ABSTRACT

ZHENG, MEIXUN. Fifth Graders' Flow Experience in a Digital Game-Based Science Learning Environment. (Under the direction of Dr. Hiller A. Spires).

This mixed methods study examined the flow experience of 5th graders in the CRYSTAL ISLAND game-based science learning environment. Participants were 73 5th graders from a suburban public school in the southeastern US. Quantitative data about students' science content learning and attitudes towards science was collected via pre-and post surveys. Quantitative and qualitative data about students' game flow experience was collected using an adapted game flow scale and focus group interviews.

The findings demonstrated that students had high flow experience in the game; however, there were no flow experience differences that were contingent upon gameplay conditions. The results revealed important factors that impacted students' flow experience, including key game design features and student individual differences such as reading proficiency and peer interaction during gameplay. Students made significant content learning gains, but their attitude towards science did not change as a result of gameplay. Flow experience was not found to be a predictor of science learning gains. The results make contributions to the understanding of the effectiveness of game-based learning and the application of flow theory with elementary school students in a game context. Results also have implications for educational game design.

Fifth Graders' Flow Experience in a Digital Game-Based Science Learning Environment

by
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DEDICATION

To my husband, Weiming Zheng. Your love and support made everything possible.

BIOGRAPHY

I started my Ph. D. program in the department of Curriculum and Instruction at NC State University in Fall of 2009. Since then, I have been working as a research assistant at the university's Friday Institute for Educational Innovation. Under the direction of my advisor Dr. Hiller A. Spires, I conduct research at the intersection of literacy and technology. I work on an NSF-funded grant entitled CRYSTAL ISLAND, which aims to develop, design, and empirically evaluate a 3-D intelligent game-based learning environment for 5th grade science education. I have been involved in the entire research process from start to finish, including research design, instrument development, data collection and analysis, and report writing. I have also had great opportunities to work with my advisor on the New Literacies Collaborative project, conducting research in the area of how technology has changed teacher education and student learning, and delivering teacher professional development workshops both in the U.S and China. I also work as an instructor for two online teacher preparation courses in my department, entitled *Content Area Reading* and *Improving Reading in Secondary Schools*, respectively. Prior to this, I earned my B. A. in English Language Arts Education in 2004, and my M. A. in Educational Administration in 2007, both from East China Normal University in Shanghai, China.

Theoretically, I hold a pragmatic worldview, which guides my research and teaching. I am committed to conducting research that will help lead to practical solutions for facilitating student learning and engagement. My personal teaching and learning experience has led me to believe that Internet and Communication Technology (ICT) has the potential to transform teaching and learning greatly, which will ultimately provide more meaningful

learning experiences for this generation of students who have grown up with technology and are often referred to as the "Net" generation. As a result, I believe that emerging technology tools should be appropriately incorporated into the classroom to make deep learning happen and to prepare students for the challenges of life and work in the 21st century.

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CHAPTER ONE: INTRODUCTION

The purpose of this mixed methods study was to examine digital game-based science learning (DGBL) with 5th grade students from a flow theory perspective. Students' game flow experience in the CRYSTAL ISLAND virtual science learning environment was examined based on the 3-stage flow experience framework, including flow antecedents, flow state and flow consequences (Hoffman & Novak, 1996).

Background of Study

In the global economy of the 21st century, science is among one of the most important subjects for the success of individuals, as well as nations. However, the National Science Board's Commission on Precollege Education in Mathematics, Science and Technology assessed the U.S. precollege mathematics and science achievement and found that American students performed below their peers in other countries by the time they were in high school (National Science Board, 2006).

Research has indicated that lack of positive attitudes towards science is one of the reasons for students' low science performance (Osborne, Simon, & Collins, 2003; Toprac, 2008). Empirical evidence revealed that there is a positive correlation between students' attitudes towards science and their academic performance (Adesoji, 2008). One main reason for students' negative attitude towards K-12 science learning is that they usually find science teaching in traditional school settings to be boring. This is a challenge because research has indicated that students' attitude towards learning, especially in subjects such as science, mathematics and technology, is related to factors that include teachers' instructional

strategies in the classroom (Adesoji, 2008; Popoola, 2002; Udousoro, 2000). Science teaching at school is often perceived by students to be disconnected from their daily life experience and such information is often abstract and difficult for them to understand (Foster, 2008). As a result, students often lack the motivation to learn science and do not see the value and importance of science learning. In this context, effective and innovative instructional approaches to K-12 science teaching have been called for in order to develop positive attitudes towards science in students, in hopes that this will lead to enhanced academic achievement in science (National Science Board, 2006).

The call for science teaching innovation, combined with the increasing popularity of digital games among young people, has increased researchers' interest in the potential of digital games as an innovative approach to 21st century science teaching (e.g., Gillispie, Martin & Parker, 2009; Klopfer, Osterweil & Katie, 2009). In the past 20 years, research in game-based learning has been conducted extensively to examine how educational games may enhance students' motivation, engagement and learning. Although mixed results have been revealed, these studies have added to our general understanding of the phenomenon.

There has also been increasing interest among researchers in examining students' game-based learning experience from a flow theory perspective (Csikszentmihalys, 1975). Flow describes an optimal experience of deep enjoyment and engagement that a person has when she or he is completely and totally absorbed in an activity. It has been suggested as a useful construct to examine emotion and the experience of playfulness in general, especially in human and computer interaction, including in the virtual game environment (Webster, Trevino & Ryan, 1993). The importance of game players' subjective playing experience,

especially a sense of playfulness, has been shown in research. Previous research has suggested that players' experience of enjoyment and playfulness is one of the most important factors that motivates players to continuously engage in learning through playing, and it might also result in other positive outcomes such as learning gains (Miller, 1973). From this sense, one advantage of studying game flow is to further understand how students perceive their interactions with game environments and how game environments could be best designed to support positive playing and learning experiences.

This strength of flow theory is especially valuable considering that educational game design and testing is still in its infancy and there remains a lack of empirical literature on how to create game environments that are both engaging and effective for students. As a result, examining students' playing experience and perceptions using flow theory will contribute to the design and evaluation process of educational games. Specifically, examining students' gameplay from a flow theory perspective will allow researchers to capture more information regarding students and gameplay, including the strengths and limitations of the game environment. Nevertheless, empirical studies on students' game flow experience are still limited and the results are not always positive. Thus, more empirical studies are needed to validate the effectiveness of educational games in facilitating students' learning experience and outcomes. Motivated by this rationale, the aim of this study was to provide insight into students' game flow experience and how it impacts science learning and attitudes.

Purpose Statement and Research Questions

The primary intent of this study was to investigate 5th graders' flow experience in the CRYSTAL ISLAND game-based learning environment based on the flow experience model proposed by Hoffman and Novak (1996), which is comprised of flow antecedents, flow state, and flow consequences (i.e., science content learning gains and learning attitude changes). CRYSTAL ISLAND is a narrative-centered game-based learning environment designed for 5th graders to learn science. In its current stage, the curriculum focuses on landforms and maps in 5th grade science. In the game, students interact with different in-game characters such as the mayor, captain, and the cartographer, each of whom give them a series of quests and tasks to finish (e.g., labeling and taking photos of different landforms, and using maps to navigate to different locations on the island to flag landmarks). Students learn science-related content while completing the quests in the game.

In view of the importance of game flow experience as mentioned above, and based on major themes/gaps identified through examination of literature, this study aimed to answer three research questions based on both the statistical survey/test and qualitative focus group interview data sets. Specifically, the three questions guiding this current study were:

- To what extent did 5th graders in a suburban elementary school experience game flow while playing the CRYSTAL ISLAND game, as reflected in the flow scale and focus group interviews?
  - What were the differences in students' game flow experience based on two different playing approaches (solo and face-to-face collaborative gameplay)?

- o What were the differences in students' game flow experience based on individual differences (i.e., gender, reading proficiency, and prior gaming experience)?
- What and how did different factors (game design features and peer interaction in the game) impact students' game flow experience?
- What was the relationship between students' game flow experience and their science content learning gains and science learning attitude changes?

Significance and Limitations

Significance

This study had several theoretical and practical implications, especially related to 21st - century science education innovations with technology. Using an experimental design, the study provided empirical evidence regarding the effectiveness of the educational game environment in supporting upper elementary school students' enjoyable playing experience (i.e., game flow experience). This study was also among one of the first studies that examined the game flow experience of students based on different playing conditions. It was also one of the few studies that have examined students' peer interaction and its impact on their game flow experience. The results will provide K-12 science teachers with empirical evidence as to whether some gameplay approaches are more effective than others, which will in turn help teachers make better decisions when it comes to the selection of gameplay approaches that they use in conjunction with their science teaching.

In addition, this research was also one of the few studies that have attempted to examine game flow experience of upper elementary school students. Therefore, it also

contributed to existing game flow literature, which has focused almost exclusively on older students such as middle/high school and college students. Specifically, the study tested the usefulness of an adapted game flow scale with 5th graders, and the results provided important instrument selection and development information for future research that seeks to examine elementary students' game flow experience.

This study also had important implications for the future of educational game design in that it sought to identify potential flow antecedents and impeding factors. Specifically, this study was among one of the few game flow studies that sought to understand how students' in-game peer interaction (for the face-to-face collaborative gameplay group, described later) impacted their game flow experience. The results will contribute to guidelines for future educational game design as related to the best techniques for designing educational games to provide students with enjoyable and effective peer interaction experiences.

Limitations

The study also has some limitations to be addressed in future studies. First, the study only examined one suburban public elementary school. The results were limited and could not be generalized to other groups (e.g., students in rural schools). A comparative study in this area will make contributions to the study reported here and provide a clearer view of the research problem. Second, this study did not include all possible variables. For example, the CRYSTAL ISLAND game incorporates a great deal of science reading materials in the multimedia format such as short video clips and pictures. However, students' reading ability was examined as an impacting factor only in terms of their reading EOG scores, which provided only information about student ability to read printed text. In addition, game flow

consequences can expand to include some other aspects, such as students' motivation and exploratory behaviors. Future studies in this area will provide valuable information about the impact of flow on learning. Third, even though using a mixed method research design helped produce more rich information to develop a better understanding of the phenomenon of game flow experience for 5th graders, the qualitative focus group interview data that was collected might be somewhat limited due to the fact that only a small number of students were selected to participate. Even though necessary actions were taken during the focus group interviews to obtain as much rich information as possible from the participants, the qualitative data obtained might also not be as representative as it would have been had a larger number of students been interviewed. A fourth limitation of the reported study was that an adaptation of an existing flow survey designed for older students to collect quantitative data with younger students was utilized. As a result, caution was taken in each step of the data collection and analysis to make sure that measuring students' game flow experience using an adapted flow scale which was originally developed for older students would not negatively impact the results.

In the following sections, procedures that were taken to answer the three research questions as well as the findings are presented in detail. In Chapter two, a literature review helps to form a larger picture of research that has already been conducted in the field of digital game-based learning, particularly the application of flow theory in the game context. In Chapter three, the methodology for this study, including both quantitative and qualitative data collection procedures, data analysis strategies, and validity and reliability of the adapted surveys, are discussed in detail. In Chapter four, both quantitative and qualitative findings are

presented (and compared) to answer each of the three research questions previously mentioned. In Chapter five, an extended discussion of the findings is presented, along with their implications for educators, teachers, and educational game designers. Suggestions about directions for future research are also proposed.

CHAPTER TWO: LITERATURE REVIEW

Context of Game-Based Learning Research

The recent interest among researchers in using digital game-based learning in education is being driven by a new generation of students who have grown up with games. Prensky (2001) argued that this generation of students, who are often referred to as the "digital natives" or "the N generation," often find emerging technology tools such as video games and the Internet to be engaging. As is widely reported, computer and video games are increasingly popular, especially among young people. In the United States, the annual revenues of video game industry is as high as 15 billion, with the game playing population falling between the ages of 10-34 years old (Chen, 2007).

As a result, today's students learn in a very different way from the older generation. Growing up in the new technology era requires that the current generation of students be exposed to engaging and fun learning environments that connect with their personal lives outside of school. This new learning style of students provides a significant challenge for our educational system, which has focused on traditional text-based instruction at school. It is becoming clear that if we don't reform our traditional methods of classroom instruction, we will not be able to engage our students in learning. In 2006, the University of Indiana at Bloomington conducted a survey with over 80,000 students in the U.S., the results of which revealed that at least two out of three students reported being bored in school at least every day, with 17% of them reporting boredom in every class (Gillispie, Martin, & Parker, 2009). This is particularly serious when it comes to subjects such as science and math, which are

usually perceived by K-12 students to be difficult and boring due to the lack of engagement incorporated into the learning experience.

Given this background, there has been a renewed interest in using digital game-based learning as an innovative approach to address the challenge in education, especially in the STEM context. Research examining the use of mainstream games in different content areas has grown rapidly over the past 20 years. Studies in this field have focused on a variety of content areas, ranging from science (e.g., Meluso, Zheng, Spires, & Lester, 2011; Rowe, et al., 2010; Spires, Rowe, Mott, & Lester, 2011; Toprac, 2008), math (e.g., Gillispie, Martin, & Parker, 2009; Kebritchi, 2008), and technology (e.g., Papastergiou, 2009), to social studies (e.g., Chen, 2007). Many articles have been published and several reviews of the literature on educational games have been completed within the last few years (Harris, 2001; Hays, 2005; Hwang & Wu 2012; O'Neil, Wainess, & Baker, 2005).

