the post-measure of interest and enjoyment of science. However, the boys showed a moderate to strong correlation between how much fun they had, how much they thought they learned, how much they enjoyed the game and a change in their interest and enjoyment of science, while girls did not demonstrate any correlations with change in interest and enjoyment. Neither boys nor girls showed a correlation between perceptions of fun, learning, or game enjoyment with changes in self-efficacy [see Table 23 and Table 24].

Table 23

*Game Girls Correlations*

| | | MLSQ PRE | MLSQ POST | MLSQ CHANGE | SE PRE | SE POST | SE CHANGE | IE PRE | IE POST | IE CHANGE |
|---|---|---|---|---|---|---|---|---|---|---|
| Fun | Pearson Correlation | .456** | .623** | -.315 | .410* | .455** | .243 | .444* | .533** | .301 |
| | Sig. | .009 | .000 | .075 | .020 | .007 | .181 | .011 | .001 | .099 |
| | N | 32 | 34 | 33 | 32 | 34 | 32 | 32 | 33 | 31 |
| Learn | Pearson Correlation | .662** | .733** | -.193 | .496** | .453** | .043 | .676** | .671** | .155 |
| | Sig. | .000 | .000 | .281 | .004 | .007 | .815 | .000 | .000 | .406 |
| | N | 32 | 34 | 33 | 32 | 34 | 32 | 32 | 33 | 31 |
| Enjoy Game | Pearson Correlation | .405* | .397* | .110 | .157 | .287 | .211 | .366* | .280 | .035 |
| | Sig. | .021 | .020 | .543 | .390 | .100 | .246 | .039 | .115 | .850 |
| | N | 32 | 34 | 33 | 32 | 34 | 32 | 32 | 33 | 31 |

Table 24

*Game Boys Correlations*

| | | MLSQ PRE | MLSQ POST | MLSQ CHANGE | SE PRE | SE POST | SE CHANGE | IE PRE | IE POST | IE CHANGE |
|---|---|---|---|---|---|---|---|---|---|---|
| Fun | Pearson Correlation | .104 | .512** | .357* | .164 | .387** | .195 | .119 | .567** | .437** |
| | Sig. | .512 | .000 | .020 | .299 | .009 | .217 | .454 | .000 | .002 |
| | N | 42 | 45 | 42 | 42 | 45 | 42 | 42 | 45 | 42 |
| Learn | Pearson Correlation | .002 | .447** | .415** | .074 | .260 | .207 | .071 | .434** | .360* |
| | Sig. | .992 | .002 | .007 | .645 | .088 | .193 | .657 | .003 | .021 |
| | N | 41 | 44 | 41 | 41 | 44 | 41 | 41 | 44 | 41 |
| Enjoy Game | Pearson Correlation | .098 | .418** | .282 | .197 | .278 | .072 | .094 | .496** | .383* |
| | Sig. | .536 | .004 | .070 | .212 | .064 | .651 | .552 | .001 | .012 |
| | N | 42 | 45 | 42 | 42 | 45 | 42 | 42 | 45 | 42 |

For boys, perception of learning was not correlated with self-efficacy, $r(42) = .260$, $p = .088$ , whereas for girls it was, $r(32) = .453$, $p = .007$. In other words, the more girls thought they had learned, the higher their self-efficacy, and vice versa, the higher their self-efficacy, the more they thought they had learned. This was not the case for boys. Boys' perception of fun was moderately correlated with their self-efficacy on the post-measure, $r(43) = .387$, $p = .009$, while girls' perceptions of fun were strongly correlated with self-efficacy on the post-measure, $r(32) = .455$, $p = .007$, meaning the more fun they thought they had, the higher their self-efficacy. However, neither boys' nor girls' perceptions of fun and learning were correlated with the changes in self-efficacy.

## Victory Experience and Game Performance

In-game victories are directly related to game performance. The more victories a player experiences, the higher his/her level game performance. Therefore, game performance is used as a proxy for victory experience. It is assumed that the more a player achieved within the game, the more victory experiences he/she had. However, a player may not perceive themselves as victorious, even if he/she achieves high levels of performance within the game. This section explores how actual game performance relates to perceived levels of victory, as well as how performance relates to perceptions of game enjoyment and difficulty. Finally, the relationship between game performance and science self-efficacy is examined.

Boys' and girls' levels of game performance differed significantly on all measures: number of challenges completed, skill units earned, badges achieved, and successful game completion (i.e. winning the game). Girls outperformed the boys on every measure. Unfortunately, some in-game data were lost, and game performance data were only available for 34/45 boys and 26/34 girls. Even so, girls had 21 game wins compared to the boys 15; they earned more than twice as many badges as the boys, 37 more skill units, and completed 40 more challenges [See Table 25].

Table 25

*Girls vs Boys Game Performance*

| Game Performance | Male (n=34) | | | Female (n=26) | | |
|---|---|---|---|---|---|---|
| | Total | Mean | Mode | Total | Mean | Mode |
| # Challenges Completed | 90 | 2.65 | 3 | 130 | 5 | 5 |
| # Skill Units Earned | 204 | 6.00 | 6 | 241 | 9.27 | 7 |
| # Badges Achieved | 22 | 0.65 | 0 | 47 | 1.81 | 2 |
| Wins | 15 | 0.44 | N/A | 21 | 0.81 | N/A |

After solving each challenge, game participants were asked to report on how difficult they felt the challenge was, how much victory they felt from solving it, and how much fun the challenge was to solve. Each player's in-game mini-survey data were averaged, giving each player an overall average score for each construct: difficulty, victory, and enjoyment. There were no differences between male and female players on any of those measures. For both genders combined, the number of challenges completed was positively and significantly correlated with challenge enjoyment, $r(58) = .380$, $p = .003$, victory, $r(58) = .408$, $p = .001$, and difficulty, $r(58) = .283$, $p = .028$ [See Table ]. Meaning the more challenges players completed, the more they enjoyed them, the more victorious they felt, and the more difficult they felt the challenges were.

Table 26

*Challenges Completed and Feelings of Enjoyment, Victory, & Difficulty*

| Challenges Completed | Enjoyment | Victory | Difficulty |
|---|---|---|---|
| Pearson Correlation | .380** | .408** | .283* |
| Sig. (2-tailed) | .003 | .001 | .028 |
| N = 60 | | | |

When boys and girls were compared, however, some interesting differences emerged. Girls only demonstrated a significant correlation between the number of challenges completed and their perception of challenge difficulty, $r(24) = .412$, $p = .036$, while boys demonstrated a significant correlation between number of challenges completed and their level of enjoyment, r(32) = .535, p = .031, and feeling of victory, $r(32) = .638$, $p = .000$ [See Table 7]. The more challenges they completed, the more enjoyment and victory were perceived by the boys, but completing challenges was only correlated with a perception of difficulty for the girls.

Table 27

*Challenges Completed and Feelings of Enjoyment, Victory, & Difficulty, by Gender*

| Challenges Completed | | Enjoyment | Victory | Difficulty |
|---|---|---|---|---|
| Boys | Pearson Correlation | .535** | .638** | .333 |
| n=34 | Sig. (2-tailed) | .031 | .000 | .055 |
| Girls | Pearson Correlation | .369 | .368 | .412* |
| n=26 | Sig. (2-tailed) | .064 | .064 | .036 |

The number of challenges completed was positively and significantly correlated with self-efficacy on the pre-survey, $r(54) = .327$, $p = .014$; however, the number of challenges completed was negatively and significantly correlated with change in self-efficacy from pre- to post-, $r(54) = -.318$, $p = .017$.  Likewise, winning the game also had a significant negative correlation with change in self-efficacy, $r(54) = -.345$, $p = .009$ [see Table 28].  This was not true for boys or girls separately, but for the overall group.  Correlation does not imply causation, but it is worth noting that the more successful a player was at completing the game, the less his/her self-efficacy increased.

Table 28

*Game Performance and Self-Efficacy*

| **Correlation** | | **SE PRE** | **SE CHANGE** |
|---|---|---|---|
| **Challenges Completed** | Pearson Correlation | .327* | -.318* |
| | Sig. | .014 | .017 |
| | N | 56 | 56 |
| **Game Win** | Pearson Correlation | .157 | -.345** |
| | Sig. | .247 | .009 |
| | N | 56 | 56 |

In summary, the quantitative findings indicate that playing the game did not have a measureable impact on the overall motivation to learn science or on the subscales of self-efficacy or interest and enjoyment of science when compared to those who visited the science center but did not play the game.  However, girls were found to have significantly higher science self-efficacy than the boys before they visited the science center.  There was no difference between boys and girls science self-efficacy after their visit to the science center.  Girls outperformed boys on every measure of game achievement. However, victories in the game did not translate to significant increases on the MLSQ for girls or boys. For boys, the more challenges they completed, the more they reported enjoying the challenges and feeling a sense of victory. Enjoyment and victory were not correlated with number of completed challenges for girls; on the contrary, the more challenges girls completed, the more difficult they felt the challenges were. Completing challenges and winning the game appear to be negatively correlated with change in self-efficacy. In the next section, the findings of the qualitative analysis are discussed.

## Qualitative Findings

The following section describes the qualitative findings related to the participants' experiences, behaviors, and perceptions of their visit to the science center. For a detailed description of the methods used in this analysis, please refer to back to Chapter 3. In this section, a full description of the findings related to the four types of fun is provided. Findings between the game and comparison groups are compared and gender differences in every each category are explored. There are also several findings related to "meta-research" that are included at the end of this section. These findings will be described in detail in the paragraphs that follow.

As expected, people fun was high for both groups. Although for the game group, people fun (32%) ranked second to hard fun (35%), while for the comparison group, people fun was the top-ranking type of fun by far (49%), accounting for nearly half of the fun references within the group. Serious fun (i.e. fun related to learning), accounted for 27% of the references in the comparison group, but only 11% of the references in the game group. While easy fun accounted for only 18% of the references in the comparison group and 23% in the game group.

Table 29

*Types of Fun, Game vs Comparison*

| | D : Easy Fun | C : Hard Fun | B : People Fun | A : Serious Fun |
|---|---|---|---|---|
| 1 : Game | 22.64% | 35.22% | 31.54% | 10.6% |
| 2 : Comparison | 17.7% | 6.52% | 48.88% | 26.9% |

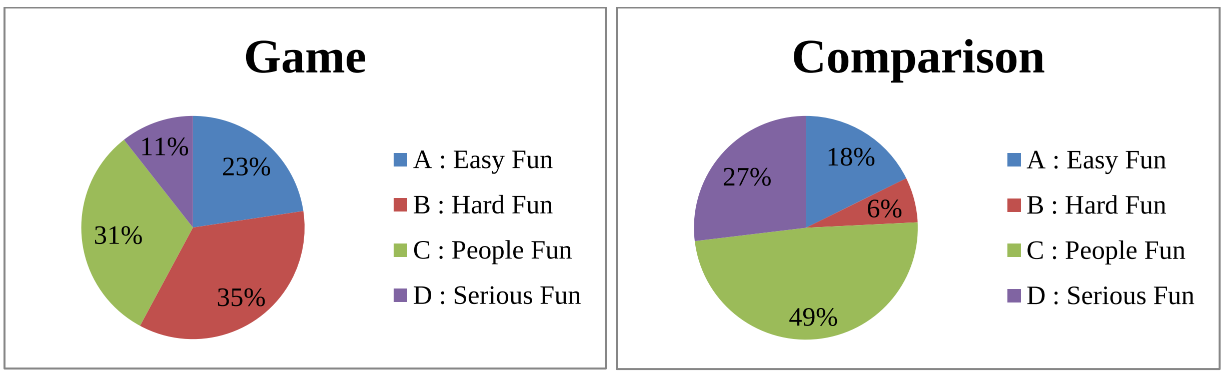



*Figure 1.* Types of Fun Distribution, Game vs Comparison

**Gameplay = Hard Fun**

The differences between the comparison and the game group were pronounced; as expected, the game group demonstrated a much higher incidence of hard fun (35% vs 6.5%) than the comparison group. Hard fun requires a goal, and the game provided exactly that. The comparison group explored the science center in the traditional way, without a specific goal provided. Table 29 and Figure 1 display the distribution of references among the four types of fun for the game group and the comparison group.

*Interviewer: What did you like about your visit to the science center?*

*Lily: Oh it was pretty awesome. It was pretty hard. It was challenging.*

*Interviewer: Did that make it good or make it bad?*

*Lily: It made it good, it was a fun trip around [the science center].*

(interview, Lily, 7th grade girl, game group, 10/13)

One of the primary indicators that participants were experiencing hard fun was their expression of "fiero" at points of in-game achievement. Fiero is easily identified when participants fist pump or make excited exclamations such as, "Yes!" or, "We did it!" The following video excerpt illustrates participants in the game group exhibiting fiero. The vignette describes two 6th grade girls who are in the process of completing the Sky Bike challenge, which is the last one they need to win the game.

Cathy: *"There are 36 bricks. Did you put that in the decoder*?"

Bridget puts the number in the decoder to complete the first half of the challenge.

Cathy: *"I counted all those."*

Bridget, jumping up and down: *"Yay!"*

Bridget: *"Okay, 450 divided by 36...12.5…"*

Bridge enters the answer into the decoder and waits for it to load.

Bridget, gasping: *"OMG, we got it right!"*

Cathy and Bridget fist pump the air and jump up and down. Then they stand shoulder to shoulder to watch the victory video.

Bridget: *"Yay, it's a Pi sign...double challenge..."*

Cathy launches in to a description to the researcher of how she was able to count the bricks, while Girl 1is still celebrating.

Bridget: *"It says we're math geniuses!"*

At this point Cathy clicks through another win video without looking at or reading it.

The girls stand shoulder to shoulder looking at the game; they are looking through inventory and click on the Engineering Badge to see what it does.

Bridget: *"Oh, it just does that. This is awesome! We won!"*

The girls in this vignette displayed excitement, enjoyment, and even surprise at being able to solve the challenge. This is a classic fiero example of players enjoying the moment when they are able to overcome a difficult obstacle. In fact, these players were enjoying themselves so much that after they won the game, they continued to play, moving around the science center looking for more challenges to solve.

Further evidence that participants in the game group particularly enjoyed the hard fun aspects of gameplay is provided by the following quotes obtained during post-visit surveys and interviews.

> "I liked that we got to go around and try new challenges involving science. I actually had a lot of fun. I also thought it was cool to try to figure out some of the challenges like the musical game. It was fun but hard at the same time." (post-survey, Kesha, 8$^{th}$ grade girl, 7/14)
>
> "It was challenging and fun. Mostly it was fun to work with my team and interact with each other. I had to challenge myself and others. It was especially fun when people asked us what we were doing and we would tell them we were F.B.I. students in training. On the whole, everything was fun. I got to enhance my math, science, and tech skills. I really enjoyed it and I wish I will be able to do it again." (post-survey, Kerry, 6$^{th}$ grade girl, 3/14 )
>
> "I like how it involved technology and science and how you got to go around all of science city and explore everything and do quests and solve problems with real

things." (post-survey, Arthur, 6th grade boy, 3/14 )

"I really don't think anything could have made it more fun! It really worked my brain!" (interview, Kerry, 6th grade girl, 3/14)

Participants in the game group particularly enjoyed the hard fun aspect of their visit to the science center. Having a goal provided motivation to explore the science center and to solve challenges. The comparison group participants also enjoyed their visit to the science center, but the fun they described was not related to solving challenges or having goal. Rather, the comparison group participants particularly enjoyed exploring the science center as a social experience.