In the following sections, the literature review is organized into two main categories. First, a synthesis of research of the effectiveness of game-based learning is presented, including research studies that have examined the impact of game-based learning on outcome variables such as student motivation, interest, cognitive skills, and content learning outcomes. In this section, a synthesis is also presented in terms of research on the effectiveness of collaborative gameplay. Second, research on the application of flow theory in game-based learning environments was synthesized. First, an overview and introduction of flow theory is provided, followed by discussion of common approaches used by researchers to collect data of game players' flow experience. Finally, research that examines students' game-based learning experience from flow experience perspective is discussed.

Research on the Effectiveness of Game-Based Learning

Educational Gameplay and Learning Outcomes

Existing game studies typically utilize differing learning theories to examine the effectiveness of educational games as a learning tool, including social constructivism (Halttunen, & Sormunen, 2000; Lim, Nonis, & Hedberg, 2006), experiential theory with Kolb's learning cycle (Egenfeldt-Nielsen, 2005; Garris, Ahlers & Driskell, 2002; Isaacs & Senge, 1992; Kiili, 2005; Lainema, 2003), activity theory (Spires et al., 2011) and also transactional theory (Spires, et al., 2010). Most of these studies have looked at common game play outcome variables such as motivation (Chen et al., 2008; Foster, 2008; Howard, 2006; Papastergiou, 2009), academic attitudes (Gillispie, Martin, & Parker, 2009), engagement (Kiili, 2005; Lim, Nonis & Hedberg, 2006; Zheng, Spires, & Meluso, 2011), learning gains (Ke & Grabowski, 2007; Meluso, Zheng, Spires, & Lester, 2012; Moreno, 2002; Rosas, et al., 2003; Spires, et al., 2011), and higher order cognitive skills (Gao et al., 2009; Kang, & Tan, 2008). Research findings support the claims that using games in learning can increase learners' level of motivation, engagement, interest, higher order thinking skills, achievement and learning (e.g., Ketelhut, Dede, Clarke, & Nelson, 2006; Prensky & Thiarajan, 2007).

Gameplay and student motivation/engagement. One of the most important effects of using games in learning is that games serve as motivators for students, especially in terms of content areas such as science and math that many students find to be difficult (Foster, 2008). In a study that looked at educational games and the impact on middle school students' motivation to learn science, Foster (2008) found that educational games could arouse

students' interest and motivation in learning science by connecting the learning process with students' personal life experiences. Foster used the concept, "hard fun," to explain why educational games can motivate students. Foster (2008) explained that game playing provides students with a challenging but meaningful learning experience that is both frustrating and life enhancing, and this kind of enjoyment (hard fun) derived from game play helps to improve students' intrinsic motivation in learning. This conclusion has been supported by other researchers' findings as well (e.g., Inal & Cagiltay, 2007; Kang & Tan, 2008; Papastergiou, 2009). Besides motivating students to play and learn, researchers have also found that educational games are an effective tool to engage students in learning (Foko & Amory, 2008; Howard, Morgan, & Ellis, 2006). Other identified positive outcomes of game-based learning include improved concentration, interest, satisfaction, and also communication skills (e.g., Foko & Amory, 2008; Gao, Yang & Chen, 2009; Gillispie, Martin & Parker, 2009; Howard, Morgan& Ellis, 2006).

However, even though there is consensus that educational games are capable of creating a motivating learning environment, not all researchers completely agree on the source of this motivation. Some researchers attribute the compelling nature of games to their narrative context (Dickey, 2005, 2006; Fisch, 2005; Waraich, 2004), while others find that motivation is closely linked to goals and rewards within the game itself or intrinsic to playing itself (Amory, Naicker, Vincent, & Adams, 1999; Denis & Jouvelot, 2005; Jennings, 2001).

Gameplay and student academic performance. While most existing studies demonstrate how computer games provide a motivating and engaging learning environment for students, results have not always demonstrated significant learning achievement as a

result of having used computer games. Previous research has reported mixed effects of game-based learning on students' content area learning outcomes (e.g., Hays, 2005; Vogel, et al, 2006). For example, in a literature review based on 32 empirical studies, Vogel et al. (2006) reported that interactive games were more effective than traditional classroom instruction on learners' academic learning gains and cognitive skill development. Also, VanSickle (1986) conducted a review of 26 empirical studies, and results showed that students made a slight improvement in learning and attitude of learners toward the subject as a result of using instructional games in the classrooms instead of traditional teaching methods. Empirical studies also have provided evidence to support the positive findings reported in the above-mentioned literature review reports. These studies revealed that game playing resulted in improved academic learning achievement in students (e.g., Kang, & Tan, 2008; Gillispie, Martin, & Parker, 2009; Meluso, et al., 2011; Papastergiou, 2009; Stevens, 2000). Stevens (2000) studied 33 students from 7 to 14 years old who played games for one hour each morning, for 30 visits. In this study, a control group of 37 students was also included that completed the same tests without playing the games. Parents of the participants who played the games not only reported improvements in school work, but also in other skills (e.g. increased interest in literature and an increased patience with daily tasks). In another study by Gillispie et al. (2009), the authors used a pre-and post test experimental design with students in a rural middle school in North Carolina to examine how 3-D digital games impacted students' math (pre-Algebra and Algebra) learning attitude and achievement. Results also revealed that there was a positive change in students' learning attitude and learning outcomes for both boys and girls. Meluso and her colleagues (2012) conducted an empirical study to

examine the effects of gameplay on 5th graders' science content learning outcomes. Similarly, the findings revealed that students who played the online science learning game not only made significant content learning gains but also showed improvement in their science-related self-efficacy.

However, some other conceptual (i.e., literature reviews) and empirical studies have reported otherwise negative results. For example, based on a review of 48 empirical studies, Hays (2005) found no clear evidence to support the claim that instructional games were a more effective method of teaching in comparison to traditional classroom instruction. Similarly, in their literature review of existing game based learning studies, O'Neil, Wainess and Baker (2005) and Wrzesien & Raya (2010) reported that clear causal relationship between academic performance and the use of computer games is not consistently evident. Besides literature review studies reported by the above-mentioned authors, some empirical studies also have not found positive learning effects of gameplay (e.g., Gao, 2007; Spires, et al., 2010). For example, in their study about digital game-based science (microbiology) learning in the game play environment with 8th graders, Spires et al. (2010) used a control group of non-game players who received a Power Point presentation of the same content that was presented in the game environment. Results indicated that, even though students in the game playing condition reported higher motivation, significant learning differences between the treatment and control groups were not evident.

Research on Collaborative Gameplay

Besides studies that examine important outcome variables such as students' motivation, engagement and content learning in the game environment as discussed above,

other examinations have been undertaken to explore other equally important variables in digital game-based learning. One of such variables that have received considerable attention from the game-based learning research community is players' peer interaction in the game environment. Research of students' interaction and collaboration in the game environment is important for at least two reasons. First, interactivity is one of the most important features of high quality games (Klopfer, Osterweil, & Katie, 2009). A well-designed game should provide opportunities for players to interact with not only the game environment but also with their peers. As a result, examining how students' peer interaction in the game environment impacts their playing experience and effectiveness will readily inform game design. Second, social interaction is one of the most important constructs of any learning experience (Picciano, 2002; Vygosky, 1987). Previous studies have shown that social interaction plays a key role in students' academic success in traditional classroom settings (Yalama & Aydin, 2004). Social interaction in technology mediated environments such as digital games, is equally, if not more, important than in traditional settings. One advantage of peer interaction during gameplay is that students can not only enjoy the game in the process of collaborating or competing with their peers, but they can also acquire strategies that other players employ during gameplay (Sweetser & Wyeth, 2005). Kiili (2005) claimed that the peer interaction processes and the competition/collaboration involved in such gameplay are factors that motivate students to learn.

In view of the importance of peer interaction in the game environment, some researchers have begun to examine important issues such as how collaborative game play affects students' learning. Some of these studies have provided initial evidence that

collaborative game play can positively impact students' content area learning gains. For example, in their study of game-based learning with middle school students, Foko and Amory (2008) found that playing in pairs was more effective than playing individually. Specifically, they found that students overcame more misconceptions about the content (photosynthesis and respiration) when they played in pairs. Playing in pairs was also found to contribute more to students' visualization, logic, and numeric skills. Moreover, Howard, Morgan and Ellis (2006) found that students highly valued the usefulness of discussion with their peers while playing games.

Some other researchers, however, have been more conservative in making their conclusions. For example, Shih et al. (2010) pointed out that the effectiveness of collaboration is highly dependent on the specific model and strategies that are used. Based on their case study of a group of fourth graders in a digital problem-solving game environment, the authors also found that positive and favorable collaborative relationships could facilitate students' learning outcomes in the game environment, while less pleasant collaborative playing experience could not. Another recent study on the effectiveness of collaborative gameplay presented similar results. Meluso and her colleagues (2012) conducted a game-based learning study with 70 5th graders. The results from this study indicated that while students across the two gameplay conditions (i.e., solo and face-to-face collaborative gameplay) made significant science content learning gains, there was no group difference based on gameplay conditions.

Summary of Effectiveness of Gameplay on Learning Outcomes

The literature review indicates there is no consensus, based on findings from both empirical and conceptual studies, regarding the learning effects of instructional games. As a result, more empirical studies are needed to validate the claimed effects of game-based learning. This is particularly important in view of the fact that empirical studies in this area are still slow to emerge (Hays, 2005; Mitchell & Savill-Smith, 2004; Vogel et al., 2006). Moreover, in view of the importance of social interactions in learning, more empirical studies are needed to understand the impact of players' peer interaction in the digital game-based learning environment.

Research on Flow Theory Related to Game-Based Learning

Besides educational game studies that investigated important gameplay variables such as motivation, engagement and content area learning gains, recent years some researchers have also begun to examine students' gameplay experience using the flow theory proposed by Csikszentmihalys (1975). This movement towards examining players' playing experience in the game environment is driven by the increasing awareness of the critical role that students' enjoyable playing experience (i.e., game flow experience) has on students' learning, as have discussed in the previous chapter. The importance of students' perceptions of their gameplay experience for the design of effective educational games is another reason why flow experience in the game environment has been receiving more attention among the research community. Specifically, examining students' playing experience from the flow theory perspective will inform educational game design because game flow studies usually examine important game design features that lead to students' enjoyable playing experience.

Overview of Flow Theory

Csikszentmihalyi (1975) introduced the flow state through a study of people doing sports such as rock climbing and chess. By interviewing these people, Csikszentmihalyi found that the term "flow" was frequently used when they described a state of optimal experience, and so he adopted the term "flow" in his study (Csikszentmihalyi, 2000). Flow experience is a state of complete consciousness and engagement that a person experiences when he or she is totally involved in an activity that is enjoyable. This experience is often referred to as the "optimal experience", and people who experience "flow" are often said to be "in the zone" (Csiksentmihalyi, 1991). While experiencing flow, a person is in an emotional state where he or she is so involved with the activity that nothing else around seems to matter. Csikszentmihalyi (1991) defined the phenomena of flow state as having eight dimensions: (1) clear goals, (2) immediate and unambiguous feedback, (3) a balance between the challenges of an activity and the skills required to meet those challenges; (4) merging of action and awareness, (5) concentration on the task at hand, (6) sense of potential control, (7) a loss of self-consciousness, and (8) a distorted sense of time. Jackson and Marsh (1996) proposed that the concept of autotelic experience that describes the rewardness of the activity be added as the 9th dimension.

Specifically, according to Csikszentmihalyi (1991), the subjective experience of flow is a result of two variables: the perceived challenges and the perceived skills. He used a three-channel model of flow experience to illustrate this idea (See Figure 2.1 below). Based on this model, the players' challenge and skill balance is one of the most important dimensions of flow experience. People feel anxious (P3) when the challenge they face is

greater than their perceived skills; they feel bored when their perceived skills are greater than

the challenges the   (P2); and they are apathetic when both perceived skills and

challenges are low (P1). People experience flow only when their perceived skills and

challenges are both high (P4).
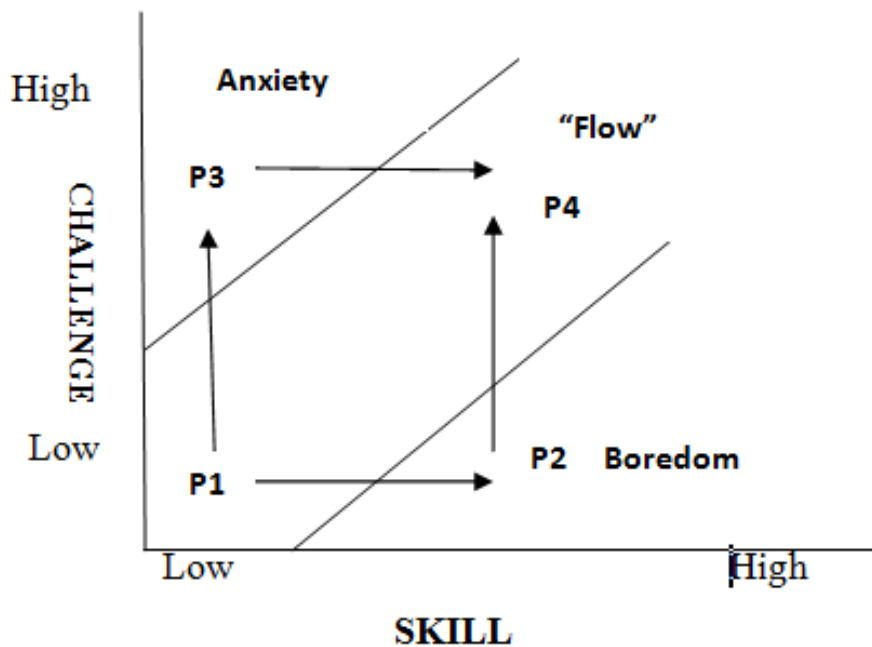
Figure 2.1. The Three Channel Model of Flow. In Flow: *The psychology of optimal experience* by Csikszentmihalys, 1991, New York: Harper Perennial.