**People Fun**

When asked what they enjoyed most about their visit to the science center, participants in both the game and comparison groups were likely to mention some version of people fun. People fun was high for both groups, although for the game group, people fun was a close second to hard fun, while for the comparison group, people fun was the top-ranking type of fun by far, accounting for nearly half of the fun references within the group. Participants in the comparison group talked about enjoying being with their friends:

> I liked just being with my friends, and I like learning new things, and there was a lot of stuff that I got to learn about. I guess just being with my friends, because I don't get to see them outside of Boys and Girls Club. (interview, Kendra, 8th grade girl, comparison group, 7/14)
>
> [What I enjoyed most was]being partnered with my friends. (post-survey, Jack, 8th grade boy, comparison group, 7/14)
>
> *I think just being with my friends was the most fun part, and then going into the*

*Nature center area and seeing the staff hold different animals. (interview, Peggy, 8th grade girl, comparison group, 7/14)*

Whereas participants in the game group interacted with one another in relation to their common goal, those in the comparison group mostly interacted on a purely social level. In the following video vignette, an 8th grade group of two boys and one girl in the comparison group are exploring the science center. Participants had been placed in same-gender pairs, but this group did not maintain its original grouping assignment. The participants move about the science center and interact with other participants in a way that illustrates the typical type of "people fun" enjoyed by participants in the comparison group.

Boy 1, Boy 2, and Girl have just finished riding the Sky Bike, Boy 3 is currently riding the Sky Bike.

Boy 1: *"Let's ditch [Boy 3]!"*

Boy 1, Boy 2, and Girl run away from the Sky Bike, across the bridge, and down the Bird Treehouse stairs and go screaming into Echo Cave. They continue to run from Echo Cave to the Sewer Tunnels.

As they run past the Giant Maze, Boy 1 exclaims, *"Ohhh, I wanna try the maze!"* But keeps running, following Girl. Girl and Boy 1 follow some other participants down the Sewer Tunnel Slide and then into the KC Rail Experience. Boy 1, Boy 2, and Girl are just jogging around the train exhibit. Boy 1 scares Girl who screams and laughs. They both go back to the Sewer Tunnel Slide and crawl up the tunnel. From the top platform they look down at friends. Boy 1 jumps down.

Girl reminds him, *"Dude! You're wearing a camera!"*

Boy 1, Boy 2, and Girl move to the Rocket Launch and engage with it for about 45 seconds until they spot Boy 3 and run up the stairs away from him.

The three continue to wander around the science center in a classic "ping-pong" manner until they see Boy 3 and commence running away again.

Participants in the game group also made reference to enjoying people fun. People fun accounted for 31% of the fun references from participants in the game group, while for those in the comparison group, people fun accounted for 49% of the fun references. Participants in the game group were somewhat less likely to identify people fun as the primary reason for their enjoyment of the visit than those in the comparison group, but when they did, the type of people fun that was described and demonstrated also differed between the game and comparison groups. The following excerpt is from an interview with Tim, a $7^{th}$ grade boy who was part of the game group. This excerpt shows how the game provided an opportunity for social interaction in a goal-oriented context.

Tim: *"I just remember one thing that I liked a lot, that pulley system. Like on one side I was facing like 11 or 12 kids and I was the only one pulling,"*

Interviewer: "On the giant lever, that goes back and forth?

Tim: *"Yeah, and then…"*

Interviewer: "And who won?"

Tim: *"I won of course, because I had the side with mechanical advantage! And then, I think it was Mr. Brownly that went, he was on the side that had mechanical advantage, I was on the other side, and I was pulling as hard as I could. It took about 30 seconds for him to win, and then we switched sides. And then I won, of course!"*

Tim continues: *"It was actually one of those times that I really loved to be with my friends, and then every once in a while I found someone to talk to that I really didn't* *know, but they still [go to my school]. I don't really get to talk to a lot of 8th graders. I usually talk to 7th and 6th graders."* (interview, Tim, 7th grade boy, 10/13)

Furthermore, when game group participants referenced experiencing people fun, it was often in the form of collaboration or competition, both of which require a goal-oriented context. The following section discusses how game group participants engaged in these particular types of people fun.

**Types of People Fun.** With the addition of a goal that comes with the introduction of a game, new kinds of social interaction fun become available. Competition and collaboration are types of people fun that require a goal-oriented situation. Whereas the comparison group overwhelmingly cited general social interaction as their primary source of people fun, those in the game group were more likely to mention collaboration (i.e. working together toward a goal) as their source of people fun. Table 30 compares the distribution of types of people fun for the game and comparison groups.

Table 30

*Types of People Fun, Game vs Comparison*

| | A : Collaboration | B : Competition | C : Social Interaction |
|---|---|---|---|
| 1 : Comparison | 0.89% | 9.39% | 89.72% |
| 2 : Game | 49.06% | 20.99% | 29.95% |

The following quotes are examples of game group participants' descriptions of the collaborative people fun (as well as other types) that they enjoyed during their visit to the science center.

*It was challenging and fun. Mostly it was fun to work with my team and interact with each other. (post-survey, Kerry,6th grade girl, 3/14)*

*I liked that we had to find different things and work in teams. We got to play games and it was like a fun little game. (interview, Damon, 7th grade boy, 10/13)*

*I enjoyed looking through things, since I'm a kind of logical person, I figured out what to do with it and stuff and helped my teammates. (interview, Lily, 8th grade girl, 10/13)*

*I liked being able to do with partners, so you could either do it with a friend, or do it with someone that you usually don't go with. But I did it with [Angela], because I know her the most out of the whole group and we go to school together. We didn't go to school together last year, but we were in the girl scout troop two years ago. But I liked that part of it. And I liked that everybody is at a different pace, so some people are behind, not behind, but they're at a different question than you, one that you've already done, or one that you've gotten to yet, and so you get to see them passing by and see what they're doing. And I liked everybody has fun and everybody wins the game. (interview, Ingrid, 6th grade girl, 10/14)*

Similarly, the following video vignette is an example of how playing the game provided an opportunity for collaborative social interaction. In this scene, a boy team is at the Giant Lever. Having just scanned the code and read the challenge, they realize that they need to find another team to collaborate with at this exhibit.

Boy 1 to Boy 2, *"You're pulling all by yourself."*

A girl team walks by, but the boys ignore them. Then a different girl team shows up.

Boy 2, *"Oh perfect!"*

The two teams confer, then the first girl team that walked by comes back, too. Both girl teams scan the Giant Lever code.

Boy 1, *"So we need someone to pull on the other side."*

The boys pull on Side A, the girls pull on Side B. Side B is the side with mechanical advantage, so the girls win. One of the girls from the other team takes the picture for the boys.

Very few participants in the comparison group indicated that collaboration or competition were types of people fun they enjoyed during their visit to the science center. Only 1% of people fun references made by the comparison group were in the form of collaboration, while for the game group, 49% of the references were about collaboration. Similarly, 9% of the comparision group's people fun references focused on some sort of competition, while 21% of the game group's references did. Interestingly, although both boys and girls in the game group were more likely to mention collaboration as a type of people fun they enjoyed, boys were more likely than girls to mention enjoying competition.

**Boys Like Competition.** Of particular interest is whether and how males and females played and perceived the game differently. In the game group, both sexes enjoyed collaboration more than competition. However, girls enjoyed general social interaction more than competition while boys expressed near equal enjoyment of those two types of people fun. Boys were more likely to display a sense of urgency or to mention a competitive aspect to the game as a source of enjoyment than girls were.

Table 261

*Types of People Fun by Gender*

| | **A : Collaboration** | **B : Competition** | **C: Social Interaction** |
|---|---|---|---|
| 1 : Female | 51.87% | 15.85% | 32.29% |
| 2 : Male | 47.53% | 25.63% | 26.84% |

In one notable GoPro clip, the boy wearing the camera is nearly running with his iPad held out in front of him, shouting "Go!  Go!  Go!"  and singing the theme to Mission Impossible (video, 5th grade boy, 6/14).  There were several examples of boys exhibiting this type of urgency, as though they were engaged in a race or competition.  Male teams would converge to compare their progress and emerge with a renewed sense of urgency.  Also, it appeared that male teams would more readily collaborate with female teams.

> *It was enjoyable, and I liked the competition of the game and how I learned with it. (post-survey, Jerry, 8th grade boy, 7/14)*
>
> Male team 1: (approaching two more male teams at the calculator QR code): *What are you guys looking at?*
>
> Male team 2: *Look at this, it froze!*  (the game froze) *Let's get back down there before they do...*
>
> Male team 1: *So wait, you guys are racing against each other?*
>
> Male team 2: *Yep*.
>
> Male team 3: leaves after scanning the calculator and male team 1 moves in to scan the calculator code.  Male team 2 is still struggling with the frozen screen.
>
> Male team 1: *Oh yeah, I got it!  Okay then, let's go downstairs so we can find some more*

(looking at the map while walking down the stairs.)

Male team 2 heads downstairs to the help desk. (video, $8^{th}$ grade boys, 10/13)

Male team 1 approaches the treehouse, female team is there, but male team 1 is not deterred by this. Male team 1 and female team appear to collaborate with each other until male team 2 enters the treehouse. At that point, male team 1 runs out of the treehouse. (video, mixed group, 7/14)

Girls, on the other hand, were more likely to mention enjoying the notion of collaboration or teamwork. They would frequently be seen comparing progress with other female teams, but were more likely to share information about where challenges could found or how to solve them.

*I liked being able to go with partners, so you could either do it with a friend, or do it with someone that you usually don't go with…And I liked that everybody is at a different pace, so some people are behind, not behind, but they're at a different question than you, one that you've already done, or one that you haven't gotten to yet, and so you get to see them passing by and see what they're doing. And I liked that everybody has fun and everybody wins the game. (interview, Ingrid, 6th grade girl, 10/14)*

*I enjoyed looking through things, since I'm a kind of logical person, I figured out what to do with it and stuff and helped my teammates. (interview, Lily, $8^{th}$ grade girl, 10/13)*

Interviewer: How could the experience at the science center have been more fun?

$7^{th}$ grade girl: *Instead of being split up, we could be as a group. (interview, Sandy, $8^{th}$ grade girl, 10/13)*

Two female teams and one male team converge inside the elevator.

Female team 1: *How many have you found? How many have you scanned? We've* *scanned three already. Here ya'll can scan this one* (they have taken the QR code from the exhibit where it belongs). *Do you know how?*

Female team 2: *It's not working* (covers the camera).

Girl from team 1 helps girl from team 2 scan code. (video, mixed group, 10/13)

Girl 1 brings a QR code to two groups and offers it for scanning before she goes to put it back in Melody Park. Two female teams scan the code (video, mixed female groups, 10/13).

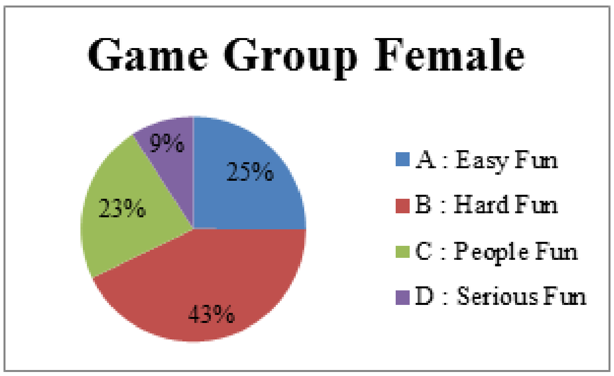
Both boys and girls were observed expressing pride in having information that another team did not possess. Girls would more typically vaunt their knowledge by sharing it with another team. Boys, on the other hand, were more likely to relish the opportunity to keep the information to themselves and making certain the other team realized they were doing it. For example, video footage shows one male team running up to another team and exclaiming, "Have you found the compass?!" The other team members reply, "No, have you? Where is it?" And the first team responds, "We're not telling! We're off to the electricity exhibit!" (video, Nate and Sam, 6$^{th}$ grade boys, 5/14)

Within the game group, both males and females highest ranking type of fun was hard fun, although it was higher for females (43%) than males (37%). The second place category for both males and females was easy fun, with easy fun accounting for a greater percentage for the males (32%) than females (25%). People fun ranked third for both males (27%) and females (23%). Finally serious fun ranked last for both males (5%) and females (9%). There was more difference between males and females in the categories of hard fun and easy fun than there was in the categories of people fun and serious fun. Table 272 and Figure *2* show the distribution of references by type of fun and gender.

Table 272

*Types of Fun by Gender*

| | **A : Easy Fun** | **B : Hard Fun** | **C : People Fun** | **D : Serious Fun** |
|---|---|---|---|---|
| 1 : Female | 25.09% | 42.78% | 23.01% | 9.12% |
| 2 : Male | 31.58% | 36.61% | 27.01% | 4.81% |



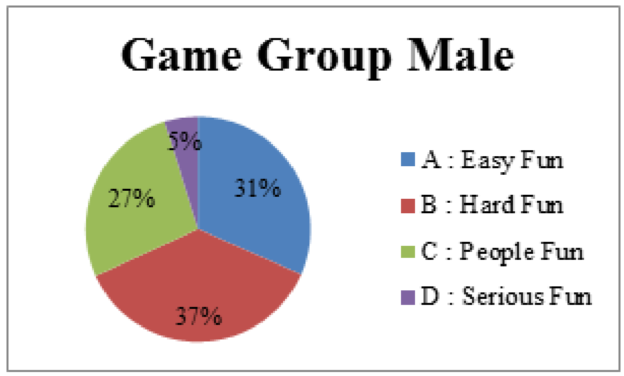




*Figure 2.* Distribution of Types of Fun, by Gender

One remarkable difference between boys' and girls' perceptions of the game and their gameplay behavior was found in areas that are classified as "hard fun". Hard fun can be described as an appreciation for challenge, mastery, and a sense of accomplishment. People who enjoy hard fun are those who like having their attention focused by a goal, constraints, or strategy (Lazzaro, 2004). Girls were more likely than boys to express an appreciation for the hard fun aspects of playing the game.

> *Oh it was pretty awesome. It was pretty hard. It was challenging.* [Did that make it good or make it bad?] *It made it good; it was a fun trip around [the science center]. (interview, Lacey, 8th grade girl, 10/13)*
>
> *Doing things that are hard makes it more fun. (interview, Cathy, 6th grade girl,*

*10/14)*

*Sometimes doing things that are hard makes it more fun…it took us awhile to find the picture thing, which made it a little bit hard and a little bit fun. (interview, Ingrid, 6th grade girl, 10/14)*

*For me though, the more challenging it is – I love strategy games, I love them, I play them a whole bunch on the internet – and whenever it involves my mind, and involves thinking, that's usually whenever I get the fun in me (starts vibrating, shaking, as she speaks) And that's what I consider fun (interview, Susan, 6$^{th}$ grade girl, 10/14)*

*I liked that we got to go around and try new challenges involving science....I actually had a lot of fun. I also thought it was cool to try to figure out some of the challenges like the musical game; it was fun but hard at the same time. (interview, Winona, 8$^{th}$ grade girl, 10/13)*

Girls' gameplay behavior also supported this interpretation. In one GoPro clip, a 6$^{th}$ grade girl animatedly describes with glee the difficult process she went through to solve the first part of the Sky Bike challenge (video, Cathy, 6$^{th}$ grade girl, 10/14). Girls displayed goal driven behavior, working hard to solve individual challenges and seeking help from other players or adults when they got stuck. In fact, girls often described having felt confused during the game, whereas boys were more likely to display frustration. In the passage below, Lacey, an 8$^{th}$ girl, explains that she liked the dino lab challenge the most, even though she found it very confusing.

Interviewer: What did you enjoy most about the Great STEM Caper game?

*Lacey: I guess I enjoyed the bone* [i.e. dino lab challenge], *even though I was really confused on how to go find it.*

Interviewer: But that was the part of the game that you enjoyed the most? Trying to figure out that crime scene?

*Lacey: Yep, I also liked the one with the fingerprint.*

*(interview, Lacey, 8th grade girl, 10/13)*

Boys would display a sense of excited urgency, but were generally not as persistent to solve a single challenge. When they got stuck with a challenge that posed particular difficulty, boys were more likely to skip it and go look for another QR code than to become deeply focused on solving the difficult challenge.

*I liked scanning all these things but I could not get any points!* (post-survey, Richard, 7th grade boy, 10/13)

*I didn't know how to answer the questions. Like, I tried to find some way to answer the questions, like I just tried rescanning the code over and over again and couldn't answer the question.* (interview, Nathan, 8th grade boy, 10/13)

In the following video excerpt, some boys come to the help desk for assistance. After they are given an explanation for how to solve a particular challenge, they half-heartedly try again, but still get frustrated and give up. The boys come back to me because they weren't getting any points for TAGGING, like I showed them on the Intro Quest. I explain what the SkyBike quest requires: counting the bricks, dividing the total weight of the ballast by the number bricks, etc. Boys walk away, exclaiming,

Boy 1: *"This is hard! We gotta go all the way back up there..."*

They go to the elevator. But they seem down, not excited.

Boy 1: *"How much is the skybike?"*

Boy 2: *"The weight is 200,"*

Boy 1 puts 200 into the decoder but it doesn't work.

Boy 1: *"Probably we gotta scan it again."*

They scan the SkyBike code again and count the bricks they can see in the picture (22).

Boy 1 puts 22 into the decoder but it does not work. Some other boys come around.

Boy 1: *"I ain't changing it, man, that's not even the code!"*

Boy 2: *"She told us to do it*!"

Boy 1: *"Man, it didn't work, though...man, I don't...where da train at*?"

Boy 1 hands the iPad to Boy 2 and takes the camera off his head.

Boy 1: *"You wanna wear this on your head?"*

Boy 2 puts the camera on his head. Both boys leave the SkyBike area.

(video, $7^{th}$ grade boys, 7/14)

**Having a Goal = Fun + Learning**

Appreciation for a goal was another specific difference between boys and girls who played The Great STEM Caper Game. Girls often expressed that having a goal while they explored the science center made the visit more fun and helped them to learn more. Boys did not express this sentiment. For girls, it seems, having a goal provided both fun and learning.

*[I liked] that me and my partner could roam around science city by ourselves and keep us entertained with a goal. (post-survey, Sarah,* $7^{th}$ grade girl, 7/14)

*I liked that you could walk around; you had something to look for instead of looking around for something to do. And also this was fun; you can't always learn and have fun so I really enjoyed this. (post-survey, Lacey, $8^{th}$ grade girl, 10/13)*

*It's more fun if you have something to play with than just looking around; it gives you more information about it. (interview, Pam, $6^{th}$ grade girl, 10/14)*

*I'd probably like to play [another] game, because you're getting steered in a* *direction of what to do there, because if you don't have a game, you're just visiting the thing and not really learning anything. I mean [the science center] is supposed to teach kids but also have fun while they're at it, so some of the exhibits, I mean there were a few things we got to do without the game, and those I didn't learn anything because there wasn't really a purpose in reading those. (interview, Cathy, 6th grade girl, 10/14)*

Girls articulated the notion that having a goal made the science center visit more fun and more educational. And they appreciated the hard fun experienced by meeting the goal through solving the challenges presented in the game. They also felt that working hard at playing the game resulted not only in more fun, but also in more learning.

**Easy Fun = Scanning QR Codes, Exploring, Autonomy**

Both boys and girls were likely to mention that they enjoyed the easy fun elements of the science center visit and playing The Great STEM Caper, although boys slightly more so. Participants particularly enjoyed searching for the QR codes and scanning them. This game mechanic was frequently described as a "scavenger hunt". A few teams (both male and female) even adopted the strategy of finding and scanning all of the QR codes before choosing a challenge to solve. It is worth noting that this was not a successful strategy and no team that followed it ultimately completed the game.

> [I liked] *Finding the QR codes and scanning the codes to get quests.* (post-survey, Nema, 6th grade girl, 8/14)
>
> *I liked searching for the scanner tags; it was like a hunting game.* (post-survey, Anna, 8th grade girl, 10/13)
>
> *I like that I got to go everywhere, how I found the scanning stuff and looked for the stars* [on the map]. (interview, Mindy, 8th grade girl, 10/13)

*I liked the little cards, you had to find the cards and stuff.* (interview, Carmen, 8th grade girl, 10/13)

[I liked that]*You could go around the whole entire place and there was stuff to find everywhere, and it wasn't just that you find the little code and then you go to the next one, there was stuff to do when you found it.* (interview, Aaron, 6th grade boy, 5/14)

*Just make it who can find the most barcodes and not have to do a quest.* (post-survey, Nate, 6th grade boy, 5/14)

Other oft mentioned sources of easy enjoyment were the notions of exploration and autonomy. Participants enjoyed the opportunity to freely move about the science center and explore the museum on their own without immediate adult supervision.

*I enjoyed going with friends from school, so I already knew some people, and it was a new experience because I got to test games and I didn't have grown-ups all surrounded around me watching me, so, yeah, I had fun. (interview, Jake, 7th grade boy, 7/14)*

*I liked that I had the freedom to explore around. It was my first time coming here and I enjoyed it and I learned some stuff. It is fun to test games. It was a good and fun thing to do. :) (post-survey, Petra, 7th grade girl)*

*It was a good activity for us, because not only did we learn, we were able to wander and try out different things and experiments within [the science center]! (post-survey, Ethan, 5th grade boy, 5/14)*

There are several exhibits in the science center that fall into categories that could be described as "rides and slides". Exhibits such as a stationary helicopter one can pretend to fly, the Sky Bike (a bicycle with 200 lbs of ballast that one rides across a tight wire), life-size trains to explore, and a simulated sewer pipe in which visitors can climb and slide. The Sky Bike and the sewer slides are also often described as “scary” by participants.  Another “scary” exhibit is the Mr. E Hotel, which is full of optical illusions and mind benders.  Many participants mentioned the easy fun of these particular exhibits because they required kinesthetic involvement and/or because they were scary.  The following interview with a Thomas, an 8th grade boy, provides an example.

> Interviewer: So, tell me about your visit to the science center.
>
> Thomas: *It was actually pretty fun.  I didn’t get on the helicopter, though.  I like the slide, but everybody else wants to go down it while there’s people sitting at the bottom, just standing there and I got stuck in there.*
>
> Interviewer: In the sewer slide?
>
> Thomas: *Yeah, and I went in this room with a mirror and I took a picture with the iPad and it showed all my bones.  And it was real cool, and somebody tapped me on my back, I was so scared!  It was fun, we went on the Sky Bike, where I got to ride backward, I was scared!  I was shaking, it was so fun!*
>
> *(interview, Thomas, 8th grade boy, 10/13)*

Finally, both boys and girls were equally likely to engage in the most common type of easy fun behavior found at museums and science centers: the “ping-pong effect”—bouncing from one exhibit to another, turning dials or pushing buttons without engaging with the science or engineering concepts demonstrated by the exhibit.  In this excerpt from the GoPro video footage, two 7th grade girls, Pam and Nancy, are moving around the science center and talking about looking for the next game objective, but getting distracted from their mission by superficial interactions with the energy exhibit.

Pam: *So, where now? We gotta go the science of energy...no we gotta go to the crime lab, let's go to the crime lab...well, the science of energy is actually right here, so...first I wanna try this* (she gets on the stationary bike). *This is fun!* (her pedaling lights the bulbs) *Okay I'm getting off.*

Pam moves to another part of the exhibit and turns the big crank wheel to light the LED bulbs. She wanders away from Nancy, who was running on the giant hamster wheel.

Pam: *So what are we supposed to do? No, no… there's supposed to be* [a QR code]...*over here...*

Pam goes to light up the model city and starts cranking and turning dials. Nancy is cranking the big wheel and then riding the bike. There is no science talk between them at all.

Nancy: *Have you found the thing?* (She is referring to the QR code for the challenge that accompanies the Unplugged energy exhibit.)

Pam: *No.*

Now Nancy is cranking and turning dials and touching the screen wall. They keep playing with the cranks and dials.

Pam: *Hey, this thing creates wind.*

She puts her hand in front of the fan to feel and then flicks the wind turbine blades with her fingers to test it, it speeds up, but then immediately slows back down to same speed as before, indicating that the wind from the fan is not blowing the blades of the turbine after all.

Pam: *Let's go to the crime lab!* (Walks past the QR code without seeing it.)

(video, Pam & Nancy, 7th grade girls, 7/14)

**Learning is Serious Fun**

Occasionally, both male and female participants would mention enjoying the fact that they were learning during the game and/or during the visit to the science center. Learning has implications in participants' real lives outside of the field trip or the game, therefore this type of enjoyment is categorized as serious fun. As evidenced by the question "How much do you think you learned?" on the post-survey, participants who played the game thought they learned between "some" and "a lot". However, when questioned in follow-up interviews, only a few could articulate what they had learned during the visit. In fact, some explicitly stated that they were having fun so they didn't realize they were learning, too. Although in hindsight, nearly all participants felt that they had learned something during their visit to the science center.

> *I think that it was a great experience for people that want to learn and have a good time. (post-survey, Serena, 7th grade girl, comparison group, 7/14))*
>
> *I thought it was more fun than learning. It was learning, but you didn't really feel like it because you were having so much fun. I mean like you didn't know you were learning, but what you were doing was just learning about science and everything.*
> *(interview, Jake, 8th grade boy, comparison group, 7/14)*
>
> *What I liked was that we could all learn and have fun all at the same time.*
> *(post-survey, Deacon, 7th grade boy, game group, 10/13)*
>
> *What I liked about the game was you got to learn and still play.*
> *(post-survey, Mary, 7th grade girl, 10/13)*
>
> *I learned about how to find evidence, kind of, you know, with the footprints, and how she might be an inch or two longer. I learned how to estimate better, because I'm not really good at estimating, but I figured it out. I also learned, like, the different types of animals,*

*like amphibians and stuff. I don't really recall what I learned...but I do recall remembering what I learned when I was there. (interview, Ingrid, 6th grade girl, 10/14)*

**GoPros Function Well**

The GoPro cameras were used successfully during this study to collect first-person video footage from participants as they explored the science center and played The Great STEM Caper. Participants were enthusiastic about wearing the cameras. In response to being asked, "What did you enjoy most about the game," several participants mentioned the GoPro cameras.

> *I liked that you could take pictures and videos. I also liked the camera on my head. I wonder if I could see the video.* (post-survey, Cathy, 6th grade girl, 8/14)
>
> *Where you get to wear the camera on your head and record everything.* (interview, Timothy, 7th grade boy, 10/13)

Participants' enjoyment of the GoPro was also evident in the video footage itself. In the following excerpt, James wants try the GoPro, so he and his partner Timothy trade for a moment.

> James: "*Aw, let me wear it, let me wear it*!"
>
> Boys trade camera, James adjusts it on his head.
>
> James: *"Does this look okay?"*
>
> James then takes the camera back off again and holds it at arm's length for a selfie smile. He holds the camera in his hands and plays with it for a minute, then gives camera back to Timothy who puts it back on. James helps him adjust the angle. (video, James and Timothy, 7th grade boys, 10/13)

The GoPro was especially good at collecting valid observational data, as the participants did not seem to perceive themselves as being observed by adults while they were wearing the camera. There were several incidents of wearers running through the science center after being instructed to walk or uttering mild obscenities which they would not have done in the presence of adults. After about an hour, the head-mounted camera could become heavy, sweaty, and uncomfortable, so most pairs ended up trading the camera about halfway through the visit. If Bluetooth were turned on to enable control of the camera via an iPad app, the battery would die after about 80 minutes, before the 2 hour visit was over. With Bluetooth turned off, the GoPro batteries lasted about 2 hours, or nearly always enough time to capture the entire visit. Both audio and video were high quality and clear.

**Technology Presents Challenges**

The most common obstacles to a successful gameplay experience came in the form of technology problems. The iPads and ARIS were not always stable, and many participants experienced freezes, glitches, and crashes which pulled them out of the gameplay experience. In addition, the wi-fi network was not as robust as it needed to be to handle the uploading and downloading of audio, images, and video by ten iPads at one time. Many times, the game would freeze during a data upload or download, sometimes even losing data in the process.

> *The game was okay; I kept having a issues with the iPad, that was kind of boring.* (post-survey, Carmen, 8th grade girl, 10/13)
>
> *A lot of the game bugged, so I didn't like that part.* (post-survey, Simon, 5th grade boy, 5/14)

These technology problems were confusing and frustrating to the participants, as well as to the researcher. The following quotes were typical of participants' reactions to the technology problems.

## Science Center Presents Obstacles to a Positive Gameplay Experience

The science center itself presented a few obstacles to a positive gameplay experience. At certain times, the science center would become so crowded that study participants had difficulty interacting with the exhibits.

> *The only thing I didn't like, which is non-fixable, is that everyone was waiting in line to do our experiment. All the little kids and grown-ups and adults were shoving in front of us, would like shove their kid in front of us and like, 'No, you can go, just go ahead, go with your sister.' And we was like, you know what? We'll come back later. That was it, but at the same time, it's unfixable.* (interview, Cecily, 8th grade girl, 10/13)

Furthermore, exhibits were often broken, in need of repair, decommissioned, or moved to another part of the science center.

> *There were some things that were broken that weren't working, because the science center has been there for a long time, so if those things got fixed up, I think it would be more fun.* (interview, Peggy, 8th grade girl, 7/14)

If the unavailable exhibit had a corresponding challenge within the game, that QR code would not be set out that day.