Three Stages of Flow Experience

      Finneran and Chang (2003) observed that the flow dimensions that Csikszentmihalyi

presented can be categorized into three stages: flow antecedents, flow experience, and flow

consequences. Several researchers have used this same categorization in their flow studies

(Ghani & Deshpande, 1994; Shin, 2006; Skadberg & Kimmel, 2004; Webster et al., 1993).

Kiili (2005) developed a game flow scale to examine the three stages of flow experience of

flow antecedents, flow state, and flow consequences (i.e., content learning gains). Later, Kiili and Lainema (2008) tested and validated this game flow scale in another game-based learning study that examined undergraduate students' flow experience in the content area of computer science. In this study, the author found that flow antecedents in the game play context include the balance of perceived skills and challenges, clear goals, unambiguous feedback, playability, gamefulness, and frame story. While some concepts presented here are easy to understand, some other concepts are more complex and require explanations. In particular, playability describes the ease by which the game can be played. A game with good playability should have an easy user interface to allow the player to find necessary functionalities and information easily. Good playability also means there are not too many distracting factors which will add to the cognitive load of the players. Gamefulness refers to aspects such as how many opportunities there are for players to use earned in-game rewards, or to what extent the players can play the game in different ways. The frame story is a technique that the game designers employ to create a main introductory game story. It provides the framework for connecting unrelated stories in the game. The dimensions of flow experience include concentration, loss of self-consciousness, sense of control, time distortion and autotelic experience. Autotelic experience refers to a state of the mind when the player plays the game out of the great enjoyment derived from playing, instead of playing for external reasons/rewards. Finally, the author examined flow consequences such as increased learning, attitude changes, and exploratory playing behaviors. This game flow model is represented in the Table 2.1.

Table 2.1

Kiili's Three Stage Game Flow Model (Kiili, 2005; Kiili & Lainema, 2008)

Game flow antecedents	Game flow state	Flow consequences
Balance of challenge/skill	Concentration	Content learning gains
Immediate feedback	Time distortion	Exploratory behaviors
Clear goals	Sense of control	
Playability	Autotelic experience	
Gamefulness	Lose of self-	
Frame story	consciousness	

The game flow scale was first developed in 2005 and has since been used by other game-based learning researchers. For example, Inal and Cagiltay (2007) used this flow scale in their game flow study with thirty-two 3rd graders. In order to make sure young children understood the survey questions, the authors administrated the flow scale through structured interviews. Findings from this study showed that a balance of challenge and perceived skill, useful feedback, and a user interface which required less cognitive process (good playability) were important factors that led to students' game flow experience. It was also found that, when students were in flow, they were so concentrated in the game that they did attend to other things that happened around them (e.g., they did not respond to their peers' request for help). These results were consistent with Kiili' s (2005) findings. In terms of flow antecedents, Inal and Cagiltay' s study also revealed that boys emphasized the challenge provided by the game more so than girls, while girls emphasized the game frame story more than boys. In terms of flow state, flow experience was found to occur more frequently among playing groups formed by boys than playing groups formed by girls (while in the gameplay,

students were allowed to form their own playing groups). Additionally, boys were also more concentrated than girls during the gameplay. This is also one of the few game flow studies that have examined individual differences based on gender. Finally, the authors also found that group competition might be more effective than individual playing and that competition among different playing groups might also increase students' game flow experience.

The current research was also based on Killi and Lainema' s (2008) validated flow model. One of the most important reasons for this decision was that flow assessment tools developed so far have focused on other contexts such as everyday work and performance, and might not be able to capture players' flow experience in the game environment. For example, Jackson and Eklund (2002) have also developed a flow state scale to measure general work-flow based on the nine dimensions of flow proposed by Csikszentmihalyi (1975). This flow scale, while showing high internal consistency, was not designed for use in the game context and accordingly does not include important game design features. Fu, Su, and Yu (2009) have also developed another flow scale to be used in the gameplay setting. This game flow scale examines flow dimensions of concentration, goal clarity, useful feedback, balance of challenge and skill, autonomy, immersion, and students' social interaction. Again, this game flow model does not include game design features such as playability, gamefulness, and game frame story, all of which are important factors to be considered in game design.

Two Approaches of Measuring Flow Experience

While researchers generally use different methods to measure flow experience in different contexts, a review of literature revealed that these methods may be categorized into two major approaches: the Activity Measurement Method and the Experience Sampling Method. In the Activity Measurement Method, participants perform a certain task or activity first. After the activity, participants are asked to report their experience with that activity, using a survey instrument. One major concern of this approach is whether participants can remember and reliably report their experience. On the other hand, researchers who adopt the Experience Sampling Method collect data about participants' experience during a certain activity. With this approach, the researcher asks participants to stop at certain times during the activity to report their temporal feeling and experience while in that particular moment. This approach is often criticized for its potential risk of interrupting participants' behavior.

The Activity Measurement Method was adopted for use in this study. This decision was based on the following reasons. First, and perhaps the most important, using the Experience Sampling Method would disturb students' playing experience and overtax their workload. Specifically, asking students to stop constantly to report their playing experience was expected to impact their attention and concentration in the game since they have to stop playing to cognitively process the experience sampling questions. Second, the students in this study were relatively young (5th graders), creating difficulties in ensuring that participants would be likely to remember to stop at the end of certain playing/learning tasks and report their experience as a function of their developmental level. However, it was also important that a balance was established between the two measurement methods. As a result, students'

game flow experience was measured immediately following the game play session to make sure students' responses reflected their true feeling and experience.

Synthesis of Game Flow Experience Studies

Even though there has been increased interest among researchers in using flow theory to examine game-based learning, the existing literature is still short of documented studies in this particular area. Nevertheless, these studies have indicated that flow theory provides a new lens to examine digital game-based learning (Kiili & Lainema, 2008). One of the most important contributions of existing game flow studies is that researchers have identified some common factors that players believe to have contributed to their flow experience. These common factors include perceived balance of challenge and skills, clear goals, immediate and unambiguous feedback, good playability and gamefulness (Hsu & Lu, 2004; Inal & Cagitay, 2007; Kiili, 2005; Kiili & Lainema, 2008). This is especially important when it comes to designing effective educational game playing environments in order to induce flow experience in players.

Another area that researchers have been interested in is the relationship between flow experience and learning outcomes such as content learning achievement, change in attitude towards the subject area, and exploratory behaviors. Unfortunately, even though there has been some consensus on the flow antecedents that contribute to students' flow experience during game play, existing game flow studies have reported mixed results when it comes to the mediating effects of game flow on players' academic learning gains. As an example, Kiili (2005) found that undergraduate students who played the game experienced flow, which was in turn highly related to their learning outcomes. In this study, students' perceived

challenge and skill balance and a sense of control were also found to contribute to the level of game flow. On the other hand, bad playability and low gamefulness were factors named by students to have impeded their flow experience. The positive correlation between students' game flow experience and their learning outcomes was found in another study by Hsu and Lu (2004). In this study, the authors applied a technology acceptance model (TAM) that incorporates social influences and flow experience as a construct to predict peoples' acceptance of online games. The survey data reported in this study indicated that social norms, attitude and flow experience explained 80% of the game playing. However, in this model usefulness plays an important role, which is problematic because this factor is not reasonable in an entertainment game context. Usefulness did not motivate users to play online games, as the results indicated (Hsu & Lu, 2004).

Some other studies, however, reported negative findings when it comes to the relationship between learning gains and game flow experience. In a study by Killi and Lainema (2008), the authors empirically tested the usefulness of the game flow scale that they developed in 2005 (see discussion above) with a group of undergraduate students who played an experimental game. Contrary to the findings in their earlier flow study in 2005, this later study only found a loose connection between students' game flow experience and their learning achievement. Lee and Kwon (2005) also studied the effect of how flow connected to success in a computer-based simulation game. In this experiment, 100 university students played the simulation for a total of 30 minutes. Similarly, the flow survey data indicated that flow was not a significant predictor in game achievement.

Summary of Research on Flow Theory Related to Game-Based Learning

Several themes emerged as a result of the literature review. The few existing game flow studies have been conducted exclusively with older players such as middle school students and above. Only one study (e.g., Inal & Cagitay, 2007; see discussion above) was found that examined elementary students' game flow experience. This study is also the only game flow study that examined gender differences in game flow experience. Another theme that emerged is that research findings differ across studies in terms of the extent to which flow experience positively impact students' content area learning. As a result, more studies are needed to understand students' flow experience in the game environment. In particular, more empirical studies should be conducted to examine flow experience in younger children such as elementary students, and to look at what and how individual characteristics (i.e., gender, race, and language proficiency, as mentioned in Chapter one) impact students' flow experience. Research in this area is very important because previous game flow studies (e.g., Inal & Cagitay, 2007) have found game flow experience differences based on gender. However, this issue has not been fully explored and other individual factors that might also impact students' game flow experience have not been examined in previous studies (Finneran & Zhang, 2005). Researchers (e.g., Pearce, 2004; Shin, 2006) have also called for more empirical studies to examine and validate the relationship between game flow experience and its consequences (e.g., content learning gains and learning attitudes). While making students learn the content being studied is clearly one of the ultimate goals, the impact of game flow experience on students' learning attitude is also worth more investigation because students' attitude towards a subject area plays a significant role in their academic performance, as

discussed previously in Chapter one. These identified themes and gaps in the literature have

guided the current study.

CHAPTER THREE: METHODOLOGY

Research Design and Methodology

This research study employed an embedded mixed methods design (QUAN + qual) (See Figure 3.1 below for the design diagram) in which the quantitative and qualitative data were collected simultaneously. The quantitative data set, however, played a more central role in the research design (Creswell, 2006). Both quantitative and qualitative data were collected to enable a better understanding of the research problem.

Mixed methods research is a research design in which the researcher uses both qualitative and quantitative data collection and analysis techniques in order to better understand the real-world problem being studied and to better answer the research questions (Johnson & Onwuegbuzie, 2004). Mixed methods research has been used in a variety of research areas due to its unique strengths. One advantage of mixed methods design is that it may help answer complex research questions and corroborate findings (DeCuir-Gunby, 2008). Specifically, mixed methods research uses data collection and analysis techniques from both quantitative and qualitative approaches in unique ways to answer research questions that could not be answered in any other way. From this sense, using mixed methods research will produce a fuller picture of the research phenomena than using quantitative or qualitative method alone. Johnson, Onwuegbuzie and Turner (2007) stated that mixed methods research is very powerful because of its capability to provide the researchers with more informative and useful research results. By collecting multiple data using different strategies and approaches, the researcher can use the strengths of an additional

method to overcome the weakness in another method by using both in a research study (Johnson & Onwuegbuzie, 2004). Moreover, mixed methods research allows researcher access to the subjects' thoughts and feelings that cannot be captured through a single quantitative approach. Of course, mixed methods research also has some weakness. For example, it has greater requirements on the part of the researcher in that the researcher has to learn about different methods and understand how to mix them appropriately (Johnson & Onwuegbuzie, 2004; DeCuir-Gunby, 2008). Mixed methods research is also more time consuming since both types of data have to be collected and analyzed throughout the whole process.

A mixed methods design was chosen for this study based on its specific research purpose and research questions. Digital game-based learning, especially the game flow experience, is a complex multi-dimensional phenomenon that requires data from different approaches to provide a more comprehensive understanding. Game flow is students' subjective feeling, and the various contributing and impeding factors also require more in-depth exploration to understand exactly how and why students experience flow while playing the game. While data collected from a quantitative survey is the focus of this study, qualitative interview data helps to provide a richer description of students' game play experience. Researchers have claimed that qualitative methods can be used to gain more in-depth information that might otherwise be difficult to convey quantitatively (Corbin & Strauss, 2008). Qualitative data collection techniques are helpful especially when the quantitative measures alone cannot adequately describe a complex situation. As a result, employing a mixed methods research approach could assist in producing a fuller picture of

the phenomena under study than a mono-method research design. The qualitative focus group interview data could help to elucidate the previously collected quantitative survey findings by exploring students' subjective thoughts and feelings. Comparing this qualitative data with the quantitative data can also allow greater confidence in research findings. In other words, collecting both types of data adds to the validity of the study because it relies on multiple forms of evidence rather than a single data set in the study. Figure 3.1 shows the embedded mixed method research design that was employed in this study.
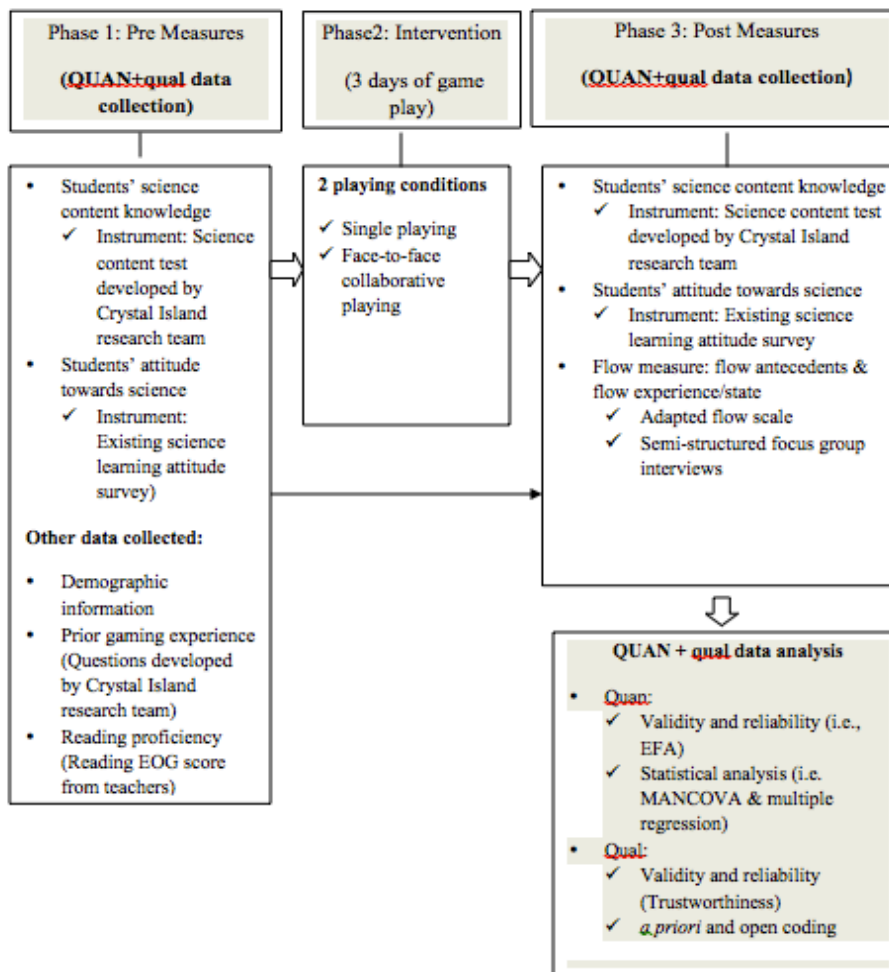
Figure 3.1. Embedded mixed method research design

Participants and Research Context

The study was conducted with 75 5th graders (from 3 different classes) in a suburban public elementary school in the southeastern U.S. All 5th graders who signed and returned the parental and student consent to the researcher were eligible to participate in the study. The school was recruited through the researcher's personal connections with 5th grade teachers at the school. As a result, the current study used a convenience sample. Thirty three percent of students at the school receive free or reduced lunch. 45 of the participating students were males and 35 of them were females. Participating students were between 9-12 years old (9 years: $n = 2$, 10 years: $n = 61$, 11 years: $n = 11$, 12 years: $n = 1$). The breakdown of students' ethnic categories was: White/Caucasian ($n = 49$), Black/African American ($n = 7$), Hispanic/Latino ($n = 7$), Asian American ($n = 3$), and American Indian ($n = 1$). The rest of the students chose "other" as their demographic categories ($n = 8$). A total of 37 students were randomly assigned to the single-player condition, whereas a total of 38 students were assigned to the collaborative playing condition.

All 75 participants completed both the pre- and post-test content-knowledge assessments (males = 40, females = 35). However, 2 students did not complete the adapted Game Flow Survey because they were absent on the 2nd day of gameplay when the flow survey was administered, as this was not on the same day as the pre and post tests (science content test and science learning attitude survey). Only students who completed all of the three tests/surveys, including the pre content test, post content test and the adapted flow survey, were included in the final data analysis. This resulted in a final sample of 73 students (males=38, females=35; single/solo players=37, collaborative players=36). All analyses

reported in the next sections were based on this final sample. Information about the surveys/tests and how and when they were administered is presented below.

Students played the CRYSTAL ISLAND game (see Figure 3.2 below) before they were exposed to the landform and map curriculums that were covered in the game. The curriculum of the game was developed by the CRYSTAL ISLAND research team to align with the NC Standard Course of Studies for 5th grade science. For a virtual walkthrough of the game, see http://www.intellimedia.ncsu.edu/videos/CI5-yearTwo-video.html.

Figure3.2. Screenshots of the CRYSTAL ISLAND game

Randomization Process

Before game play, participants within each class were randomly assigned to two different game playing conditions: single playing and face-to-face collaborative playing condition. This randomization process was done by having each student in the class draw a token from a hat when they were taken from their classroom to outside the gameplay room (the computer lab). Students who received a "Shark" token were assigned to the single

playing condition and were directed by a volunteer to the solo playing area in the gameplay room. Students who got a "Falcon" token were assigned to the face-to-face collaboration condition. It is important to note that due to space and Internet connection constraints, all students played the game in the same room (computer lab) but sat at different areas. The computer lab was spacious enough to ensure necessary distance between the two groups. The total number of students in each playing condition was approximately the same, as reported above. Students remained in their respective playing conditions during the 3-day gameplay process. On day one and day two of gameplay, the total designated time for game play was appropriately 45 minutes for both gameplay conditions. On the third day of gameplay, the total designated time for gameplay was shortened to about 35 minutes because student took the post-test after gameplay on this day (which took appropriately 20-25 minutes). Students in the single playing condition finished the 3-day game play independently. Students who were assigned to the face-to-face collaborative playing condition were then randomly assigned to playing pairs/dyads before they were directed to their playing area inside the computer lab. All collaborative game players stayed in line outside the computer lab and each of them selected a playing station number (e.g., station 1, 2, 3, and so on) from a bowl. The bowl contained two copies of each station number. Students who selected the same numbers were paired up and preceded to the appropriate station. This meant that the two students in each playing dyad might not necessarily be of the same gender. Students collaborated with the same partner on each day. Students in the face-to-face collaboration condition switched who was playing half way through the game on each of the three days

(i.e., one student was the game character "driver" for the first 25 minutes while the other student was the "observer / planner" and vice versa).

Data Sources

This study employed an embedded mixed method research design. Both quantitative surveys/tests and qualitative focus group interviews were used in this study to collect different sources of data. In the following sections, the quantitative and qualitative data sources and instruments are described.

Pre Measures

The pre measures consisted of 4 parts, including (a) demographic information (i.e., age, gender and race), (b) prior gaming experience, (3) prior science content knowledge, and (d) science learning attitude.

Science content knowledge test. The science content knowledge test consisted of a series of 27 multiple choice questions that measured STEM content knowledge about topics (i.e., landforms, map navigation, and models) covered in the game. The content knowledge test assesses both basic, low-level recognition knowledge and higher-level application and transfer knowledge (e.g., students' understanding of the problem solving process and their ability to use maps in new situations). These content test items were collaboratively generated by the CRYSTAL ISLAND research team (including computer scientists, educational researchers, science educators, educational psychologists, and graduate students) based on FOSS (Full Option Science System) assessments and 5th grade science EOG tests. The full pre test is presented in Appendix E. The reliability values of the pre and post tests are presented later.

Science learning attitude survey. Students' attitudes toward science were measured using the Attitude Towards Science Inventory constructed and tested by Weinburgh and Steele (2000) (See Appendix C). The scale was designed for elementary students. It contains 25 5-point (from 5=*strongly agree*, to 1=*strongly disagree*) Likert scale items, which ask students to rate the extent to which they agreed with the statements. The survey has 5 items to measure each of the 5 dimensions of students' science learning attitude, which are: perception of the science teacher, anxiety about science, the perceived value of science in society, self-concept of science, and the desire to learn science. Some of the items were reverse-scored because they were worded in the negative. A higher score indicated a more positive attitude towards science learning, except for the anxiety about science dimension where a lower score indicated more positive attitudes (less anxiety). The instrument was tested by the authors (creators of the original survey) with a group of 5th graders in an urban elementary school and the overall reliability was found to be good ($r > .7$). Content validity was determined by using a jury of science teachers and by carefully constructing the instrument so the attitude object would be embedded in each statement. Construct validity was ascertained using a variety of techniques, including divergent validation.

Students' prior gaming experience. Students' prior gaming experience was measured with an open-ended question in which students had to enter the amount of time (i.e., how many hours) during a week they spend in playing video games.

Students' reading proficiency. Students' reading proficiency data was provided by the students' classroom teachers. Specifically, their reading EOG scores from the previous

semester (the end of 4th grade) were obtained from their teachers. The scores were measured

on a 4-point scale, with a higher score indicating higher reading proficiency.

Post Measures

The post measures consisted of 3 different categories, including (a) science content

knowledge, (b) science learning attitude, and (c) game flow experience and flow antecedents.

Both the post science content knowledge test and the post science learning attitude survey

were identical as the pre test/survey. Students' game flow experience was measured by using

both an adapted game flow survey and semi-structured focus-group interviews, both of which

were introduced in the following sections.

Adapted game flow scale. Students' game flow experience was measured with a

Game Flow questionnaire adapted from an existing flow scale that Kiili (2005) constructed

and tested in a later study (Kiili & Lainema, 2008), as was discussed in the earlier chapter

(see discussion in next section for information about how this flow scale was adapted). The

original Game Flow questionnaire, consisting of 33 items in the 5-point (from 5=*strongly*

agree, to 1=*strongly disagree*) Likert-type response format, can be divided into two parts.

The first part measures the following flow antecedents: goal, feedback, playability, challenge,

gamefulness, and the frame story. The second part measures the flow state through five

dimensions of concentration, time distortion, autotelic experience, sense of control and loss

of self-consciousness. Each dimension is measured with 3 items. Students rate the extent to

which they agree or disagree with the statements about the flow antecedents and flow

experience. A higher score means that the student has a higher level of flow experience.

Some of the items had to be reverse-scored since they were worded in the negative. The full survey is presented in Appendix B.

This original flow survey was tested and validated by Kiili and Lainema (2008). For the flow state/experience measures, the reliability estimates of the five sub-scales of concentration, time distortion, sense of control, lose of self-consciousness, and autelic experience, were acceptable (r= .62, .75, .79, .80, .85, respectively). The reliability of flow experience as a single construct was also found to be acceptable ($r = .81$). For the flow antecedents measures, the reliability of the sub-scales of challenge/skill balance, clear goals and gamefulness was found to be poor (r=.57, .58, and .42, respectively). This means indicates that the items measuring these sub-scales should be rewritten in order to improve the internal consistency. However, the reliability of other flow antecedents (ranging from .68 to .88), as well as the overall reliability of flow antecedents as a single construct *(r = .83)* was found to be acceptable.

In order to validate the flow antecedents, Kiili and Lainema (2008) calculated the sum variables of each flow antecedent and the overall flow experience. Correlations between these sum variables were then calculated to study the relationship between flow state and each antecedent measured in the survey. The authors found that, except the game frame story *(r = .28)*, each of the other flow antecedents had medium to strong positive correlation with flow experience (ranging from .32 to .66). However, other validation data is not provided.

The authors claimed that the flow survey served as a satisfactory tool to measure students' game flow experience. Based on the data reported above, they acknowledged that some of the items had to be developed further, and the impact of game frame story on flow

experience needed to be further studied. As a result, these items were revised before data collection. In order to fit the target participants (i.e., upper elementary school students), some items were reworded accordingly since the original flow scale was developed for an older student population (i.e., college students). The purpose for this revision was to enable 5th graders to understand the flow statements clearly. At the end of the flow scale, an open-ended question was also added which asked students if the survey questions were easy for them to understand.

Since there was also a face-to-face collaborative game playing group in the current study, three new Likert-scale items were created and added to the adapted game flow survey, asking students how they perceived their peer interaction experience in the game environment (See Appendix B). The purpose of collecting this data was to examine the relationship between students' in-game peer interaction and their game flow experience, and to explore whether positive peer interaction could also serve as another game flow antecedent. The reliability and validity of the revised flow survey are discussed in detail in the following data analysis section.

Semi-structured interviews. The semi-structured interview provided supplementary qualitative data about students' perceived flow experience in the game play process. In the focus groups, students from both playing conditions were asked questions that focused on game flow experience and factors that they thought have impacted (contributed to or impeded) their flow experience while they were playing the CRYSTAL ISLAND game. Specifically, during the focus group interviews, students were first asked more general questions about their overall gameplay experience in the CRYSTAL ISLAND game environment.

Then students were asked specific questions about their game flow experience based on the 5 theorized flow experience sub-dimensions of total concentration, sense of potential control, sense of time distortion, loss of self-consciousness, and autotelic experience. Following that, students were asked questions related to the CRYSTAL ISLAND game design features and how they thought these game design features impacted their game flow experience. For students in the collaborative gameplay condition, their perceptions of peer interaction and how peer interaction impacted their game flow experience were also examined in the focus group interviews. The interview questions and protocols were presented in Appendix D.

Data Collection Procedures

In this section, both quantitative and qualitative data collection procedures are presented in detail.

Administration of Pre-test Instruments

Students took the pre measures, including science content test, science learning attitude survey, and prior gaming experience, on Survey Monkey (Web-based survey) one week before the gameplay. This took about 20-25 minutes.

Day One of Gameplay

On day one of gameplay, the basic procedures included (a) a game background story video, (b) game tutorial, (c) gameplay for about 40 minutes, and (d) follow-up semi-structured focus group interview with 5 solo game players.