## Players Don't Always Play as Intended

Somewhat to the surprise of the researcher, players would not always watch an in-game victory video or complete the mini-survey after completing a challenge. This was important because the videos and the surveys were an integral part of the research design. The intensity of the victory videos were tied to the difficulty of the challenge that was completed. This design element was intended to affect players' self-efficacy by giving them a greater victory experience when they completed more difficult challenges. When players did not view the victory videos, that game element became moot. Likewise the same was true with the mini-surveys that would pop-up after every completed challenge to ask the player about their experience of fun, victory, and difficulty with that challenge. Many players completed the surveys, but many did not. More valid results could have been collected if the players were forced to complete the survey before "clicking out" of the survey screen. Unfortunately, the ARIS game design platform did not allow this.

**Elevator Offers Quiet and Private Place to Focus**

An unexpected phenomenon occurred when participants entered the elevator. It was only due to the GoPro cameras that the phenomenon was observed. When players entered the elevator, their behavior and conversation frequently changed. Without other teams around or the distraction of all the noise and activity in the larger science center, players turned to one another to discuss strategy. In the following video excerpt, Nate and Sam, 6th grade boys are entering the elevator:

> Sam exclaims as he enters the elevator, *"The tardis! The tardis awaits! Adios! Adios amigos!"*
>
> As soon as the elevator door closes, the two boys sit down on the floor of the elevator.
>
> Sam: *"Okay, so let's see what we actually have for quests, we have new quests, active…*
>
> Nate: *"I'm not sure."*
>
> Sam: *"We need to go back down. Press A.*
>
> Nate: *"This is floor A."*
>
> Sam: *"Oh, okay, B. Okay we need to go trade out something, we need to go get our magnifying glass, or stopwatch."*
>
> They leave the elevator when it stops at floor B and head down the stairs.
>
> (video, Sam and Nate, 6th grade boys, 5/14)

In a similar scene, two 8th grade boys, Tony and Michael, have just entered the elevator and the boy holding the iPad takes a moment to express his pleasure at being in the elevator; then he stops to take stock of their situation and progress within the game.

> Tony: *"I feel awesome in this thing [elevator]! I just can walk around..."* (He stops to look at the map.) *"Where we going? How about, uh, Music Park?"*
>
> Tony goes to QUESTS to find out everything that needs to be done, but seems to gloss over some of the instructions. He then goes back to QUESTS and reads aloud the Melody Park quest...reads again...goes back to NOTEBOOK (speaking aloud the whole time) gives it a title, forgets to tag or share.
>
> Tony: *"I just like doing this, it's kind of..."*

Tony doesn't finish his sentence because the elevator stops, but one might interpret his meaning as an appreciation of the quiet calm inside the elevator. For many participants, the elevator seemed to offer a moment's respite from the hectic atmosphere outside in the science center.

## Summary of Qualitative Findings

Although gameplay did not result in changes in self-efficacy, as hypothesized, it did provide a qualitatively different experience for participants. Whereas participants in the comparison group found people fun and social interaction to be the most enjoyable aspect of the visit, those in the game group found goal-oriented hard fun to be the primary source of enjoyment, especially the girls. Furthermore, both boys and girls enjoyed the collaborative aspect of gameplay. Boys enjoyed being part of a team, but they were also more likely than girls to imbue the game with a sense of urgency as though it were a race or a competition. For girls more so than boys, having a goal was equated with both fun and learning. A related finding is that girls often express confusion, while boys were more likely to display frustration. Boys were less likely to persist in solving a particularly difficult challenge, but were more likely to choose to look for a new challenge instead. Both boys and girls enjoyed the easy fun aspects of gameplay, such as exploring, autonomy, and code scanning, although boys were slightly more likely to mention easy fun experiences as the primary source of enjoyment. Interestingly, serious fun, or fun derived from learning, was the second most common source of enjoyment for the comparison group, after social interaction and people fun. Ultimately, qualitative analysis showed that boys' and girls' gameplay behaviors and perceptions of the game were similar, with some minimal differences related to collaboration vs competition and enjoying the focus on achieving a difficult goal.

Qualitative anlaysis also provided several insights into research methods and designing games for the science center. The most positive finding was the success of using head mounted GoPro cameras to capture high definition video from the player's perspective. On the negative side, the iPads, ARIS, and the wi-fi connection were not trouble-free. Players experienced many glitches, crashes, and freezes that could be very frustrating, pulling them out of the game until the problem was fixed. Players didn't always play through the game as intended, either. They often skipped watching victory videos or completing the mini-surveys after each completed challenge. The noisy, crowded science center, broken exhibits, and hungry participants also presented obstacles to a fun and successful experience. Finally, an unexpected change in game-focused behavior and conversation occurred when players would step inside the science center's glass elevator. These findings will inform the next iteration of exhibit-based game development.

## Summary of Results

Together, the quantitative and qualitative analyses tell an interesting story about the affect of playing the Great STEM Caper during a group field trip to a hands-on science center. There were not any differences in change outcomes on the overall MSLQ or the subscales of self-efficacy and interest/enjoyment between those who played the game and those who did not. Girls in the game group began their visit to the science center with higher science self-efficacy than the boys in that group. As would be expected from a group with higher self-efficacy, girls did outperform the boys in game achievement. However, neither girls nor boys demonstrated a significant change from pre- to post-, and when the visit was over, there was no longer a difference between girls' and boys' science self-efficacy. In fact, success at completing challenges and winning the game was negatively correlated with change in self-efficacy. The qualitative analysis provides a deeper explanation into what might have happened.

In alignment with Brophy's position that self-efficacy is a strong predictor of performance (1987), it makes sense for the girls to have outperformed the boys on game achievement, considering that the girls had higher self-efficacy going into the gameplay situation. This might lead one to think that the boys thought the game was harder than the girls did. Further analysis of the data does not support that conclusion. girls were more likely to describe the game both as "too hard" and "too easy". The more challenges girls completed, the more difficult they thought the challenges were; while the more challenges boys completed, the higher their reported enjoyment of the challenges and their experience of victory. Although girls expressed enjoyment of challenge and working toward a goal during their visit to the science center, and their game performance supports this disposition, their efforts seemed to have had the opposite effect from what was intended and expected. Girls associated their achievements with a feeling of difficulty. Boys did not perform as well as girls, nor were they as persistent, but as they achieved, they associated their achievement with a feeling of enjoyment and victory. For boys, in-game victories were more likely to represent mastery experiences, whereas for girls, this did not hold true.

# CHAPTER 5: DISCUSSION

## Project Summary

The primary purpose of this study was to determine if playing an exhibit-based mobile game during a group field trip to a hands-on science would have an effect on participants' affective outcomes: motivation to learn science, science self-efficacy, and interest and enjoyment. Furthermore, this study examined whether there were gender differences in the affective outcomes between participants. It was hypothesized that in-game victory experiences would be equivalent to mastery experiences (Bandura, 1997), which would lead to increased self-efficacy.

The Great STEM Caper was designed to encourage players to engage in science and engineering practices with certain exhibits. The game was intended to be collaborative-- played with a partner and winnable by everyone. It was also specifically designed to preserve the free-choice nature of informal learning. Players sharing one iPad would search for and scan QR codes located at each of the 15 exhibits for which the game had a corresponding challenge. There were three levels of challenge: easy, medium, and hard which, when completed, would earn the players skill units in science, technology, engineering, or mathematics. Easy challenges earned the team one skill unit, medium challenges earned two, and hard challenges earned three. Earning three skill units in any category would earn the team a badge and seven units of any combination would win the game. Players were free to choose which challenges to complete and could do them in any order.

The study used a quasi-experimental, mixed-methods design. Participants were either part of the game group or the comparison group. The game group played the Great STEM Caper during a two hour “goal oriented” visit to the science center. The comparison group explored the science center for two hours in the traditional discovery-oriented way. Both groups completed the Motivation to Learn Science Questionnaire (MLSQ) one to two weeks before their visit to the science center as a pre-survey. Both groups completed the MLSQ again with some additional and open-ended items as a post-survey before they departed the science center. The game group consisted of 79 participants, 45 boys and 34 girls. The comparison group consisted of 42 participants, 22 boys and 20 girls. Follow-up interviews were conducted with a sample of participants from both groups: 22 interviews with game group participants (14 girls, 8 boys) and 6 interviews with comparison group participants, (6 girls and 6 boys). During the visit to the science center, one male pair and one female pair in each group volunteered to wear a head-mounted GoPro camera to record first-person perspective and interactions with the exhibits, the game, and other people. The final piece of quantitative data collected were mini-surveys after each challenge completed in the game which asked about players’ enjoyment, feeling of victory, and perception of difficulty in relation to each individual challenge completed.

Quantitative analyses included comparing the score change from pre-MLSQ to post-MLSQ, along with the subscales of self-efficacy and interest and enjoyment. Change scores for game group vs comparison group, as well as male vs female were compared using independent samples t-tests. Game group participants’ in-game achievement levels were also recorded. Finally, game group participants also produced a team score for challenge enjoyment, experience of victory, and perception of difficulty. Analyses were run to see if there were any correlations between game achievement, enjoyment, victory experience, perception of difficulty, and self-efficacy.

Qualitative analysis used a general inductive approach to examine themes from 40 hours of GoPro video footage, 28 interview transcripts, and open-ended responses on the post-survey.

All qualitative analyses were conducted using the NVIVO software program. The analysis process occurred in five stages. The first stage was to prepare the data for analysis: transcribing videos and interviews and uploading the data into NVIVO. The second stage created codes for each of the fifteen challenge exhibits as well as classifications for male/female and game/comparison. The third stage of qualitative analysis involved multiple close readings of all the data and identification of emerging codes until no further relevant codes could be identified. The fourth stage was focused on reducing overlap and redundancy among the codes and categories. The final stage of qualitative analysis was to examine the frequencies of occurrence for codes and categories to identify the major themes emerging from the data.

Quantitative data analysis indicated that there were no differences in affective change outcomes between the game and comparison groups or between boys and girls in the game group. Girls in the game group scored higher in science efficacy than boys on the pre-MLSQ, but there was no difference in self-efficacy between boys and girls on the post-MLSQ. Correlational analysis indicated that game performance was negatively correlated with change in self-efficacy. For girls, game achievement was correlated with perceptions of difficulty, while boy, on the other hand, associated game achievement with feelings of victory and enjoyment. Finally, girls outperformed boys on every measure of game achievement.

Qualitative analysis suggested that participants enjoyed their visit to the science center in ways that aligned with Lazzaro's 4 Keys to Fun (2011): hard fun, easy fun, people fun, and serious fun. Both boys and girls enjoyed the hard fun aspects of playing the game more than any other type, although girls slightly moreso. Both boys and girls enjoyed easy fun aspects of the game, such as searching for and scanning barcodes, but boys engaged in easy fun more than girls. Both boys and girls engaged in people fun at a similar rate, and most often this took the form of collaboration. However, boys also sometimes imbued the game with a sense of playful competition, which the girls rarely did.

Several things were learned about conducting a design-based study like this one in a museum setting. Firstly, this study serves as proof of concept that the GoPro cameras can be used successfully for capturing first-person data with middle school-age students. Secondly, technology issues such as app glitches, iPad freezes, and unstable wi-fi can cause obstacles to a successful game experience. Some institutional issues to be aware of include excessively noisy environment, crowded conditions, and broken, relocated, or decommissioned exhibits. Over the next several pages, the implications of these findings are explored.

## Interpretation of Findings

Overall, this study demonstrated that an exhibit-based mobile game for middle school students visiting a science center could be a fun and successful addition to the field-trip experience. However, certain outcomes of the study were unexpected and resulted in several insights for those concerned with increasing interest and motivation to learn science in middle school students. In particular, the results of this study offer implications for science center educators, designers of locative and location-based games for learning, and science teachers. This study also provides additional insight into the ways science self-efficacy may be developed in middle-school students. However, instead of providing definitive answers, this study has been more productive at highlighting potential follow-up questions and further avenues for inquiry.

One possible explanation for why gameplay did not appear to have the intended positive effect on the affective outcomes of motivation to learn and self-efficacy is the limited amount of time spent at the science center and playing the game. One 2-hour experience may simply be insufficient time to create any sort of significant change. However, other studies have concluded that short-duration experiences do indeed have the potential to change affective outcomes.  In a rigorous qualitative study of the Scientist in the Classroom program, researchers determined that students who participated in the short-duration science outreach program demonstrated enhanced science interest and engagement in the medium and long-term (Laursen, Liston, Thiry, & Graf, 2007).  A better explanation for the lack of change on the MLSQ may lie in the disparity between students' science museum experience (whether in the game or comparison groups) and their school science experiences.

The MLSQ survey had students rate their feelings about statements related to school science and their ability to do school science.  Self-efficacy is known to be a task-specific construct but it can also be transferred to tasks in related domains under certain conditions (Bandura, 1997).  The conditions for transfer of self-efficacy are 1) the tasks rely on similar sub-skills, 2) the skills in related domains are developed together, and/or 3) a task results in an extremely powerful mastery experience (Bandura, 1997; Woodruff & Cashman, 1993). Although The Great STEM Caper was designed to require players to use science and engineering practices to succeed, it appears that players did not perceive their successful use of those skills in the game as related to their success in school science.  Other studies have found similar results when using technology to provide feedback to participants during the performance of a task.

In one study, participants were given the task of walking blindfolded with scuba fins across a room in exactly 14, 16, or 18 seconds (Achterkamp, Hermens, Volenbroek-Hutten, 2015).  After 15 trials, participants reported increased self-efficacy on the task when they received corrective or positive-only feedback via speakers in the form of a statement and a relative number of claps.  However, participants' increased self-efficacy did not transfer to physical activity in general.  The Achterkamp et al.  study has many notable similarities to The

Great STEM Caper study. In the "walking blindfolded while wearing scuba fins" experiment, researchers could be fairly certain that their participants had never participated in a similar task. Before this study, the science center had not ever implemented an exhibit-based mobile game and the field of location-based games is so new, it is quite unlikely that any of the participants in The Great STEM Caper had ever experienced a similar set of tasks. The Great STEM Caper offered 15 challenge opportunities and provided the players with positive technology-based feedback via animations and bursts of applause that varied in intensity after successfully completing challenges of different levels of difficulty. In contrast, however, Great STEM Caper participants were not asked to rate their self-efficacy with the game task itself, but only for the related domain of school science. If players experienced increased self-efficacy toward the game task, it did not transfer to their self-efficacy toward doing and learning science in school.