Specifically, before the game play began on the first day, a background story about the CRYSTAL ISLAND game was presented to students in the form of a 3-minute video. Due to the slow Internet speed and bandwidth when the video was loaded on all computers at the

same time, the original plan of having students watch the video individually on their own computer was altered. Instead, students watched the background story video on a big screen in the playing room. The purpose of this background story was to provide students with a general idea about the context of the game. After the background story, students completed a 10-15 minute tutorial game play that familiarized them with the game environment, including how to drive the in-game characters using different hot keys in the keyboard. After the game background story and the tutorial play, students began to play the game for about 40 minutes.

At the end of gameplay on the 1st day, a semi-structured focus group interview was conducted with 5 selected solo game players. Two students were girls, and the other three were males. Also, four were White Americans, and one was Asian American (Korean) (for a discussion regarding how students were selected to participate in the focus group interview, see discussion below). Originally, it was proposed that 8-9 students in each gameplay condition would be interviewed, in the format of 4-5 students in one focus group (meaning that I would conduct 2 focus groups for each gameplay condition. However, due to time constrains (e.g., students' class schedule), only one focus group was possible each day. After discussing this issue with my committee, it was decided that only 5 students in each gameplay condition would be interviewed.

One concern related to the change in the number of students in the focus group interviews was that I might not get as much information as when the originally proposed number of students from each gameplay condition was interviewed (i.e., 8-9 students from each condition). To minimize the potential negative effect associated with this change, I altered the focus group interview student selection procedures accordingly. In particular, in

order to get as much rich information as possible from the limited number of students in the focus group interviews, I decided that it was important to consult with the classroom teachers, asking them to recommend students who are more talkative and would be more likely to share their gameplay experience (see discussion below). Upon consulting with my committee on this issue, it was agreed that conducting one focus group with 5 students from each gameplay condition would still be sufficient for answering the research questions, as long as the students were talkative and that the focus group process was appropriately facilitated, e.g., making sure each student had the chance to talk and asking appropriate follow-up questions to get more in-depth information.

The interview focused on flow antecedents, impeding factors and flow state (see Appendix D for interview questions). During the interview, students were first asked questions related to their general gameplay experience and feeling in the CRYSTAL ISLAND game environment. Next, they were asked very specific game flow experience questions based on the subscales examined in the adapted flow survey. The focus group interview lasted for about 30-40 minutes.

To make sure students understand the interview questions that asked about the sub-dimensions of game flow experience, I used general vocabularies to replace the terminology associated with flow theory. For example, when asking students about the flow experience subscale of loss of self-consciousness, one sample question I asked was "When you were playing the CRYSTAL ISLAND game, were you worried that your friends would finish the quests earlier than you or that they collect more sand dollars?" By phrasing the interview questions in this way, I was able to express abstract concepts associated with flow theory

using more specific and understandable examples. Another technique that I used to make sure students understand the interview questions was that I provided follow-up explanations whenever I felt that students did not seem to understand the questions (e.g., silence)

One of the most obvious advantages of conducting focus group interviews is that it enables the researcher to collect in-depth qualitative data to supplement quantitative data (Umana-Taylor, & Bamaca, 2004). Umana-Taylor and Mamaca (2004) stated that, it is important to consider participants' characters such as gender and ethnical background while conducting focus groups. According to the authors, it is a wise decision to conduct separate focus groups based on different genders and ethnical backgrounds because participants' perspectives and subjective feeling might be different due to these individual differences. Particularly, if a focus group consists of both boy and girls, boys tend to dominate the group discussion (Umana-Taylor & Bamaca, 2004). Based on this rationale, it was originally proposed that girls and boys would be put in different interview groups. However, it was also important to ensure that the students in the focus group were more talkative so that more in-depth data could be collected. Thus, I consulted with their science teachers about which students were more talkative. The final 5 solo game players selected to participate in the focus group interview were based on the teacher's recommendation. The conversations were not dominated by particular students during the interview process; this was not surprising since all students were talkative. The focus group interview was recorded using an audio recording device for further data analysis. The flow theory framework was used as the base for the qualitative video data analysis.

Day Two of Gameplay

On day 2 of the gameplay, the procedures consisted of three main parts, including (a) gameplay, (b) administration of the adapted game flow scale, and (c) focus group interview with collaborative players. First, students played the game for another 45 minutes. Students continued the game from where they stopped on day one. Second, immediately after the gameplay, the adapted game flow scale was administrated, which took about 15 minutes. Finally, semi-structured interview was conducted (immediately after the flow scale) with 5 collaborative game players. Three of them were girls and the other two were boys. Three of them were White Americans, one was Asian American, and the other one was African American. The procedures of participant selection and interview process were similar with the solo game players.

Besides the game-related features that were examined in the flow survey (i.e., challenge/skill balance, clear goals, feedback, game frame story, playability and gamefulness), students in the face-to-face collaborative gameplay condition were also asked about their peer interaction experience in the game and how they thought this had impacted their flow experience. The 5 students were from 5 gameplay pairs/dyads. This ensured that students could share their true gameplay experience (especially their peer interaction experience) freely without the presence of their gameplay partners. The focus group interview also lasted for about 30-40 minutes.

Day Three of Gameplay

On the third (last) day of gameplay, students played the game for about 35 minutes. After the gameplay, students took the post science content test and the science learning

attitude survey again, which took about 20-25 minutes. The post science content test and the learning attitude survey were identical as the pre-test.

Data Analysis

Separate data analysis strategies were used to analyze the quantitative and qualitative data to answer the three research questions. In the following section, data analysis procedures are described by each research question.

Data Analysis for Research Question One

The first research question was: To what extent do 5th graders experience flow while playing the CRYSTAL ISLAND game, as reflected in the flow scale and focus group interviews? Within this umbrella question, two sub-questions were asked: a) What were the differences in students' game flow experience based on two different playing approaches (solo and face-to-face collaborative playing)? b) What were the differences in students' game flow experience based on student personal characters such as gender, race, prior gaming experience, and reading proficiency?

Quantitative data from the flow scale was downloaded and imported directly from Survey Monkey to SPSS for analysis (Survey Monkey supports SPSS format download). Basic statistical descriptive data such as mean and standard deviation for each subscale in the flow survey was reported to help describe the problem. To answer the sub-questions, preliminary univariate ANOVAs were first conducted to examine flow experience differences (i.e., mean score for each flow experience subscale) based on gender. Note that most students were White Americans and very few of them were of other ethnic groups. Therefore, it did not make sense to also conduct the originally proposed ANOVA to examine

flow experience difference based on students' race. Separate simple regressions were also conducted to examine the impact of students' reading proficiency and prior gaming experience on each of the game flow experience subscales. As reported previously, students' reading proficiency data was provided by their teachers (reading EOG ranking from the previous semester) and was measured one a 4-point scale, with a high score indicating higher reading proficiency. Since a majority of the students received a reading EOG score of 3 or 4, this variable could not be treated as a categorical variable (i.e., low and high reading proficiency levels) to examine group differences. Therefore, simple regressions were conducted instead. All these analyses helped to explore potential flow experience differences based on student personal characters as mentioned above.

Next, based on the results from the preliminary analyses and in order to examine the impact of gameplay conditions on students' game flow experience (i.e., different flow experience subscales), a 2(Gameplay condition: solo and collaborative players) *2(Gender: male and female) MANCOVA analysis controlling for the effect of reading EOG scores was conducted.

The qualitative focus group interview transcripts were analyzed using both open and *a priori* coding (using flow theory). I first read the interview transcripts a couple of times to get familiar with the qualitative data that was collected. I then made the "first pass" to identify the flow experience sub-dimensions which were mentioned by the students in the interview. The flow theory (Csikszentmihaly, 1991) served as the analytical lens in the first round of data analysis. The frequency of the sub-dimensions mentioned in students' interview responses was also counted. Then, on a second pass, I used open coding to identify

other additional factors that were not in examined in the flow model but were mentioned in students' interview responses. Frequency of themes was also counted to identify the most frequently cited dimensions by the students. I also compared interview responses of students in the two different game playing conditions. This technique helped to highlight and explain similarities and differences among the groups' game flow experiences. Findings from the focus group interviews were also compared and integrated with the statistical findings from the adapted game flow survey to help better understand students' true feelings and experience during gameplay.

Specifically, for each of the 4 flow experience subscales, I compared the quantitative survey results (e.g., mean score) with student focus group interview responses. For example, if results from the statistical analyses demonstrated that students had a mean score within a certain range (e.g., above 4 on a 5-point scale, meaning that they had high flow experience) for a specific flow experience subscale, I went back to the focus group data to examine whether their answers to the interview questions which asked about the same flow experience subscale supported or contradicted with the quantitative findings (e.g., did most or all students in the focus group interviews gave very positive answers during the focus group, indicating that they had a high flow experience for that specific subscale). In addition to the descriptive data such as the mean score for each flow experience subscales, to confirm findings from statistical analyses that aimed to examine whether there were differences based on student personal characters and gameplay conditions, I also went back to the focus group interview data to see if students' interview responses also revealed that there were differences based on student personal factors (e.g., did girls and boys in the focus groups

report similar or different gameplay experience) and gameplay conditions (e.g., did students from the two gameplay conditions report similar or different gameplay experience during the focus groups). To better understand students' game flow experience, important quotes from students' interview responses were also selected to support the findings.

Data Analysis for Research Question Two

This question examined factors that impacted students' game flow experience. Specifically, this question was: What and how did different factors (game design features and peer interaction) impact students' game flow experience? Quantitative data analysis included reporting basic descriptive statistics such as mean and standard deviation for each flow antecedents (i.e., game design features) examined in the adapted flow survey. A series of multiple regression analysis were then conducted to examine the relationship between each of the 6 flow antecedents measured in the flow scale and students' flow experience (mean score for each of the theorized flow experience subscales). Simple regression analyses were also conducted to examine the relationship between collaborative game players' self-reported in-game peer interaction and their flow experience**.**

Qualitative data was analyzed in the same way as in the 1st research question to identify themes (factors) that students perceived to have contributed to or impeded their game flow experience. The interview responses of students in the different playing groups were compared to highlight potential similarities and differences in major categories of findings. The qualitative findings were also compared with statistical findings from the flow survey to better understand what students perceived to be flow antecedents.

Data Analysis for Research Question Three

The third research question was: What was the relationship between students' game flow experience and their science content learning gains and science learning attitude changes? Basic descriptive statistics such as mean and standard deviation for each group was reported. Repeated measures ANOVAs was then conducted in order to determine if there has been growth in science learning outcomes and any changes in students' attitudes towards science learning before and after gameplay.

In order to study the relationship between flow experience (again, the theorized subscales) and students' science content learning gains, students' science content learning residual gain scores from pre to post content tests were calculated. Then separate simple linear regressions were conducted to examine how each of the flow experience subscales predicted students' residual content learning gain scores. The same procedures were conducted to examine the relationship between flow experience and changes in students' attitude towards science.

Originally it was proposed that students' flow experience score would be assigned into 3 different categories of high flow experience (e.g., a mean score of between 4 to 5), medium flow experience (a mean score of between 3-4), and no/low flow experience (below 3). However, based on preliminary descriptive data from the survey, it was found that most students reported high flow experience (between 4 to 5 on a 5-point scale). Therefore, it did not make sense to divide students into different groups based on their flow experience to examine how flow experience categories impacted their science learning gains.

Validity and Reliability-Trustworthiness

Validity and reliability are very important in mixed methods research study. Because mixed methods research involves combining complementary strengths and non-overlapping weakness of quantitative and qualitative research, assessing the validity of mixed methods research can be a complex issue (Onwuegbuzie & Johnson, 2006). Onwuegbuzie and Johnson (2006) suggested that validity should be conceptualized as legitimation in mixed methods research, which is a continuous process as opposed to an outcome product. Particularly, one of the most important approaches to address this issue is making sure that the data is handled appropriately (Johnson & Turner, 2003; Teddlie & Tashakkori, 2003). To this end, this study employed the following different strategies to make sure that both data collection and analysis were credible processes.

Pre-Post Science Content Tests

In order to address content validity, the CRYSTAL ISLAND research team generated the science content test items based on the FOSS (Full Option Science System) informative assessment and NC standard course of science study. The items were also returned to 5th grade science teachers at the school for content critique. Also, the research team played the game and did a content analysis of the game to make sure the test items aligned with the concepts covered in the game. To address reliability, Cronbaph's alpha was calculated to provide evidence of internal consistency (r = .79 and .85 for pre and post test, respectively).

Science Attitude Survey

The study used an existing science attitude survey, which has proved to have satisfactory validity and reliability (see discussion above). Since the survey was developed

for K-5 students and my participants fell within this age range, no revision was made to the survey (e.g., rewording). However, it is important to also report my own reliability and validity data in this study. As a result, exploratory factory analysis (EFA) was conducted on the survey to examine the overall structure and underlying patterns. Also, reliability analyses (Cronbach's alpha) were conducted to examine internal consistency of the survey items. The results are presented in Chapter 4.

Adapted Game Flow Scale

In order to address validity, exploratory factor analysis (EFA) was conducted on the flow scale to establish construct validity. Cronbach's alphas were calculated to examine the reliability of for each of the flow experience sub-scales. Other descriptive data, such as item-total and inter-item correlations, are also presented in Chapter 4.