A second possibility to take into consideration is that participants' moods while completing the pre- and post- surveys may have influenced their self-reported attitudes toward science. There is some concern that a survey given at the end of an event may be a better indicator of participant's level of enjoyment than the constructs the survey was intended to measure (Bogue, 2005 in Laursen et al, 2006). However, if this were the case, based on observations of the participants enjoying themselves during the museum visit as well as their self-reported high level of enjoyment immediately following the visit, one would expect the participants' post-survey scores to show an increase over their pre-visit scores, and this was not the case. On the other hand, one can imagine that participants were in a state of heightened positive mood while they completed the pre-MLSQ in anticipation of going on a field trip and visiting the science center. Likewise, when the experience was over, participants faced the eminence of leaving the science center, re-boarding the bus, and returning to a familiar daily routine. Transient mood has been shown to affect attitude judgments, with “bad” moods influencing subjects to report poorer attitude toward unrelated constructs and “good” moods resulting in higher ratings (Schwarz & Clore, 1983). One can imagine that participants’ moods at the time they were completing the post-MLSQ may have been less positive than during the pre-MLSQ. Positive or negative, participants’ transient moods may have affected their survey responses. One possible way to avoid the potential “everything reflects enjoyment” effect would be to have participants complete the post-visit survey after returning to their schools. If participants are experiencing a negative mood due to the conclusion of the field trip, perhaps that could be counteracted by offering the participants a small but exciting reward for completing the post-survey. For instance, each participant could be offered a free ticket to return to the science center upon completion of the post-survey. By offering a free ticket to return, the researcher might be able to recreate a similar mood state in participants as when they completed the pre-survey in anticipation of their visit. In the next section, we take a deeper look at self-efficacy research and how the gameplay experience may have fit into the current understanding of how people form their science self-efficacy beliefs.

**Relation to Previous Research**

Self-efficacy beliefs are positively associated with other motivational constructs such as self-regulation (Zimmerman & Bandura, 1994) and mastery goal orientation (Pintrich, 2000). In their science self-efficacy study of 319 $5^{th}$ -$8^{th}$ grade students, Bitner and Pajares (2006) found that boys and girls reported equal science self-efficacy although girls had higher science grades. Boys reported stronger mastery experiences than did girls, but girls reported higher levels of self-efficacy for self-regulation. In The Great STEM Caper study, girls scored significantly higher than boys on the pre-visit MLSQ subscale measure of self-efficacy (girls = 18.76, boys = 16.92, $t$ $=2.19$, $p = .032$) but showed no significance difference from the boys on the post-measure.

Although in this study, “self-regulation” was not measured by a separate subscale, girls’ gameplay behaviors seem to support Britner and Pajares’(2006) explanation that those with high levels of self-regulation science self-efficacy are more likely to believe they can succeed in science tasks, choose to participate in such tasks, work hard to complete them successfully, and to persevere in the face of difficulty. In the Great STEM Caper, the girls moreso than boys demonstrated and expressed enjoyment of the hard fun of working toward a goal and persistence in the face of difficulty.

This study also confirms Brophy’s (1987) theory that self-efficacy is a strong predictor of performance. The girls had higher self-efficacy than the boys going into the gameplay experience and they outperformed the boys on every measure of game achievement. However, this study was unable to confirm the primary hypothesis that in-game victories would serve as mastery experiences which would lead to increased self-efficacy. After gameplay, girls self-efficacy scores had decreased (although not significantly) and boys self-efficacy had increased (also not significantly). The resulting difference between boys’and girls’self-efficacy scores was no longer significant. One of Britner and Pajares’(2006) findings was that boys reported stronger mastery experiences while girls reported higher science anxiety and related physiological states. This disparity between boys’ and girls’ experience may be echoed in the correlations between game challenges completed and the perceptions of game enjoyment, victory, or difficulty. For boys, the more challenges they completed, the more victorious they felt and the more they enjoyed the game; but for girls, the more challenges they completed, the more difficult they felt the game was. It seems that boys and girls interpreted the experience of in-game success differently. Further investigation into previous research may provide some possible explanations for this phenomenon, as well as suggest new questions to investigate.

In previous studies of science self-efficacy, girls were found to have more confidence in their ability to succeed in school generally (Britner & Pajares, 2001). The researchers speculated that girls' greater facility with language may result in their experiencing success and mastery in science during elementary and middle school when such classes are more likely to be taught using language-related methods than inquiry-based methods. The Great STEM Caper is a text-based game requiring players to read challenges, quests, and descriptions, as opposed to the more common animated digital game that communicates with the player via audio and video. This fact may be a contributing factor to the greater success that girls experienced while playing the game. However, the practice-based tasks required to complete each challenge would be unfamiliar to both boys and girls whose school science experience has been language-based. Girls' assumed greater facility with reading may have contributed to their game success, but the practice-based tasks themselves may have caused high levels of confusion and anxiety, diminishing the positive effect of success on their science self-efficacy.

Bandura (1997) explained that the most influential source of self-efficacy belief isn't merely the experience of success or failure, but rather, how the experience is interpreted. Successes that occur as a result of overcoming challenges may promote a more resilient sense of self-efficacy than those that are easily achieved (Bandura, 1997, Britner & Pajares, 2006). However, even hard won success does not automatically translate into a mastery experience. Rather, individuals must cognitively process these experiences along with factors such as previously held beliefs of self-efficacy, the perceived difficulty of the task, the effort expended on the task, and the help received to complete the task (Britner & Pajares, 2006). It may be that the girls who played The Great STEM Caper did not perceive themselves as particularly successful although they clearly surpassed the boys in game achievement. As the game was designed to be collaborative, there were no mechanisms in place to communicate to the players how they performed in comparison to others.  Perhaps the girls were unaware that they had done so well.

Although mastery experience is the most influential source of self-efficacy, Bandura (1986, 1997) theorized that there are three other sources as well: vicarious experience, social persuasion, and physiological states.  People form their self-efficacy beliefs in part by the vicarious experience of observing others similar to themselves perform tasks.  The judgments of others also effect the formation of self-efficacy beliefs through social persuasion.  Social persuasion can work to empower or weaken self-efficacy beliefs, but it is easier to weaken self-efficacy through negative feedback than to strengthen it through positive appraisals.  Finally, people gauge their degree of self-confidence by the psychological or emotional state they experience when they contemplate or engage in a particular task.  The physiological states of anxiety, stress, and arousal provide information about efficacy beliefs (Bandura, 1997). Emotional states that are perceived as negative such as high anxiety, stress, and tension may inhibit performance and contribute to lower self-efficacy.  People more readily expect success when they experience a state of positive emotional arousal.  These three other sources have proven less consistently predictive than mastery experiences (Britner & Pajares, 2006) but there have been some studies that have found gender differences.  Social persuasion has been shown to be predictive of self-efficacy for girls, but not for boys (Usher & Pajares, 2008).  Conversely, vicarious experience and physiological state predicted self-efficacy for boys (Usher & Pajares, 2008).  Although they were not analyzed for this report, it could be productive to reanalyze the in-game and video game data to determine what role these three contributors to self-efficacy may have played during the Great STEM Caper experience.

In the context of playing The Great STEM Caper, some of these other sources of self-efficacy may have had a negative influence that effectively diminished the positive impact of simple game performance.  Girls more often expressed a feeling of confusion in relation to gameplay, while boys were more likely to express frustration.  The physiological state of feeling confused or frustrated may have had a negative effect on players' self-efficacy beliefs.  Locative and location-based mobile games are so new that all participants were likely to be equally unfamiliar with the genre and format.  It is also likely that the game design and individual challenges may have lacked clarity.  Suggestions for improvement are discussed in the section titled "Implications for Game Designers."  Another possibility that should concern all science educators, formal and informal alike, is that challenges designed to get players to engage in science and engineering practices may have asked them to think and perform in ways that were unfamiliar, resulting in anxiety, tension, or stress.  Rather than increasing science self-efficacy, the practice-based nature of the challenges themselves may have kept players from perceiving their success as a mastery experience.

Finally, it should be noted that most of the questions on the MLSQ are specifically focused on participants' school science experience.  It may be that participants did not recognize game challenges as related to their in-school science experience.  Neither boys nor girls showed significant change from pre- to post- on the MLSQ or any of the subscales.  If participants did not recognized challenges based on the NGSS science and engineering practices as related to their school science experience, perhaps a game such as The Great STEM Caper could be used to provide a practice-based bridge between informal, out-of-school and formal, in-school science learning experiences.

**Enjoyment and Perceptions of Game Differ by Gender**

One of the most important findings of this study was that participants enjoyed the game for different reasons and that boys and girls played and perceived the game a little differently. Nicole Lazzaro's 4 Keys to Fun (2011) were found to be useful for describing players' experiences while playing The Great STEM Caper. Although boys and girls all enjoyed the hard fun, easy fun, people fun, and serious fun aspects of the gameplay experience, they also differed in the degree to which they engaged in and enjoyed each type of fun. Hard fun was particularly appreciated by the girls, whereas easy fun was particularly enjoyed by boys. Likewise, both boys and girls enjoyed people fun and collaboration in particular, but boys were also more likely to imbue a sense of competition into gameplay than girls were. The following sections discuss what these different gameplay behaviors might tell us about the way boys and girls perceived the experience differently and what that might mean for educational, location-based game design.

**Hard Fun.** The game group participants enjoyed the hard fun aspect of solving challenges. The enjoyment of hard fun was evident for both boys and girls when they exhibited "fiero" after completing a challenge. However, in follow-up interviews, girls were more likely to mention explicitly how much they enjoyed having a goal during their visit to the science center and that having "something to look for" or "something to play" made the visit more fun. Several participants also mentioned that they had been to the science center before, some of them several times, and that having the game to play resulted in an experience that was more fun than aimlessly exploring the science center would have been.

*I liked that me and my partner could roam around [the science center] by ourselves and keep us entertained with a goal. (post-survey, Sarah, 7th grade girl, 7/14)*

*It's more fun if you have something to play with than just looking around; it gives you* *more information about it. (interview, Maggie, $6^{th}$ grade girl, 10/14)*

The game was designed to allow players to choose the type and difficulty of challenges they wanted to do. They could choose not only which category of challenges to complete (i.e. S, T, E, or M), but they could also choose challenges of three difficulty levels: easy, medium, and hard. Designing the game this way allowed players to customize their gameplay experience to fit their interests, strengths, and abilities. The game provided a goal, and this customizable, goal-based experience made engaging with the science center exhibits more fun, especially for the girls.

**Easy Fun.** Easy fun was also enjoyed by both boys and girls. Participants enjoyed the autonomous nature of the game, appreciating the opportunity to explore the science center without direct adult supervision. Participants also enjoyed seeking and scanning of QR codes. Boys were especially motivated by finding and scanning the QR codes. More so than girls, boys would exhibit "fiero" after having merely found a QR code. They enjoyed the treasure hunt aspect of the game. Some teams chose to find and scan all of the codes before choosing any challenges to complete. A few participants even suggested that the game would be more fun if it were only about finding and scanning codes, rather than having challenges to complete. A few others complained that the barcodes were too hard to find.

*Just make it who can find the most barcodes and not have to do a quest. (post-survey, Nate, $6^{th}$ grade boy, 5/14)*

*I did not like the fact that the barcodes were hard to find. I never found the one in the astronaut center and that bugged me a whole lot, but other than that I loved it! It was very fun! (post-survey, Stanley, $6^{th}$ grade boy, 5/14)*

The game mechanic of finding and scanning barcodes was introduced into the game because it was an affordable and effective method for implementing a location-based digital game inside the science center. An outdoor game would have been able to utilize true location-based capabilities of ARIS by using GPS to determine the player's location. However, indoors, this is not possible. To avoid having to buy additional equipment, such as RFID tags or beacons, the decision was made to incorporate QR codes for players to find and scan to launch each challenge. This necessity resulted in a game mechanic that ended up adding its own element of easy fun for players to enjoy.

**People Fun.** People fun was the most common type of fun when game and comparison groups were combined, accounting for about 40% of all of the fun references between the two groups. However, the type of people fun in participants engaged looked markedly different between the groups. Participants in the comparison group expressed or displayed enjoyment of simple social interaction in 49% of the references to fun. This was the most common type of fun, by far, experienced by participants in the comparison group (the next common being serious fun with 27% of the references). In the comparison group, participants enjoyed being with their friends in a social way that was not particularly associated with the museum or its exhibits. In contrast, people fun accounted for 32% of the game group participants' references to fun, but the type of people fun experienced by the game group was more goal-directed and oriented toward the exhibits and their accompanying challenges.

***Collaboration and Competition.*** For both boys and girls in the game group, collaboration was the most common type of people fun expressed, accounting for 52% of the girls' references to people fun and 48% of the boys'. The Great STEM Caper was designed to be played collaboratively and all players could "win" game, so it was expected that collaboration should be high in the game group. What was interesting is that some players, especially boys, also imbued gameplay with a playful spirit of competition which was not purposefully designed into the game. Twenty-six percent of game boys' references to people fun were classified as competitive in nature, while girls only expressed this type of people fun in 16% of their people fun references. Interestingly, enjoying competition did not mean that one didn't also enjoy collaboration. The two sub-types of people fun coexisted for game group participants. This outcome reinforces the notion that, when a game's design allows it, players will customize gameplay to maximize their experience of fun.

***The Notebook.*** The ARIS Notebook proved to be a particularly well-received game mechanic that engaged players in people fun and social interaction. Many participants specifically mentioned enjoying the social networking aspect of the Notebook. They enjoyed taking pictures and making audio and video recordings with the Notebook. On a few occasions, players would use the notebook to take pictures "just for fun" or make recordings that were not related to a challenge. Participants especially enjoyed sharing, "liking", and commenting on those pictures and recordings with the larger group via the "Share" function in the ARIS Notebook. The "share" mechanic was introduced during Orientation and the Introductory Challenge and players continued to use it throughout the game. This function provided a connection between teams around the science center and supported either a collaborative or competitive approach to gameplay.

**Serious Fun.** Participants in the comparison group were more likely to reference an appreciation for "serious fun" (27%) than those who played the game (11%). In the context of a visit to the science center, serious fun can be described as the enjoyment of an activity because the outcome is meaningful in the real world; in this case, that meaningful outcome was learning about science and engineering. An appreciation of serious fun is illustrated by the following post-survey quote from one of the 7$^{th}$ grade girls in the comparison group, "*I think that it was a* *great experience for people that want to learn and have a good time (Serena, 7/14.)"* Some of the game group participants also appreciated the serious fun afforded by the game, recognizing that the game was helping them learn science and engineering skills: "*What I liked about the game was you got to learn and still play (post-survey, Mary, 7th grade girl, 10/13)."* Several others understood that the visit to the science center was supposed to be related to learning science, but they described the experience as one that didn't feel particularly like learning, whether they played the game or not:

> *Because [Nancy], she told me that she didn't really understand what she was supposed to be learning from that thing, it was more like a game to her, and she said all she was trying to do was get the badges. And I was like, I'm with you half the time, because sometimes I didn't get what I was supposed to be learning from the exact activity.* (interview, Cathy, $6^{th}$ grade, game group, 10/14)
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> *I thought it was more fun than learning. It was learning but you didn't really feel like it because you were having so much fun…. I mean like you knew you were…you didn't know you were learning, but what you were doing was just learning about science and everything.* (interview, Jake, $8^{th}$ grade, comparison group, 7/14 )

It appears as if having a game to play provided players with a goal that motivated their activities in the science center, while those who did not have a game were guided by other types of motivation. A desire to learn from the experience and the enjoyment of learning were more likely to be expressed by the comparison group (27%) that did not have a more goal-oriented type of motivation offered to them, whereas the game group was far more likely to reference "hard fun" (35%), the enjoyment of achieving a goal.

**Choice is Fun.** Providing players with opportunities to engage in each of the four types of fun allows them to be the ultimate designers of their experience. Games that offer rich and varied opportunities for players to participate in the kinds of fun they most enjoy are more likely to appeal to a variety of people and to engage them more deeply (Koster, 2010). Designers of games for learning, like teachers and informal educators, should strive to engage all learners. The value of free choice learning has long been recognized by informal learning institutions (Falk and Dierking, 2000) such as the science center in this study. When people are given the freedom to choose which exhibits with which to interact and how to interact with them, they are intrinsically motivated to participate in the ways that are most engaging to them (Falk and Dierking, 2000). Likewise, offering players of learning games the opportunity and choice to engage in any or all of the four types of fun is an effective approach to designing learning games that will engage and motivate the widest variety of players.

## Implications for Science Teachers

Science teachers take students on field-trips for reasons that span both cognitive and affective goals. Many teachers view field-trips as an opportunity to enhance students' interest and motivation in science (Kiesel, 2005). However, in this age of increasing accountability, teachers often find it more difficult to justify the expenditure of time and resources to take students out of school without solid evidence that the experience will have a positive and measureable impact on their students' attitudes toward science or their conceptual understanding. While it was hoped that this study might help provide teachers with just that sort of evidence, the outcomes were not that simple. However, there are still some valuable findings here for teachers who are interested in engaging students in science and engineering, as well as game-based learning.

This study shows that most $5^{th}$-$8^{th}$ grade students, boys and girls alike, are intrinsically motivated to play a locative mobile learning game such as The Great STEM Caper and that they enjoy the experience greatly. Furthermore, students report that they would rather play a game than to explore the science center on their own without a game. Students appreciate the goal-directed experience provided by the game. As illustrated by the following quotes, this study suggests that students have more fun on field trips that include a game-based structure, than those that are simply discovery oriented.

> *It was pretty cool; it was a lot more interesting with the game because I'd already done everything there a lot of times, so it gave something else to do, so that made it more fun. (interview, Arthur, $6^{th}$ grade boy, 3/14)*
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> *I'd probably like to play a different game, because you're getting steered into a direction of what to do there, because if you don't have a game, you're just visiting the thing and not really learning anything. I mean* [the science center] *is supposed to teach kids but also have fun while* [they're] *at it…there were a few things we got to do without the game, and those I didn't learn anything because there wasn't really a purpose in reading those. (interview, Cathy, $6^{th}$ grade girl, 10/14)*

With a game like The Great STEM Caper, students are intrinsically motivated to engage in science and engineering practices with the exhibits and the field trip is more likely to fulfill its purpose.

Because The Great STEM Caper was built on the ARIS platform, game design utilized the ARIS Notebook. To solve challenges, players were often required to record audio explanations of scientific phenomena, to take pictures of particular examples, or to make a video of a team-designed investigation. Each of these player-created media were uploaded to the

Notebook and shared among all teams playing the game. With the ability to "like" and "comment" on each other's contributions, players formed a social network within the game.

> In the Nature Center, [Cathy] talks to the bird who catcalls her, *"I think this is my favorite one here, I want to take a picture. I'm going to take a video to show everyone."* (video, Cathy, 6th grade girl, 10/14)
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> *Well, it was fun that you got to take pictures and videos with it and that you got to type. I also like that you got to scan things. That was kinda cool actually.* (interview, Cathy, 6th grade girl, 10/14)
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> *I liked that you could take pictures and videos. I also liked the camera on my head. I wonder if I could see the video.* (post-survey, Carey, 8th grade girl, 8/14)

Many players referenced how much they enjoyed using the Notebook and the social aspect of the game. The Notebook served to facilitate the social construction of knowledge during the game. These interactions may also have provided a conduit of social persuasion, whether positive or negative, that contributed to the formation of self-efficacy beliefs in participants.

This study did not explore the full potential of ARIS and the Notebook feature to support student learning, however. All of the player-created media in ARIS reside on the ARIS server, meaning that the media are all accessible from the internet when a group returns to the classroom. By giving students the opportunity to reflect on and discuss their own and classmates' solutions to challenges back in the classroom, the teacher could provide an opportunity for metacognitive reflection and extended social constructivism. Based on students' lived, hands-on experiences, the richness of the student-generated media artifacts could be valuable for focusing and engaging students more deeply in the relevant science and engineering concepts when groups return to a formal learning context.

## Implications for Informal Education Settings

The open-source ARIS platform has brought locative and location-based game development within reach of anyone, not just computer programmers. Informal science education centers should take note, because the addition of a virtual game layer to an existing exhibit layout has the potential to increase visitor engagement and attendance. Some of the participants in this study remarked how playing the game contributed to their having the most fun during this particular visit to the science center, when compared to all of their previous visits. Similarly, participants felt that it was more fun to explore the science center with a goal in mind.

> *This was the most fun I've had out of all my visits.* [I liked] *that me and my partner could roam around science city by ourselves and keep us entertained with a goal.* (post-survey, Sarah, $7^{th}$ grade girl, 7/14)

Because the game was challenge and QR code based, it was flexible enough to be easily adjusted when problems arose with specific exhibits. Furthermore, should new exhibits be developed at the science center, new challenges could easily be added to the game. Although some individual challenges did have a narrative element, the game was not sequential in nature, affording the challenges to be thought of as modules: easily added or removed as necessary. Using ARIS, games are simple enough to create that a science center could potentially create many different games for different audiences or different learning objectives. In this way, visitors could have a customized and unique experience across multiple visits. With a different game to play during each visit, the experience could be completely new every time, even with the same exhibits. Participants enjoyed playing the game and nearly all indicated that they would prefer to play another game rather than to explore the science center on their own. This sentiment held true for participants in the comparison group as well. In spite of shortcomings with the game design, problems with the wi-fi, and glitches with the technology, participants enjoyed playing the game and wanted to play more games like it.

This study also demonstrated the viability of using head-mounted GoPro cameras to collect first person video data with middle school age subjects. The participants enjoyed wearing the cameras and they successfully captured high-quality video and audio of participants' interactions with the game on the ipad, with the exhibits, and with other participants. There is a common assumption that the presence of a video recording device affects participant behavior and could possibly lead to invalid results (Speer & Hutchby, 2003). However, the recommended approach is to examine the video for evidence that the presence of the camera influenced participant behavior (Heath, Hindmarsh, & Luff, 2010). In this study, participants appeared to behave naturally while they were wearing the camera and did not generally modify their behavior due to awareness that they were being observed. Occasionally another participant would remind the camera-wearer that their actions and vocalizations were being recorded and "could be seen", but even these occasional reminders did not appear to affect participant behavior beyond a few seconds. This type of wearable recording device is so new that there have not been any studies about their use in research thus far. Participants in this study expressed excitement about the possibility of wearing the camera and appeared to enjoy the experience. The GoPro would be a valuable evaluation tool for science center education teams. The camera allows researchers or evaluators to observe exactly how visitors interact with the exhibits and whether or not visitors are truly engaging with the intended science concepts. Furthermore, the design element of pairing participants during gameplay not only serves to encourage collaboration, but it also gives the researcher or evaluator a window into the thinking of the players as partners must discuss and explain their ideas to each other.

**Locative Games for Learning: Lessons Learned *(a.k.a Implications for Game Designers)***

This project was conceived not only as a research study, but also as an opportunity for the researcher to delve into designing a mobile, locative learning game for the first time. As with anything done for the first time, there were many lessons learned along the way to creating a game that met the minimal criteria required. On the most basic level, the game had to be functional; it had to work. After that, the game needed to get players engaged in science and engineering practices. Finally, the game needed to be fun; participants had to be intrinsically motivated to play the game because they enjoyed playing it. On all three counts, this first game was a limited success, but many improvements could be made to create a better locative game-based learning experience. The following paragraphs outline the lessons learned throughout this study regarding game design.

**Orientation Required.** The pilot study made it clear that a whole-group orientation to the game at the beginning of a group's visit was critical. Due to technical difficulties, the planned group orientation was scrapped during the pilot study. As a result, none of the pilot teams were able to complete the game, and in fact, even with 8 teams playing, only one challenge was completed. The orientation consisted of three major components. First, the whole group views the animated introductory video to the game on a large screen with amplified sound. The video tells the players what the game objectives are and what is required to win the game. Due to noise levels in the science center, the video could not be viewed on the iPads as originally intended because the audio could not be heard. Second, the group was introduced to ARIS and the tabs that one uses to navigate around in the game: Inventory, Quests, Notebook, Decoder, and Attributes. In Inventory, players were introduced to the map of the science center with stars that indicated where each challenge QR code was located. The final, and most critical, piece of the orientation was the Introductory Quest. After participants were paired, given an iPad, and had created a login name and password, they were ready to complete their first quest. The Introductory Quest showed participants what the QR codes looked like that they would be looking for. It also gave every team the chance to successfully scan a code, complete a Notebook-based challenge, and see the change in their Quests and Attributes tabs before heading out into the science center on their own. That way, if there was any confusion, everyone was still together to offer and receive assistance. After the whole-group orientation and Introductory Quest was implemented, many teams were able to complete the game and nearly all teams were able to complete one or more challenges during the two-hour visit. A group orientation was critical for a successful gameplay experience.

**Simplify Language & Instructions.** Qualitative feedback from participants gave several suggestions for improving the gameplay experience. The most common criticism was that the game was confusing. Due to the difficulty of playing with a partner in a noisy, open area, the challenges were all text-based, rather than audio. Therefore, players had to read each challenge carefully to understand what they had to do with the exhibit in question to earn the skill unit(s) for that challenge. GoPro video revealed that simply reading the text was challenging for some participants and language should be simplified. Navigating around in the game, especially in the Notebook was also confusing to many players. A further conundrum was designing a game that truly engaged players in science and engineering practices that could be confirmed through the game. This was done through the use of players tagging and sharing their Notes as well as solving puzzles or answering questions in the Decoder. For example, to solve the Giant Lever challenge, players must take a picture of two teams competing at the Giant Lever and then record an audio explanation of why no matter who is pulling, the same side always wins. Once the picture and audio were uploaded into the Notebook, players had to tag the Note "mechanical advantage" and they had to share the note with the rest of the group. There were several steps required to create a media piece in the Notebook , share it, and tag it. If any of the steps were overlooked, the challenge would not be completed. Likewise, the Decoder requires that the player enter in the precise alphanumeric code that solves a challenge. If the code entered isn't spelled properly, or if it isn't capitalized incorrectly, then the code will not satisfy the challenge. These detailed requirements made the game confusing or frustrating to many players. A simple solution might be to build in generic pop-up notices that remind players to double check quest requirements such as tagging and sharing if a challenge quest remains incomplete.

**Add Audio.** Besides simplifying the language, another solution to the problem of participants encountering difficulty reading the challenges could be to add audio to every challenge and quest explanation. If both teammates wore a wireless Bluetooth earphone that was synched to the same iPad, then both partners could hear the game instructions clearly while ambient noise would be diminished. Adding audio would also allow the introduction of music and character voices. Audio is a proven way to engage players on a more emotional level and could make the game not only clearer, but more fun to play as well. Furthermore, the addition of audio would be a tremendous improvement toward making the game more accessible for players of varying abilities and preferences.

**Players Skip Important Game Elements.** Video data clearly show that some participants did not watch the in-game victory videos, clicking through them instead of clicking the "play" button. The victory videos were an important element in the study as they were intended to reinforce to the player the level of victory achieved with each challenge. Unfortunately, ARIS does not facilitate videos that play automatically, without the player clicking the play button. From a design perspective, there could be several ways to improve this situation. One strategy might be to do away with the victory videos altogether, and instead give the player a token for their Inventory for every challenge completed that reflects the magnitude of each victory. Another strategy might be to keep the videos, but to make each one different and more interesting to watch so that the players would want to click play to satisfy their curiosity. This method could also be used to add more fun into the game by creating a different humorous video for every challenge victory.

Another similar problem was players not completing the mini-surveys after each challenge. The survey would launch, but players would often click out of the survey without completing it. Again, ARIS does not facilitate forcing a player to interact with a weblink such as the SurveyMonkey mini-survey. This situation also causes a bit of an ethical dilemma, as one might argue that in a research study such as this one, it is most ethical to give players the freedom to choose whether or not to complete the survey. Ultimately, it was decided that making players aware of the importance of the mini-surveys during the group orientation would be the most effective and ethical course of action. The percentage of mini-surveys completed increased after this practice was implemented.

**Managing Technology Limitations.** At times, unstable technology posed a significant obstacle to successful gameplay. To alleviate the frustration associated with the iPads and game crashing during gameplay, the game should be downloaded onto each device prior to gameplay. Currently, ARIS works by constantly accessing the network to upload and download data for the game. The possibility exists, however, to create a game that is played offline, except for player upload of Notebook media and connections between players using the “like” and “comment” features in the Notebook. To strengthen the wi-fi network within the science center, perhaps hotspots could be introduced into the physical space near the exhibits that have challenges requiring substantial player upload. Alleviating technical frustrations would help participants stay in the flow of gameplay and decrease the amount of confusion and frustration experienced.

**Players Need Scaffolding.** Another game design improvement would be the addition of scaffolding within the game. Many participants expressed confusion and frustration with the game and some even specifically suggested that the game should include hints, manuals, or a choice of levels. Adding scaffolds such as these would align with best practices of Universal Design for Learning as well as good game design. Alleviating player discomfort experienced as a result of confusion or frustration might serve to improve the player's emotional or physiological state, which is a contributing factor toward the formation of positive self-efficacy beliefs.

## Study Limitations

This study has several limitations, most of which involve inequalities between the groups being studied and the data collected from these groups. Museum exhibits were in constant flux and every group that visited science center had a slightly different experience. Interviews could not be conducted with a sample from every group that visited the science center. Working with many different groups that volunteered to participate in the study resulted in varying levels of adherence to the research protocol. Additionally, there were also many technical difficulties which not only introduced unintended obstacles to gameplay, but also contributed to some loss of in-game data. These limitations made the study challenging and influenced how the data could be analyzed.

The comparison group (n=45) was approximately half the size of the game group (n=79) and was about a year older. On average, the comparison group participants were in $8^{th}$ grade while the game group participants were entering $7^{th}$ grade. Furthermore, the game group was a more disadvantaged group with approximately 79% of game group participants coming from schools with higher than 50% free/reduced lunch population. Only 48% of the comparison group came from such schools. There were significant differences on the MLSQ pre-test between the game and comparison groups, as well. Due to these differences, this study focused on comparing the change from pre- to post- between the groups, rather than the actual scores.

Despite a well-planned research protocol, working with many different volunteer groups resulted in a couple of major deviations from the original study design. First, there were two groups that did not complete the pre-MLSQ prior to arriving at the science center. These two groups, one in the game group (n=10) and one in the comparison group (n=15), had to complete the pre-MLSQ upon their arrival, approximately two hours before completing their visit and taking the post-MLSQ. This deviation from protocol introduced internal validity concerns about pretest effects due to taking the pretest and the posttest so close together. Since the 10 compromised data points in the game group only represented a small portion of the whole game group (n=79), those data were retained. However, since the 15 compromised data points in the comparison represented a much greater percentage of the overall comparison group (n=45), those data were excluded from quantitative analysis.