Pilot test results. Based on the revised flow scale, the adapted game flow experience scale was pilot tested with a class of 19 5th graders in an urban public elementary school in Raleigh, North Carolina. Students' responses to the additional open-ended questions added at the end of the flow survey (which asked them if they understood the questions) indicated that all of the participants could clearly understand what they were asked. Due to the small number of participants, a meaningful factor analysis could not be conducted. However, an initial reliability analysis of the revised/reworded survey was conducted. The overall reliability of the flow antecedents as a whole construct was found to be acceptable ($r = .89$). The reliability of the flow antecedents, challenge/skill balance ($r = .67$), clear goals ($r = .72$), feedback ($r =.75$), game frame story ($r =.89$), playability ($r =.79$), and gamefulness $(r =.69)$ were all at an acceptable level. The overall reliability of the flow experience as a whole

construct was also found to be good ($r = .83$). The reliabilities of the flow sub-scales of concentration ($r = .75$), sense of control ($r = .82$), time distortion ($r = .73$), and autotelic experience ($r = .89$) were all acceptable, except for the sub-scale of loss of self-consciousness ($r = .53$). The low reliability for the subscale of loss of self-consciousness is understandable considering that the participants were only 10-12 years old and might not fully understand this concept.

The three Likert-scale items measuring in-game peer interaction experience of students (the face-to-face collaborative playing group) were created and added after the reworded game flow scale was pilot tested. As a result, no reliability data for these three extra items was available at this point of the data analysis but is reported in Chapter 4.

Taken together, these preliminary results demonstrate that the adapted survey served as a satisfactory tool to measure flow experience of 5th graders. Further revisions were then made based on these results. Specifically, I consulted with elementary English teachers on the further rewording of some of the survey items to make sure they were within students' overall readability level. A series of new analyses were then conducted to see if the results improved when the flow scale was implemented during data collection with another group of 75 students.

Focus Group Interviews

Merriam (2000) offered several strategies that researchers may employ to ensure that appropriate procedures are followed during the entire research process. For my study, the focus group interview transcripts were coded twice, once during *a prior* coding and the other during the second round of open coding, in order to ensure that any important findings were

not overlooked. This was very important especially for the open-coding process to ensure that additional dimensions (e.g., game play experience) that students mentioned but were not examined in the flow survey were not overlooked.

In addition, the researcher's bias was also discussed. For example, in the focus group data, I discussed my personal experiences and theoretical orientation, and how these affected my interpretation of data. Umana-Taylor and Bamaca (2004) believe that this is important because it will allow others to examine the lens and perspective through which the data is interpreted and the credibility of the research. Personally, I believe that when appropriately integrated into the classroom, computer-mediated learning (i.e., game-based learning) would be able to provide students with learning experiences that are not only fun but also meaningful and life enhancing. As a research assistant working on the CRYSTAL ISLAND game-based learning project, I have been involved in data collection for the past three years and have seen how excited students were about playing the CRYSTAL ISLAND game. I myself have also played and enjoyed the game. Upon reflecting on my own gameplay experience and examining the game design features, I have also developed a better understanding of why students loved playing the game so much (e.g., fancy game characters, interactive learning quests, as well as earning external rewards). In addition, I also had a basic idea of how certain game design features impacted my own playing experience. During my qualitative data analysis process, I made every attempt to control my predispositions about students' CRYSTAL ISLAND gameplay experience and their perceptions of the overall game design.

It was originally proposed that a peer reviewer would code a subset of the interviews in order to establish inter-rater reliability. However, the study did not actually employ a peer

reviewer as originally proposed. This change was made for two main reasons. First, the way the questions were structured (e.g., based on the flow experience subscales) made it easy to code students' responses with high accuracy (reliability). For example, when students were asked questions about their flow experience during gameplay, the questions that were asked were all based on the 5 theorized flow experience subscales. For instance, when I examined students' feeling about time during gameplay, a sample question that I asked was "Did you feel that time went by very fast when you were enjoying playing the game?" When I coded students' answers to these interview questions, it was straightforward to identify the corresponding codes (i.e., which flow experience subscale) that they were talking about. Second, the focus group interview findings (e.g., the frequency counts) were not going to undergo any statistical analysis. Therefore, calculating an inter-rater reliability was not needed for my research purpose. The changes as described here were agreed upon by the committee because the changes would not negatively impact the overall trustworthiness of the data analysis results.

Ethical and Political Considerations

It is the responsibility of every researcher to conduct an ethical study. Since this study involved collecting students' personal information and using focus group interviews as a qualitative data source, the first action I took was in informing the students of the nature and purpose of this research. I provided all students with information relating to what I would actually do in the study, what I would do with the findings, and what the benefits of the study could be for all of them. Parents were also informed of the purpose of the study and consent forms were sent out to be signed by parents before data collection. In order to ensure full

protection of participants, information for the study was kept confidential. All raw data was stored in my laptop that was password protected. Audio files from the student focus group interviews would also destroyed at the end of this research study. No reference was made in oral or written reports that could link participants to the study.

In terms of political considerations, this current research might have different audiences, including educational policy makers, funding agencies, and other educational practitioners. Educational research should always try to add to the current knowledge and practice in the field. It is important to remember that, in order for a research study to make a contribution to the field, it should be appropriately written and disseminated to appropriate audiences.

Summary of Research Methodology

In short, this study employed an embedded mixed method research design (QUAN+qual) in which both quantitative survey and qualitative focus group interview data were collected at the same time, while quantitative data played a primary role. However, qualitative focus group interview data also played a critical role in answering the research questions guiding this study. In particular, data from student focus group interviews helped me to form a clearer picture of students' gameplay experience (especially their game flow experience) by providing more in-depth information.

To reiterate, the pre measures of this study included science content knowledge test, science learning attitude survey, and individual student data such as gender, race, prior gaming experience, and reading EOG scores. The post measures included science content

knowledge test, science learning attitude survey, with the addition of game flow experience

measure using the adapted game flow survey and semi-structured focus group interviews.

Based on the nature of embedded mixed method research design, quantitative and

qualitative data were analyzed and reported in a mixed/integrated manner, which helped to

highlight potential differences and similarities found in the two different data sets.

CHAPTER FOUR: RESULTS

This study was designed to better understand 5th graders' flow experience in a 3-D intelligent game-based science learning environment, the impact of different gameplay approaches and game design features on students' game flow experience, and how game flow experience impacted students' science content learning and changes in their attitude towards science learning.

This chapter presents the findings from my attempts to answer the 3 research questions guiding this study. The chapter was organized into two sections. In the first section, the validation results of the adapted game flow survey (flow state items and flow antecedent items separately) and the science learning attitude survey are reported. Particularly, in this section, my step-by-step decision-making process regarding item deletion/ retention for the EFA analyses is reported. In the second section, quantitative and qualitative results for each of the 3 research questions are reported. Particularly, for the focus group interview analysis results, results from both *a priori* and open-ended coding are reported and compared with the quantitative survey findings.

Validation of the Adapted Flow Survey and Science Attitude Survey

Validation of the Flow Experience Items

The original survey developed by Kiili (2005; 2008) consisted of 15 items measuring 5 dimensions of students' game flow experience and 18 items measuring 6 key game design features (i.e., game flow antecedents). The author asserted that the game flow scale provided an acceptable measure of college students' game flow experience. However, based on their reliability and validation analysis results (see Chapter 3), they also suggested that some of the

items need further revisions in future studies. Since some of the questions were reworded to accommodate the readability level of 5th graders in my study, exploratory factor analyses were conducted to validate the adapted survey. In this section, the validation results for the 15 flow experience items are presented first, followed by the validation results for the 18 flow antecedent items. Finally, the validation results for the science attitude survey are also reported.

The validation analyses that were conducted included both univariate and multivariate methods using SPSS 19. The univariate analyses included descriptive statistics such as item means, standard deviation, kurtosis, and item analysis such as inter-item and item-total correlations. Items that demonstrated non-normal distributions (e.g., kurtosis values greater than 2.0) and items with low inter-item and item-total correlations (lower than .30) were noted. The multivariate analysis involved using exploratory factor analysis, only considering factor loadings of .30 or greater as meaningful. Any final decisions made concerning item deletions were based on both the univariate and multivariate analyses.

Descriptives. Descriptive statistics were implemented on the final 73 participants. Based on this final sample, it was noted that 2 of the 15 items measuring the 5 theorized sub-dimensions of flow experience demonstrated non-normal distributions. One item in the subscale of sense of control (for ease of reading, in the following text, this item was labeled "control 3" since it was the 3rd item in the subscale of sense of control) had kurtosis of 2.46. Another item in the subscale of autotelic experience (item "autotelic 1") had kurtosis of 4.948. These two items were flagged as possible problematic items.

Reliability. A reliability analysis was then conducted on each of the 5 flow experience subscales. The analysis for the total sample, the subscales of concentration/attention focus, sense of control, loss of self-consciousness, distorted sense of time, and autotelic experience revealed internal consistencies of .81, .84, .63, .78, and .79, respectively. The results showed that the internal consistencies of all 5 flow subscales were acceptable. However, the subscale of loss of self-consciousness had the lowest internal consistency (0.63). As discussed previously, this might be due to the fact that the participants were only 10-12 year old and the construct of loss of self-consciousness might be difficult for them to understand. Nevertheless, compared with the reliability results from an earlier pilot test of the flow survey (see Chapter 3), the reliability of this subscale showed improvement (from .52 to .63). However, the result indicated that more work is warranted on this subscale.

Item-total correlations. In addition to the internal consistency of the subscales, the item-total correlations were examined to examine whether any item was not consistent with the rest of the sub-scale. The ranges for the 5 flow experience subscales were presented in Table 4.1. De Vaus (2002) suggested that correlation values higher than 0.3 are considered acceptable for item-analysis purposes. This means that all the 15 items in the flow scale were adequate to very good.

Table 4.1

Item-to-total Correlations for Flow Experience Items

Subscales	Ranges
Concentration	.64 to .70
Sense of control	.66 to .74
Loss of self-consciousness	.41 to .46
Distorted sense of time	.60 to .63
Autotelic experience	.52 to .69

Inter-item correlations. Next, inter-item correlations found in all five subscales were explored. According to Clark and Watson (1995), the mean inter-item correlation values of .15 to 0.50, or from .40 to .50 for a narrower construct are considered acceptable. The mean inter-item correlations fro the concentration, sense of control, loss of self-consciousness, distorted sense of time, and autotelic experience subscales were .59, .64, .37, .54, and .56, respectively. The lower mean for the loss of self-consciousness subscale was consistent with the weaker alpha previously reported.

As previously reported, the kurtosis values of two of the items, one in the subscale of sense of control, and the other in the subscale of autotelic experience, were greater than 2.0. These two items were identified as possible problematic items. However, it was decided that these two items would not be deleted at this point since there were only three items for each subscale. As a result, the first exploratory factor analysis reported below was based on all 15 flow experience items.

Exploratory factory analysis. The goal of the exploratory factor analysis was to identify how many factors/dimensions the adapted flow experience items would yield for younger participants in my study.

There have been debates regarding the adequate sample size for running exploratory factor analysis. While there is general agreement among researchers that an adequate sample size is very important for exploratory factor analysis, there has not been consensus regarding what sample size is appropriate. For example, Guilford (1954) suggested that a minimum sample size of 200 is required to produce consistent factor patterns and structures. Some other researchers, however, have suggested that the most prevalent ratio for sample size to number of items for meaningful EFA is 10: 1 (Costello & Osborne, 2005). Unfortunately, my final sample size fell well short of this guideline.

I still felt it was important to attempt to investigate the internal structure of the survey items, and so I ran an EFA analysis using Maximum Likelihood factoring and an Oblique (Promax) rotation. In the following section, results from the EFA analysis were presented in detail.

Theoretically, flow experience consists of 5 dimensions for older populations (Csikszentmihalyi, 1975; Kiili & Lainem, 2008). However, for 5th graders, the EFA extracted only four factors (with Eigenvalue > 1), accounting fro 56.87% of the total variance and reproducing 84% of the original correlations (with 17 or 16 % of the residual correlations greater than .05). The factor loadings for each item are presented in Appendix F.

The results revealed that the 3 items in the subscale of distorted sense of time and the 3 items in the subscale of loss of self-consciousness loaded on the same factor (factor 2).

This might be explained as previously mentioned because the participants were too young to fully understand and tell the differences between time distortion and loss of self-consciousness. Based on this result, however, it seemed reasonable to combine these two subscales into one single subscale. This new factor was labeled "*time distortion and loss of self-consciousness*."

Moreover, two items had double loading. Specifically, one item in the subscale of attention focus/concentration (item "attention 3") had double loading on factor 2 and factor 3 (attention focus), with higher loading (.48) on factor 2 and lower loading (.41) on its theorized factor 3. This item was therefore flagged as a possible bad item that should be deleted in further analysis. Also, one item in the subscale of distorted sense of time (item "time 2") had double loading on factor 2 and factor 4 (autotelic experience), but with higher loading on its theorized factor 2 (.50) and lower loading on factor 4 (.41). Therefore, this item was considered acceptable and was kept for later analysis. However, further work to improve these items is required. The correlations among the four new factors are presented in Table 4.2 below.

Table 4.2

Factor Correlations for Flow Experience Items

Factor	1	2	3	4
1	1.00	.361	.18	.42
2	.36	1.00	.53	.56
3	.18	.533	1.00	.45
4	.42	.555	.45	1.00

Exploratory factory analysis after item deletion. As revealed above, one item (item "attention 3") had double loading on two factors, with higher loading on the non-theorized factor instead of on its theorized factor. As a result, the decision was made to delete this item and run another EFA to examine how this item impacted the overall structure of the survey. In the next sections, the new EFA results are presented in detail.

After deleting this item, the EFA also extracted 4 factors, accounting for 56.80% of the total variance and reproducing 87% of the original correlations (with 12 or 13 % of the residual correlations greater than .05). The new factor loading for each item is presented in Appendix G. The results showed that the new structure was similar to the original EFA structure. The subscales of time distortion and loss of self-consciousness still hung together in factor 2. Again, it was noted that further revisions to these items are warranted (e.g., rewording the items in these two subscales), as there were still two items that had double loadings. Specifically, one item in the subscale of loss of self-consciousness (item "loss of self-consciousness 2") had double loading on factor 2 and factor 3, with higher loading on its theorized factor (factor 2). Also, the same item in the subscale of time distortion still had double loading on factor 2 and 3 (this similar to the EFA analysis before item deletion), with higher loading on its theorized factor 2. Therefore, these two items were considered acceptable and were kept in for later analyses. However, it was also noted that further work on these two items is required. The new factor correlations are presented in Table 4.3 below.

Table 4.3

New Factor Correlations for Flow Experience Items

Factor	1	2	3	4
1	1.00	.33	.48	.16
2	.33	1.00	.55	.48
3	.48	.55	1.00	.43
4	.16	.48	.43	1.00

Summary of exploratory factor analysis for flow experience items. Overall, the results indicated that the 4-factor structure worked well with 5th graders. The final structure after deleting the problematic item (item "attention 3") was interpretable and appeared better than it was before item deletion. Based on these results, the decision was made that game flow experience has only 4 subscales for 5th graders in my study instead of the theorized 5 subscales. These 4 dimensions are attention focus/concentration, sense of control, time distortion and loss of self-consciousness, and autotelic experience. Further analyses were conducted to answer the three research questions were all based on the 4-factor structure after item deletion.

It is important to note that the 4-factor flow experience structure was based on a relatively small sample size. Research has showed that EFA based on a small sample size may not yield valid or reliable solutions (Dewinter, Dodou, & Wieringa, 2009). In future studies, a larger sample size should be recruited to further validate the adapted survey. It should be noted that the current study included very few items for each subscale in the flow survey. Costello and Osborne (2005) noted that a subscale with fewer than three items might

not produce stable results. Moving forward in working on the adapted survey, more items need to be written for the subscales. With all the suggested revisions, including rewording the double-loaded items and the 6 items that hung together to form the new subscale of time distortion / loss of self-consciousness, the EFA analysis may yield a potentially different structure. In the following sections, new descriptive data for each of the final 4 flow subscales is presented.

Reliability after item deletion. Because the previous EFA analyses indicated that flow experience in the game environment only has four subscales for 5th graders and because one problematic item was deleted from the final survey, additional analyses were conducted taking these findings into consideration. Another reliability analysis was then conducted on the four new flow subscales. The new reliabilities for the subscales of attention focus, sense of control, time distortion / loss of self-consciousness, and autotelic experience were .77, .84, .76, and .79, respectively. The results indicated that the internal consistencies of the subscales were all acceptable.

Item-total correlations after item deletion. Additional analyses were also conducted to examine the new item-total correlations based on the final survey structure. The results were presented in Table 4.4. According to the Ebel's (1965) guidelines, all of the item-to-total correlations were in very good ranges.

Table 4.4

New Item-total Correlations for Flow Experience Items

Subscales	Ranges
Concentration	.64
Sense of control	.66 to .74
Loss of time and self-consciousness	.44 to .60
Autotelic experience	.52 to .69

Inter-item correlations after item deletion. The new mean inter-item correlations fro the concentration, sense of control, time distortion /loss of self-consciousness, and autotelic experience subscales were .64, .64, .39, and .56, respectively. The value for the new combined subscale of loss of time and self-consciousness was still lower than other subscales.

Validation of the Adapted Flow Antecedent Items

As mentioned previously, in the adapted flow scale, there were another 18 items that measured 6 flow antecedents (game design features). similar procedures were gone through to validate these adapted flow antecedent items. In the following sections, the validation results are presented in detail.

Descriptives. Descriptive statistics for the 18 items measuring the 6 game design features were also implemented on the final 73 participants. Based on this final sample, all of the 18 items measuring the 6 flow antecedents demonstrated normal distribution, with kurtosis value of smaller than 2.

Reliability. A reliability analysis was then conducted on each of the 6 flow antecedents. On the analysis for the total sample, the subscales of challenge/skill balance,

playability, gamefulness, clear goals, instant feedback, and frame story had internal consistencies of .71, .80, .74, .76, .81, and .74, respectively. The results showed that the internal consistencies of all 6 low antecedents were all acceptable.

Item-total correlations. In addition to the internal consistency of the subscales, the item-total correlations were examined to check whether any item was not consistent with the rest of the sub-scale. The ranges for the 6 subscales were shown in Table 4.5. Again, based on the suggestion of De Vaus (2002) that correlation values greater than 0.3 are considered acceptable for item-analysis purposes, all 18 items were adequate to very good.

Table 4.5

Item-total Correlations for Flow Antecedent Items

Subscales	Ranges
Challenge/skill balance	.49 to .60
Playability	.62 to .67
Gamefulness	.53 to .61
Clear goals	.54 to .64
Immediate feedback	.61 to .70
Frame story	.47 to .62

Inter-item correlations. Next, inter-item correlations found in all 6 subscales were explored. The mean inter-item correlations fro the subscales of challenge/skill balance, playability, gamefulness, clear goals, instant feedback, and frame story were .45, .59, .49, .51, .59, and .49, respectively. These values were all acceptable based on the guideline discussed earlier.

Exploratory factory analysis. Next, an exploratory factor analysis using Maximum Likelihood factoring and an Oblique (Promax) rotation was used to investigate the internal structure of the 6 flow antecedents. It was postulated that there would be 6 factors, challenge/skill balance, playability, gamefulness, clear goals, instant feedback, and frame story. The EFA extracted six factors (with Eigenvalue > 1), accounting for 60.34% of the total variance and reproducing 83% of the original correlations (with 27 or 17 % of the residual correlations greater than .05). The factor loadings for each item are presented in Appendix H.

The results revealed that one item in the subscale of clear goals (item "goal 3") had double loading on factor 2 (frame story) and factor 4 (clear goals), with significantly higher loading on its theorized factor 4. One item in the subscale of "immediate feedback" (item "feedback 3") had double loading on factor 2 (frame story) and factor 3 (immediate feedback), with higher loading on the non-theorized factor 2. This item was labeled as a potentially poor item that should be deleted in further analyses. In addition, another item in the subscale of "immediate feedback" (item "feedback 1") had a loading value of greater than 1 (1.06), indicating that this item explained most of the variance in this subscale. This problem was noted but the item was still kept in the survey for further analysis; however further work is warranted for this item (e.g., rewording the question). There were no problems found with items in other subscales.

Exploratory factory analysis after item deletion. As revealed in the first EFA analysis presented above, there was one item in the subscale of "immediate feedback" (item "feedback 3") that had higher loading on the non-theorized factor. It was thus decided that

this item should be deleted. After item deletion, another EFA analysis was run to see how this item affected the overall structure of the flow antecedent items. This time the EFA extracted 6 factors again, accounting for 60.91% of the total variance and reproducing 84% of the original correlations (with 23 or 16% of the residual correlations greater than .05). One item in the subscale of clear goals (item "goal 3") still double loaded on factor 2 (clear goals) and factor 3 (frame story), but with significantly higher loading on its theorized factor 2 (loading value of .73) than on the non-theorized factor 3 (loading value of .34). Besides, the same item in the subscale of immediate feedback (item "feedback 1") still had a loading value of greater than 1 (1.04) on its theorized factor. These results indicated that these two items require further work in future studies; however, they were acceptable in this study since there was not overwhelming evidence that they were problematic. The new factor loadings are presented in Appendix I.

Summary of exploratory factor analysis for flow antecedent items. The EFA analyses illustrated that the 6-factor flow antecedent structure after deleting the problematic item in the subscale of immediate feedback (item "feedback 3") worked well with 5th graders. Further analyses were all based on the structure of the remaining 17 items. In the next sections, new descriptive data after item deletion is reported.

Reliability after item deletion. A reliability analysis was conducted on each of the 6 flow antecedents. On the analysis for the total sample, the subscales of challenge/skill balance, playability, gamefulness, clear goals, instant feedback, and frame story have internal consistencies of .71, .80, .74, .76, .79, and .74, respectively. The reliability of the new subscale of instant feedback decreased from the original .81 to .79; however, it was still

acceptable. The results showed that the internal consistencies of all 6 low antecedents were all acceptable.

Item-total correlations after item deletion. Item-total correlations were examined again for each of the remaining items. The ranges for the subscales were presented in Table 4.6. Results revealed that the item-to-total correlations for each of the subscales were adequate to very good.

Table 4.6

New Item-total Correlations for Flow Antecedent Items

Subscales	Ranges
Challenge/skill balance	.49 to .60
Playability	.62 to .67
Gamefulness	.53 to .61
Clear goals	.54 to .64
Immediate feedback	.65
Frame story	.47 to .62

Inter-item correlations after item deletion. Next, the inter-item correlations were reexamined. The mean inter-item correlations for the 6 subscales of challenge/skill balance, playability, gamefulness, clear goals, instant feedback, and frame story were .45, .59, .49, .51, .65, and .49, respectively. The inter-item correlation for the two items in the subscale of instant feedback went from .59 to .65 after item deletion. These results indicated that the values were all acceptable.

Validation of the Science Learning Attitude Survey

As reported in Chapter 3, the original science learning attitude survey has 25 items to

measure 5 theorized subscales of K-5 students' science learning attitude, including students' perception of the value of science in society (5 items), desire to learn science (7 items), perception of science teachers (3 items), anxiety about science (5 items), and self-concept of science (5 items). I went through similar procedures to validate this survey. In the following sections, the validation results based on the data I collected with the students are reported in detail.

Descriptives. Descriptive statistics were implemented on the final 73 participants. Based on this final sample, it was noted that 5 of the 25 items demonstrated non-normal distributions. Specifically, one item in the subscale of perception of the value of science had kurtosis of 2.78. Two items in the subscale of anxiety about science had kurtosis of 4.77 and 2.58 respectively. One item in the subscale of self-concept of science had kurtosis of 3.12. Still one item in the subscale of perception of science teachers had a kurtosis of 2.36. These items were flagged as possible problematic items, and it was decided that they should be deleted in further analyses except for the item in the subscale of perception of science teachers. This item was not deleted because there was only 3 items for this subscale. However, it was also noted that further work on this item is required.

Reliability. On the analysis for the total sample, the subscales of perceived value of science in society, desire to learn science, perception of science teachers, anxiety about science, and self-concept of science had internal consistencies of .77, .71, .71, .76, and .82, respectively. The results showed that the internal consistencies of all 6 flow antecedents were acceptable.

Item-to-total correlations. In addition to the internal consistency of the subscales, the item-to-total correlations were examined to check whether any item was not consistent with the rest of the sub-scale. The ranges for the 5 science learning attitude subscales in the survey were presented in Table 4.7. Again, using .3 as the cutoff (De Vaus, 2002), the values for all 25 items were adequate to very good. However, it was noticed that 2 items from the subscale of desire to learn science had very low item-to-total correlations (-.01 and .24 respectively). These two items were labeled as potentially bad items and should therefore be deleted in further analyses.

Table 4.7

Item-to-total Correlations for Science Learning Attitude Survey

Subscales	Ranges
Perceived value of science in society	.48 to .62
Desire to learn science	-.001 to.68
Perception of science teachers	.46 to.58
Anxiety about science	.40 to.66
Self-concept of science	.49 to.75

Inter-item correlations. Next, inter-item correlations found in all 5 subscales were explored. The mean inter-item correlations of the subscales of perceived value of science in society, desire to learn science, perception of science teachers, anxiety about science, and self-concept of science were .40, .29, .44, .40, and .50, respectively. It was found that two items in the subscale of desire to learn science had very low correlations with other items. The correlation between the item "Sometimes I read ahead in our science book" and other

items in this subscale ranged from -.20 to .13. The correlation between the item "It is important to me to understand the work I do in science class" and other items in this subscale ranged from -.20 to .36. Moreover, this item had correlation values over .30 with only two other items in this subscale. The problems found with these two particular items were consistent with their very low item-to-total correlations previously reported. As mentioned previously, these two items had to be deleted. No problem was found for other subscales. After deleting these 6 problematic items (4 of which demonstrated non-normal distributions, and the other 2 items had very low item-to-total and inter-item correlations), the number of items remained in the survey were 19 at this point. Based on these 19 items, an EFA was run to explore the internal structure of the survey.

Exploratory factor analysis after deleting 6 identified poor items. The EFA extracted 5 factors (Eigenvalue > 1), accounting for 55.61% of the total variance and reproducing 81% of the original correlations (with 33 or 19% of the residual correlations greater than .05). The factor loading patterns were presented in Appendix J.

The results showed that that the 3 items in the subscale of anxiety about science and the 4 items in the subscale of self-concept of science all loaded on the same factor (factor 1). It was also noted that 3 items had double loadings. Among these 3 items, one item in the subscale of anxiety about science had double loading on factor 1 (anxiety about science) and factor 5, with significantly higher loading on the non-theorized factor (factor 5; loading value of .72) than on its theorized factor (loading value of .47). Therefore this item was labeled as a problematic item that should be deleted. Another item in this same subscale (anxiety about science) also had double loading on factor 1 and factor 5, but with significantly higher

loading on its theorized factor (factor 1; loading value of .68) than on the non-theorized factor (loading value of .39). Therefore this item was still considered acceptable; however it was also noted that further work is required for this item. One item in the subscale of self-concept of science loaded complexly on factor 1, factor 2, and factor 5, with loading values of .33, .82, and -.33 respectively on each of these three factors. Again, this item had significantly higher loading on the non-theorized factor 2 than on the theorized factor 1. Therefore this item was also labeled as a problematic item and should be deleted.