The second significant deviation from protocol occurred when five out of the ten groups were unable to schedule follow-up interviews with the researcher. Four of these groups were game group participants and one was the same comparison group that did not complete the pre-MLSQ prior to arriving at the science center. This resulted in an uneven number of male (n=10) and female (n=18) interviews, which caused complications during qualitative analysis.

Due to institutional changes, no two groups experienced the science center in exactly the same way. It was a common occurrence for exhibits to be broken and in need of repair or for an exhibit to be removed altogether. Exhibits were also moved around the science center, causing confusion with players trying to read the map. Fortunately, the nature of QR-codes makes it easy to adjust game content when necessary. If an exhibit was broken or removed, that QR code would not be put out, effectively removing that challenge from the game. If an exhibit were moved to another location, the QR code would be placed appropriately; however, this fix did not alleviate any confusion due to an inaccurate map. Although these issues created a situation in which not every group in the study encountered the same science center experience, they also provided the opportunity to test and demonstrate the flexibility of an exhibit-based mobile game. The game always worked, even when some of the challenges were unavailable.

Technical issues represented a final type of limitation of this study. The game was designed to engage players in science and engineering practices, which, for some challenges, involved recording audio or video explanations of a scientific investigation or even just taking pictures of various phenomena. Due to wi-fi instability and/or bandwidth limitations, players would frequently encounter difficulty uploading these media within the game. Sometimes their media were lost, causing unnecessary frustration during gameplay. It was not uncommon for the game or iPad to crash or freeze, requiring players to return to the help desk so that the researcher could restart the game for them. It is likely that these unintended difficulties contributed to players' sense of frustration and even lack of success during gameplay.

## Future Research

This project was the first iteration of a design-based research agenda and there are several logical next steps to pursue in exploring the affective effects of playing a mobile, locative game for learning inside a science center. The primary focus of further study should be looking for ways to improve both the game and research design to maximize the possibility that participants would experience a measureable increase in affective outcomes such as self-efficacy, interest and enjoyment, and overall motivation to learn science.  However, this study also uncovered some interesting phenomena around the way participants experienced their visit to the science center and gameplay in particular, especially some unexpected and previously unexplored differences between the way that girls and boys perceived location-based gameplay.  Further study should also aim to better describe and explain these phenomena.  Some possible next steps are outlined in the paragraphs that follow.

**Increasing Self-Efficacy**

Several changes to game and research design could be made to increase the likelihood that participants would experience a measureable change in affective outcomes such as self-efficacy.  First and foremost, there are concerns that the science center visit and gameplay experience are so different from participants' in-school science experiences, that the MLSQ instrument is not well-aligned for detecting changes in affective outcomes such as interest and enjoyment, self-efficacy, and overall motivation to learn science (i.e.  a mastery experience in the game may be perceived as having no relation to success in school science.) Secondly, increasing the game-value of sharing one's achievements and providing positive feedback to other players through the ARIS Notebook could be an effective strategy for leveraging people fun to enhance the effect of vicarious experience and social persuasion within the game.  Related to that is the fact that the game provided no mechanism for players to compare their achievements with others.  Girls did very well in the game, but perhaps they did not realize how well they had performed.  Finally, decreasing the amount of confusion and frustration related to gameplay should help improve players' physiological states throughout the visit to the science center.  With the goal of increasing positive and measurable change in players' affective outcomes, these three areas should be the foci: 1) more opportunity for positive social persuasion and vicarious experience, 2) improving players' physiological states throughout gameplay, and 3) better alignment in research design between experiences and the measurement instrument.

To increase the positive vicarious and social persuasion experiences provided through the game, one game design improvement could focus on leveraging players' enjoyment of people fun. In addition to mastery experiences, vicarious experiences and social persuasion also have a strong influence on the formation of self-efficacy beliefs (Bandura, 1997). Whether it was due to poor alignment with the instrument or flaws in game design, it is apparent that in-game success alone was not effective at increasing participants' science self-efficacy. Because participants demonstrated their enjoyment of people fun, especially through use of the ARIS Notebook, perhaps more focus on how participants perceive their performance would help lead to the desired outcomes. Participants enjoyed the people fun of connecting with other players through the game, either for collaborative or competitive purposes. In particular, they enjoyed uploading their media-based challenge solutions to the ARIS Notebook and receiving "likes" and/or "comments" on their posts from other teams. Having those social connection features of the Notebook occupy a more central role in gameplay would encourage players and teams to be more connected to one another through sharing their progress and providing feedback to others. These connections could provide players with more positive vicarious experiences through seeing what other teams had accomplished, as well as more positive social persuasion experiences through feedback received from other players. These two factors could help contribute to an increase in self-efficacy.

More sharing of progress and feedback among all of the teams playing would offer players more opportunities for both people fun and hard fun. This type of sharing might spur more competition for those teams that particularly enjoy a competitive approach, most likely male teams. But it would also provide the opportunity for greater collaboration by giving teams information about who had already completed a challenge and might be willing and able to assist another team who might be struggling with that particular challenge. Leveraging the connectivity provided by the Notebook more heavily would use what players enjoy (i.e. interacting with peers) to improve their science center and gameplay experience and hopefully increase the positive affective outcomes of the visit.

To reduce confusion and frustration and induce a more positive physiological state, a system of hints and scaffolds could be designed to assist players who would like hints to help them solve the challenges. Challenges are already categorized by a three-level difficulty system, with easy challenges earning one skill unit, medium challenges earning two, and hard challenges earning three. ARIS game designers can create “conversations” in which players interact with non-playing characters. These conversations can be written to provide hints to players who ask for them. It is also possible to decrease the number of skill units earned for completing a challenge based on how many hints a player had received. The addition of conversations and hints would make the game more complex, less frustrating, more interesting, and more accessible to players of a varying of skill levels. These changes could ultimately make the game more fun to play and improve each player’s positive physiological state.

After these relatively simple adjustments to the game and gameplay experience, the more interesting avenue for further research is to explore why in-game mastery experiences did not result in increased science self-efficacy, as measured by the MLSQ. As mentioned earlier, it seems likely that the items on the MLSQ were not well-aligned with participants’ perceptions of what they experienced through gameplay at the science center. I hypothesize that participants did not relate their gameplay and science center experiences to their experiences of in-school science. One solution to this problem might be to adapt the MLSQ to be more reflective of attitudes toward practice-based science experiences, rather than school-based science experiences. Or possibly to find an existing instrument that would be better aligned with the science center and gameplay experience. However, this route would ignore the more pressing concern that participants perceive an experience that engages them in hands-on science and engineering practices as unrelated to their school science experiences. A more meaningful change to the research design would explore how to use the game to extend and connect participants' experience at the science center to their formal learning back in the classroom. After completing the science center visit, all of media created by players is recorded and available online in the ARIS "Web Backpack." The next phase in this research agenda should involve creating classroom-based follow-up activities that utilize the data collected within the game and the media produced by the players themselves. By connecting the gameplay and science center experience to classroom-based science lessons, students may be more likely to see the connections between the two. If so, perhaps the MLSQ might then be a more appropriate instrument for measuring the impact of gameplay on student's self-efficacy, interest and enjoyment, and motivation to learn science.

## Gender, Gameplay, and Affective Experience

The results of this study indicate that girls and boys achieved and perceived gameplay differently. Girls and boys appreciated the hard fun of having a goal, the people fun of interacting with friends, and the easy fun of exploring and scanning QR codes. Hard fun accounted for more of girls' (43%) fun references than boys (37%) while easy fun accounted for more of boys'(32%) fun references than girls'(25%). People fun accounted for 23% of girls' fun references and 27% of boys'. Interestingly, girls outperformed boys on every measure of game achievement. However, the more challenges girls completed, the more difficulty they experienced; whereas boys experienced more enjoyment and victory the more challenges they completed. Before the gameplay experience, girls displayed significantly higher science self-efficacy than the boys, but after gameplay, there was no longer a difference in self-efficacy between girls and boys, although neither gender's scores changed significantly from pre- to post-measure. The data indicate that girls enjoyed playing the game as much as boys did, but they seem to have perceived the experience differently. Britner and Pajares'(2006) study found that although girls achieved higher levels of success in school science, this did not result in their reporting more mastery experiences (higher in boys) or developing stronger science self-efficacy. In fact, boys reported stronger mastery experiences while girls reported higher science anxiety and related physiological states (Britner and Pajares, 2006). The results of this study are in alignment with those of Britner and Pajares' work. It would seem that the next phase of this research should focus on1) adjustments to game design that serve to decrease girls' anxiety or stress about playing the game, 2) improving girls' physiological state through positive vicarious experience and social persuasion, and 3) ultimately encouraging them to interpret their game success as a mastery experience. Clarifying the challenge language and providing a scaffold of optional hints might be effective at decreasing anxiety. Increasing the use of player-to-player connections through the ARIS notebook and designing that feature to provide more positive vicarious and social persuasion experiences as a primary game mechanic. Girls were successful at playing the game, so using the in-game, player-created media to connect the gameplay experience back to their classroom science lessons might help participants to interpret their game success as a mastery experience in science.

## Connecting Science Center Gameplay to Classroom Learning

The results of the study suggest that having access to the game results and the player-created media back in the classroom could be a powerful resource for science teachers and learners. Participants expressed their enjoyment of using the Notebook to take pictures and audio/video recordings; they also enjoyed wearing the GoPro camera. Some even asked if they could watch the video from the GoPro. Unfortunately, I was unable to make this happen, but the value of the idea began to grow as I contemplated sharing all of the media with the participants. Using ARIS' built-in the "web backpack", anyone can have access to all of the player-created media within a game. Teachers and students could discuss their solutions to the various challenges, solutions could be compared, and students would have the opportunity to engage in metacognitive reflection on their game-playing experience. Metacognition is a key component to developing conceptual understanding in science (Donovan & Bransford, 2005) and reflecting on the gameplay experience offers a perfect opportunity to engage students in this practice. Ideally, relationships could be developed with 6-8 classroom science teachers of demographically similar classes. As in this first study, half of the classrooms would be assigned to the comparison group while the other half would be assigned to the game group. Each teacher would administer the pre-MLSQ a week or two before bringing their classes to the science center and then to have the researcher visit their classroom within the next day or two after the visit. During the follow-up visit, the researcher would lead each group in a metacognitive reflection activity based on the student-created media artifacts created during the visit to the science center. The researcher would also administer the post-survey after the exercise. Finally, follow-up interviews would be conducted with a sample of students from each participating class. By scheduling the follow-up visit before groups arrive at the science center, deviations from the research protocol can be minimized.

Unlike the original study, the comparison group in the second phase would also have the opportunity to record their visit within the Notebook of a discovery-oriented ARIS "game". A discovery-oriented "game" would provide cues for using the Notebook to record interactions with the exhibits, but no goal-oriented challenges, points, or victories. By providing the comparison group with the technology and means to record their exploration of the science center, the follow up visit for both groups could center on a metacognitive activity focused on student-created media. If differences are found when MLSQ change scores between the game and comparison groups are compared in the second phase, it will likely be due to the difference between goal-oriented game-based experience and a discovery-oriented experience since all other variables will be kept the same. If enough teachers from classes with similar demographics volunteer to participate, a third group could be brought into the study that would explore the science center in the traditional discovery-oriented way, just as the comparison group in this original study, without the addition of technology or a follow-up metacognitive activity with the researcher.

**Overall Game Design**

In the context of game design, whether re-working the same game or creating a new game for a different science center, further work should focus on improvement through simplifying and clarifying language, adding audio, and implementing a scaffolding system of hints. Simplifying the language and making challenge instructions easier to understand should help players experience less confusion and frustration, hopefully contributing to a more positive physiological state. Adding audio with wireless Bluetooth earphones would also be a major improvement. Audio would alleviate the need for players to read every screen in the game and should result in more "heads up" posture during gameplay. Audio integrated into the game could serve to increase emotional engagement through the use of music, sound effects, and character voices. The addition of audio would make the game more accessible for participants who are sight challenged or have lower reading ability. Finally, with both partners wearing a wireless earphone, even the partner not holding the iPad could remain more engaged in the game. Simpler language and the addition of audio would hopefully result in a game that is easier to understand, more engaging, and possibly even more fun to play.

## Conclusion

Future research related to this project will focus on using the kinds of fun that players enjoyed to improve the game design with the goal of increasing the likelihood that participants, especially girls, will experience in-game success as a mastery experience. In addition to game design improvements, the research design will be augmented to include a follow-up classroom based metacognitive activity that will incorporate in-game, player-created media. It is hypothesized that these improvements to game and research design should lead to a measureable improvement in science self-efficacy. It is my ultimate goal to use technology, game-based or otherwise, to facilitate the most meaningful and effective connections between formal and informal science education.

## APPENDIX ITEMS FROM CH 3

Table 33

*Challenge Characteristics*

| | **Exhibit** | **Game Element/Mechanic** | | | | **Difficulty Level** | **Content Area** | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **Story** | **Collab** | **Surprise/ Easter Egg** | **Tool Use** | | **Science** | **Tech** | **Eng** | **Math** |
| 1 | Dino Dig | X | | | | Easy | X | | | |
| 2 | Ball Ramp | | | | X | Easy | X | | | |
| 3 | Giant Lever | | X | | | Hard | X | X | | X |
| 4 | Unplugged | | | | X | Hard | X | X | | X |
| 5 | Crime Lab | X | | | | Medium | X | X | | |
| 6 | Nature Center | | X | | | Easy | X | | | |
| 7 | Bird ID | X | | | | Easy | | X | | |
| 8 | Rocket Launch | | X | | | Medium | | X | X | |
| 9 | Melody Park | | X | | | Medium | | | X | X |
| 10 | Maker Bridge | | X | | | Medium | | | X | X |
| 11 | Water Table | | X | | | Easy | | | X | |
| 12 | Sky Bike | | | | X | Medium | | | | XX |
| 13 | Mr. E Hotel | | | X | | Easy | | | | X |
| 14 | Maze | | | X | | Easy | | | | X |
| 15 | Brain Puzzles | | X | X | | Easy | | | X | |
| | ***TOTAL*** | ***3*** | ***7*** | ***3*** | ***3*** | ***8 5 3*** | ***6*** | ***5*** | ***5*** | ***7*** |


*Figure 3.* QR Code


*Figure 4.* Badges


*Figure 5.* Challenge Examples

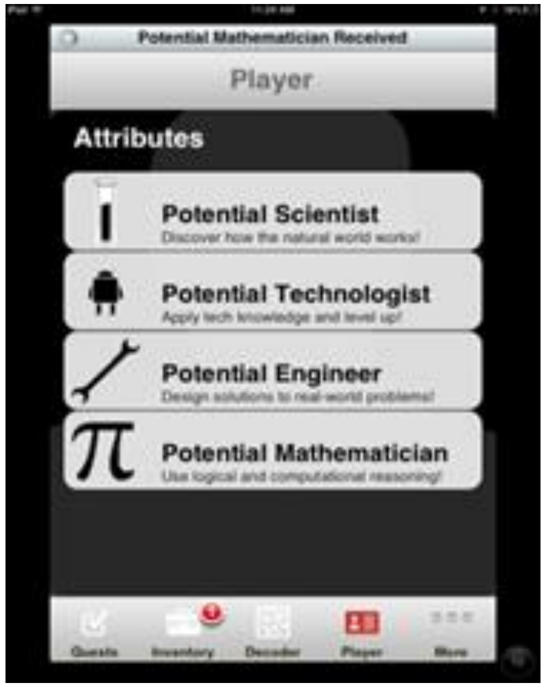


*Figure 6.* Player Attribute Tab

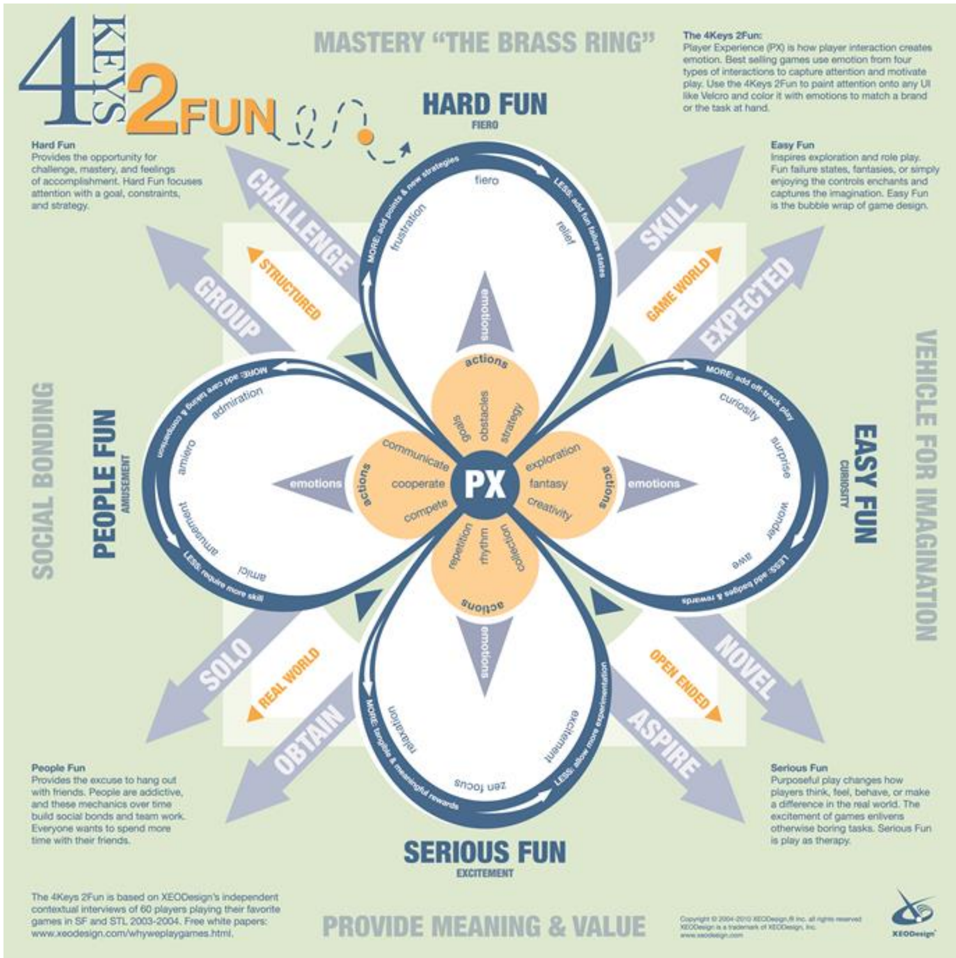


*Figure 7.* Keys to Fun (Lazzaro, 2004)

APPENDIX A – MOTIVATION TO LEARN SCIENCE QUESTIONNAIRE

Barak, Ashkar, Dori (2011)

The Motivation to learn science questionnaire includes 20 1-to-5 Likert-type items, divided into four categories:

a. Self-efficacy (statements: 4, 10, 14, 15, 19)
b. Interest and enjoyment (statements: 1, 7, 8, 11, 17)
c. Connection to daily life (statements: 2, 3, 12, 16, 20)
d. Importance to the student (statements: 5, 6, 9, 13, 18)

| Statement | Agree strongly | Agree | Agree partially | Disagree | Disagree strongly |
|---|---|---|---|---|---|
| 1. I think that science is a very interesting subject. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 2. In science lessons I can get answers to questions that intrigue me. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 3. In science lessons I can express my own ideas. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 4. I can succeed in science even without the teacher's help. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 5. Science shouldn't be an obligatory subject in schools. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 6. The number of hours per-week for science lessons should be increased. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 7. Science lessons fascinate me. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 8. Science lessons bore me. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 9. It is important for me to understand the topics taught in science lessons. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 10. Science lessons are easy for me to study. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 11. I enjoy learning science. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 12. In the future I would like to be a scientist. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 13. Science studies enable me to understand daily phenomenon. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 14. I have confidence in my ability to succeed in science studies. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 15. I help others in science lessons. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 16. I read articles and watch TV broadcasts that present science topics. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 17. I am very interested in explanations of scientific phenomenon. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 18. I think that understanding science is important to everyone. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 19. It is difficult for me to learn science. | ☐ | ☐ | ☐ | ☐ | ☐ |
| 20. Science has no connection to my life. | ☐ | ☐ | ☐ | ☐ | ☐ |

APPENDIX B – POST-SURVEY GAME GROUP

Q1 Based on how you feel right now, please rate the following 20 statements about learning science.

| | **Agree Strongly (1)** | **Agree (2)** | **Agree Partially (3)** | **Disagree (4)** | **Disagree Strongly (5)** |
|---|---|---|---|---|---|
| I think that science is a very interesting subject. (1) | ○ | ○ | ○ | ○ | ○ |
| In science lessons I can get answers to questions that intrigue me. (2) | ○ | ○ | ○ | ○ | ○ |
| In science lessons I can express my own ideas. (3) | ○ | ○ | ○ | ○ | ○ |
| I can succeed in science even without the teacher's help. (4) | ○ | ○ | ○ | ○ | ○ |
| Science shouldn't be a required subject in schools. (5) | ○ | ○ | ○ | ○ | ○ |
| The number of hours per week for science lessons should be increased. (6) | ○ | ○ | ○ | ○ | ○ |
| Science lessons fascinate me. (7) | ○ | ○ | ○ | ○ | ○ |
| Science lessons bore me. (8) | ○ | ○ | ○ | ○ | ○ |
| It is important for me to understand the topics taught in science lessons. (9) | ○ | ○ | ○ | ○ | ○ |
| Science lessons are easy for me to study. (10) | ○ | ○ | ○ | ○ | ○ |
| I enjoy learning science. (11) | ○ | ○ | ○ | ○ | ○ |
| In the future I would like to be a scientist. (12) | ○ | ○ | ○ | ○ | ○ |

| | | | | | |
|---|---|---|---|---|---|
| Science studies enable me to understand daily phenomena. (13) | ○ | ○ | ○ | ○ | ○ |
| I have confidence in my ability to succeed in science studies. (14) | ○ | ○ | ○ | ○ | ○ |
| I help others in science lessons. (15) | ○ | ○ | ○ | ○ | ○ |
| I read articles and watch TV programs that present science topics. (16) | ○ | ○ | ○ | ○ | ○ |
| I am very interested in explanations of scientific phenomena. (17) | ○ | ○ | ○ | ○ | ○ |
| I think that understanding science is important to everyone. (18) | ○ | ○ | ○ | ○ | ○ |
| It is difficult for me to learn science. (19) | ○ | ○ | ○ | ○ | ○ |
| Science has no connection to my life. (20) | ○ | ○ | ○ | ○ | ○ |

Q2 Please choose the response that most accurately reflects your feelings right now.

| | **A lot (1)** | **Some (2)** | **Little (3)** | **None (4)** |
|---|---|---|---|---|
| How much fun did you have inside Science City? (1) | ○ | ○ | ○ | ○ |
| How much do you think you learned during your visit to Science City? (2) | ○ | ○ | ○ | ○ |
| How much did you enjoy playing The Great STEM Caper? (3) | ○ | ○ | ○ | ○ |

Q3 What did you like about The Great STEM Caper game?
Q4 What didn't you like about The Great STEM Caper game?
Q5 What would make The Great STEM Caper a better game?

Q6 What could have made your visit to Science City more fun?
Q7 What could have made your visit to Science City more educational?
Q8 Would you like to visit Science City again?

- Yes (1)
- Maybe (2)
- No (3)

Q9 If you visit Science City again, would you like to play another game or explore without a game?

- Play another game (1)
- Not sure (2)
- Explore without a game (3)

Thank you very much for participating in this research study. Your responses are very valuable to our understanding of how kids can learn from digital games in a science center.

APPENDIX C – POST-SURVEY COMPARISON GROUP

Q1 Based on how you feel right now, please rate the following 20 statements about learning science.

| | **Agree Strongly (1)** | **Agree (2)** | **Agree Partially (3)** | **Disagree (4)** | **Disagree Strongly (5)** |
|---|---|---|---|---|---|
| I think that science is a very interesting subject. (1) | ○ | ○ | ○ | ○ | ○ |
| In science lessons I can get answers to questions that intrigue me. (2) | ○ | ○ | ○ | ○ | ○ |
| In science lessons I can express my own ideas. (3) | ○ | ○ | ○ | ○ | ○ |
| I can succeed in science even without the teacher's help. (4) | ○ | ○ | ○ | ○ | ○ |
| Science shouldn't be a required subject in schools. (5) | ○ | ○ | ○ | ○ | ○ |
| The number of hours per week for science lessons should be increased. (6) | ○ | ○ | ○ | ○ | ○ |
| Science lessons fascinate me. (7) | ○ | ○ | ○ | ○ | ○ |
| Science lessons bore me. (8) | ○ | ○ | ○ | ○ | ○ |
| It is important for me to understand the topics taught in science lessons. (9) | ○ | ○ | ○ | ○ | ○ |
| Science lessons are easy for me to study. (10) | ○ | ○ | ○ | ○ | ○ |
| I enjoy learning science. (11) | ○ | ○ | ○ | ○ | ○ |
| In the future I would like to be a scientist. (12) | ○ | ○ | ○ | ○ | ○ |

| | Agree Strongly (1) | Agree (2) | Agree Partially (3) | Disagree (4) | Disagree Strongly (5) |
|---|---|---|---|---|---|
| Science studies enable me to understand daily phenomena. (13) | ○ | ○ | ○ | ○ | ○ |
| I have confidence in my ability to succeed in science studies. (14) | ○ | ○ | ○ | ○ | ○ |
| I help others in science lessons. (15) | ○ | ○ | ○ | ○ | ○ |
| I read articles and watch TV programs that present science topics. (16) | ○ | ○ | ○ | ○ | ○ |
| I am very interested in explanations of scientific phenomena. (17) | ○ | ○ | ○ | ○ | ○ |
| I think that understanding science is important to everyone. (18) | ○ | ○ | ○ | ○ | ○ |
| It is difficult for me to learn science. (19) | ○ | ○ | ○ | ○ | ○ |
| Science has no connection to my life. (20) | ○ | ○ | ○ | ○ | ○ |

Q2 Please choose the response that most accurately reflects your feelings right now.

| | A lot (1) | Some (2) | Little (3) | None (4) |
|---|---|---|---|---|
| How much fun did you have inside Science City? (1) | ○ | ○ | ○ | ○ |
| How much do you think you learned during your visit to Science City? (2) | ○ | ○ | ○ | ○ |

Q3 What could have made your visit to Science City more fun?
Q4 What could have made your visit to Science City more educational?
Q5 Would you like to visit Science City again?

- Yes (1)
- Maybe (2)
- No (3)

Q6 If you were to visit Science City again, would you like to use an iPad app that turns the visit into a game or would you prefer to explore Science City on your own, without a game?

- Explore on my own (1)
- Not sure (2)
- Play a game (3)
- Thank you very much for participating in this research study. Your responses are very valuable to our understanding of how kids learn during field trips.

## APPENDIX D – POST-FIELD TRIP INTERVIEW PROTOCOL—COMPARISON GROUP

As you might recall, my name is Dana and I am studying how kids learn during field trips to places like Science City. I am going to ask you some questions about your recent trip to Science City. You may remember that you took a survey immediately after your visit. Some of the questions I ask you today may reflect your responses on that survey. There are no right or wrong answers. No one will be mad at you no matter how you answer the questions.

1. Tell me about your trip to Science City.
2. In the survey, you responded that you had (a lot, some, little) fun at Science City. What did you enjoy most about your visit to Science City?
    a. Why do you think Science City wasn't any fun? (if survey response was "no fun")
3. Which exhibits did you most enjoy, and why did you like them?
4. How could the field trip to Science City have been made more enjoyable?
5. In the survey, you responded that you learned (a lot, some, little) while you were at Science City. What do you think you learned from your visit to Science City?
    a. In the survey, you responded that you felt you didn't learn anything from your trip to Science City. Can you tell me more about why you feel that way? (if survey response was "learned nothing")
6. How could the field trip to Science City have been more educational?
7. Would you like to visit Science City again?
8. If you were to visit Science City again, would you like to use an iPad app that turns the visit into a game or would you prefer to explore Science City on your own, without a game—and why?

Thank you so much for participating in this study. Your responses are very helpful to my research to understand how kids learn during field trips. Do you have any questions for me?

## APPENDIX E – POST-FIELD TRIP INTERVIEW PROTOCOL—GAME GROUP

As you might recall, my name is Dana and I am studying how kids learn during field trips to places like Science City. I am going to ask you some questions about your recent trip to Science City. You may remember that you took a survey immediately after your visit. Some of the questions I ask you today may reflect your responses on that survey. There are no right or wrong answers. No one will be mad at you no matter how you answer the questions.

1. Tell me about your trip to Science City.
2. In the survey, you responded that you had (a lot, some, little) fun at Science City. What did you enjoy most about your visit to Science City?
    a. Why do you think Science City wasn't any fun? (if survey response was "no fun")
3. Which exhibits did you most enjoy, and why did you like them?
4. How could the field trip to Science City have been made more enjoyable?
5. In the survey, you responded that you learned (a lot, some, little) while you were at Science City. What do you think you learned from your visit to Science City?
    a. In the survey, you responded that you felt you didn't learn anything from your trip to Science City. Can you tell me more about why you feel that way? (if survey response was "learned nothing")
6. Can you tell me what you enjoyed about playing the TGSC game?
7. What didn't you like about playing TGSC game?
8. What do you think would make TGSC a better game?
    a. More fun?
    b. More educational?
9. How could the field trip to Science City have been more educational?
10. Would you like to visit Science City again?
11. If you were to visit Science City again, would you like to play another game or explore without a game—and why?

Thank you so much for participating in this study. Your responses are very helpful to my research to understand how kids learn during field trips. Do you have any questions for me?

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