Based on these results, it was necessary to delete these two bad items and run an EFA again to examine how they impacted the overall structure of the survey. In the next section, the new EFA results after deleting these two additional double loading items are presented. It should be noted that, after deleting these two extra items, the total number of items in the survey was 17 at this point. Specifically, the number of items left for the subscales of perceived value of science, desire to learn science, perception of science teachers, anxiety about science, and self-concept of science were 4, 5, 3, 2, and 3, respectively.

Exploratory factory analysis after deleting two extra items. The EFA extracted 4 factors (in the previous EFA, 5 factors were extracted), accounting for 51.40% of the total variance and reproducing 75% of the original correlations (with 35 or 25% of the residual correlations greater than .05). The new (2nd) factor loading patterns were presented in Appendix K. The results showed that the two items in the subscale of anxiety about science and the 3 items in the subscale of self-concept of science still loaded on the same factor 1, which was similar with the results from the previous EFA analysis. Upon close examination of these items, it was intuitive to combine these two subscales into a single subscale. This

new subscale was thus labeled "anxiety and self-concept of science." Moreover, the new factor loading pattern showed that one item in the subscale of desire to learn science (item "science is something that I enjoy very much") had a loading value of greater than 1 (1.003). This suggested that this item explained most of the variance in the particular subscale. Therefore, further work is required on this item to see how it would impact the overall structure.

Summary of exploratory factor analysis for science attitude survey. Results showed that science learning attitude has only 4 dimensions for 5th graders in my study instead of the 5 dimensions reported by the authors who created the original survey. These 4 subscales are perceived value of science, desire to learn science, perception of science teachers, and anxiety/ self-concept of science. All further analyses were based on this 4-factor science learning attitude structure. Again, it should be noted that the EFA analysis results were based on a relatively small sample size. The results might have been different had the sample size been larger. As a result, the survey needs to be further developed and validated. In the following sections, new descriptive data after the 2nd EFA analysis is reported.

Reliability after item deletion. Analyses were conducted to reexamine the internal consistency of the 4 final subscales of science learning attitude. Results showed that the 4 subscales had internal consistency value of .73, .82, .71, and .79, respectively. These indicated that the reliability values were all acceptable.

Item-to-total correlations after item-deletion. The item-to-total correlations were also examined. The ranges for the new item-to-total correlations for each subscale were presented in Table 4.8. The results indicated that the ranges were all acceptable to good.

Table 4.8

New item-to-total Correlations for Science Learning Attitude Survey

Subscales	Ranges
Perceived value of science in society	.46 to .60
Desire to learn science	.43 to .72
Perception of science teachers	.46 to .58
Anxiety and Self-concept of science	.41 to .75

Inter-item correlations after item deletion. Besides the new item-to-total correlations, the inter-item correlations were also examined again. The results showed that the mean inter-item correlations for the 4 subscales were .41, .47, .44 and .45, respectively. Upon close examination of the correlations between each individual item in the 4 subscales, it was also found that the correlations between all items were between .30 to .70, except for one item that had a correlation of .297 (close to .30) with another item in the subscale. It was thus concluded that all items in each subscale correlated fairly well with each other.

Quantitative and Qualitative Analysis Findings

After all the survey structures were finalized, further analyses were conducted to answer the 3 research questions guiding this present study. In the following sections, findings are presented based on each research question.

Findings for Research Question One

The first research question of this study was: To what extent did 5th graders experience flow while playing the CRYSTAL ISLAND game, as reflected in the flow scale and focus group interviews? Two sub-questions were asked under this umbrella question: (a) What were the differences in students' game flow experience based on two gameplay approaches (solo and face-to-face collaborative playing)? (b) What were the differences in game flow experience based on students' personal characters (i.e., gender, reading proficiency, and prior gaming experience)?

Descriptive data for two gameplay conditions. The descriptive data (i.e., mean and standard deviation) for the 4 subscales of game flow experience for each gameplay condition were presented in Table 4.9. The table provided an overall picture of how effective the game was in supporting students' flow experience in each gameplay condition. Table 4.10 showed more details, with information of the ranges of mean score for each subscale (average of all the items measuring each subscale) for all students across playing conditions as well as the number of students at each flow experience category.

Table 4.9

Descriptive Data for Game Flow Experience based on Playing Conditions (N=73)

Subscales	Solo (n=37)		Collaborative (n=36)		All (N=73)	
	Mean	SD	Mean	SD	Mean	SD
Attention focus	4.51	.48	4.36	.65	4.44	.57
Sense of control	4.20	.70	4.06	.76	4.13	.73
Loss of time and self-consciousness	4.03	.56	3.99	.51	4.01	.53
Autotelic experience	4.58	.53	4.63	.44	4.60	.49

Table 4.10

Number of Students in Each Flow Experience Category across Playing Conditions (N=73)

Subscales	Mean score range	Number of students		
		(1,3)	(3, 4)	(4, 5)
Concentration	3 to 5	0	9	64
Sense of control	1.33 to 5	6	11	56
Time distortion and Loss of self-consciousness	2.67 to 5	3	32	38
Autotelic experience	3 to 5	5	1	67

These results showed that, regardless of students' gameplay condition, the mean scores for all of the 4 flow experience subscales were greater than 4 based on a 5-point scale, indicating high game flow experience for students. Specifically, the mean scores for the two subscales of concentration and autotelic experience (4.44 and 4.60 respectively) were higher

than the subscales of sense of control and time distortion/loss of self-consciousness (4.13 and 4.01 respectively).

The results from the flow survey as presented above were supported by qualitative data from student focus group interviews. When asked about their general gameplay experience, all 10 students interviewed (5 of them solo players and 5 collaborative players) reported that they enjoyed playing the game. Specifically, students used words such as "enjoyed", "good" "comfortable", and "fun" to describe their feeling during gameplay. For example, one girl in the solo player condition commented that she felt happy even when she "messed it up" while playing the game because it provided very encouraging feedback (e.g., using language such as "nice try"). Besides, when asked to rate the CRYSTAL ISLAND game on a scale of 1 to 10, with a higher score meaning more positive attitude and feeling, all gave the game a score of at least 9; several gave it a 10. In addition, when asked to compare the CRYSTAL ISLAND game with other games that they have played before, all reported that the CRYSTAL ISLAND game was more fun than the games that they have played before.

Results from students' focus group interview responses also revealed what students did in the game that led to their enjoyable gameplay experience as reported above, providing valuable supplemental information that would otherwise have been impossible to collect in the flow survey. Specifically, students in the solo player condition mentioned that the treasure box (each time students answer a science question correctly, the treasure box opens up automatically and students receive sand dollars as rewards), taking pictures of different landforms, collecting and using sand dollars (to buy certain things such as films for the camera), and doing different science quests were the things that enjoyed most in the game.

The activity of taking pictures of landforms (and small animals on the island such as birds and turtles) using the camera was mentioned by two solo players (both girls); the "treasure box" was mentioned once by a girl; collecting and using sand dollars was mentioned by two students (one girl and one boy); and doing science quests were mentioned by three boys. Students in the collaborative player condition also mentioned the same things as solo players did. Specifically, the "treasure box" was mentioned by three collaborative players (two girls and one boy); "sand dollars" were mentioned by two students (one boy and one girl); taking pictures was mentioned by one girl; and doing the science quests was mentioned by two boys. In addition, one collaborative player (girl) mentioned that she liked the IslandPedia app and the tablets that were embedded in the game to help them with the playing / learning tasks (e.g., short text message application, and the map and other multimedia resources that were provided to scaffold student engagement and problem solving while they were doing a quest). Other dimensions/factors that students thought to have contributed to their enjoyable gameplay experience included the game design feature that the game was 3-D, and "educational" at the same time.

Besides these general comments about gameplay feeling and experience, the *a priori* coding results of students' responses (i.e., based on the flow experience subscales) also revealed more specific information about students' gameplay experience, helping to better understand students' self-reported feeling in the flow survey. First, students' self-reported high sense of concentration (mean score of 4.44 for all students across gameplay conditions) during gameplay was supported by their focus group interview responses. All 10 students interviewed reported that they paid all their attention to the game during gameplay because

the game was so much fun. Specifically, two girls in the solo player conditions reported that they were so focused on the game that they did not pay attention to other things around. For example, one of the girls commented, " I think it is so much fun that it is difficult for me to take my eyes off the screen…" There was also one boy in the solo player group who reported that he was not totally concentrated in the game at the beginning as it took him some time to get familiar with the playing rules. However, he also reported that once he got used to the game environment, he began to pay all his attention to the game. The interview data indicated that, regardless of playing conditions, students were able to be totally concentrated during gameplay. The only difference found between the two groups was that two students in the collaborative player condition reported that they were totally concentrated in the game only when they were the "drivers" (the one who drove the game characters). These two students reported that when they were "planners", they were more likely to turn around and look at other students' screen, consistent with my observations during the gameplay sessions.

As for the flow experience subscale of autotelic experience, students' interview responses were again consistent with their answers to the flow survey questions in that all of the 10 students interviewed reported that they enjoyed playing the game because it was very interesting and that they "felt very good" during gameplay. Students also commented that they enjoyed the game and they only "played the game for the fun of it", an indicator of their intrinsic motivation. Due to this enjoyable gameplay experience, they also expressed their desire to play the game again in the future.

For the flow experience subscale of sense of control, statistical findings from the flow survey revealed that the grand mean score was also greater than 4 for all students across the

two playing conditions, indicating that students felt a high sense of potential control during gameplay. This was also supported by students' focus group interview responses. All students in the focus group interviews reported that they felt in good control of their own playing actions, which was an indicator of high sense of control during gameplay. On the other hand, as the table above also shows, this grand mean (4.13) was a little lower than the means for the subscales of attention focus and autotelic experience. This could found its explanation in students' interview responses. Among all the students interviewed, 3 of the 5 solo players and all 5 collaborative players reported that, even though they were able to control their own playing actions, sometimes they felt "frustrated" that it was difficult to control the game characters. For example, one girl in the solo player group commented:

"It was easy for me to control myself but it was kind of hard to control the person (in the game) because when I pressed the arrow keys, it always went too far ahead… so I did not know how I can press and have it go as far and then stop…"

Finally, for the 4th new flow subscale of time distortion and loss of self-consciousness, its mean score was also greater than 4 (4.01), indicating that students had a high sense of time distortion and loss of self-consciousness during gameplay. Again, this could also be demonstrated in students' interview responses. For example, when asked specific gameplay experience as related to how they felt about time during gameplay, all 5 solo players in the focus group reported that they felt time went past by faster than usual. One solo player commented about his distorted sense of time by saying that, "…you were just having so much fun…and you felt like you have played for only 10 minutes…" All 5 collaborative players in the focus group also reported similar feeling. For example, one boy commented,

"When I was on the island talking to people and doing the missions, time went so fast that it is almost time to go and I got so mad…" Taken together, these statements showed that regardless of playing approaches, all students had a sense of time distortion when they were enjoying the game-based learning process.

For the other facet of loss of self-consciousness in this 4th flow experience subscale, 4 out of the 5 solo players in the focus group reported that they played the game just for the fun of it and that they did not have time to worry about things such as how he or she was doing in the game as compared with their peers. Students' responses also illustrated that flow experience in the CRYSTAL ISLAND game was categorized as the tendency to shut themselves off from the outside world and ignore other people around them. For example, when asked about what their reactions would be if someone next to them wanted to talk to them during gameplay, the phrase "zoned out" was used a couple of times by more than one student in the focus groups. One girl in the solo player group said, "I was so zoned out because I was having so much fun…people kept talking to me but I was not listening because I was so zoned out…" Another solo player also commented, "When I was doing CRYSTAL ISLAND, somebody talked to me…and I was just totally zoned out that I did not answer her…and she asked me 'are you going to answer me', and I said "what did you say"…I could not answer her because it (the game) was so cool…"

There was, however, one boy in the solo player group who reported that he was worried about how well he was performing in the game as compared with his peers at the beginning of the gameplay session. He said that he was worried when he saw the student next to him finish the tutorial earlier than him as well as when his neighbor got more sand dollars

than him. However, he added that he no longer worried about this as he played the game more because he was "having so much fun". This might partially explain why the grand mean for the flow experience subscale of time distortion and loss of self-consciousness was the lowest among all the 4 subscales.

Collaborative players' feeling towards the aspect of self-consciousness was similar in some way with that of solo players as reported above. For example, one boy in the collaborative players focus group said, "…I did not hear anybody because I was looking at the game and playing with it and looking at the controls…and finally a person next to me tapped at my shoulder, and it took me 20 seconds to look back at him." On the other hand, despite the similarities reported here, a comparison between solo and collaborative game players also revealed a slight difference between these two gameplay groups in that collaborative players were more likely to lose their self-consciousness when they were the game "driver". For example, one girl said she would not stop the game to talk with anyone around especially when she "did the control."

It is also important to note another issue that was revealed during the focus group interview data coding. As discussed earlier in the EFA results section, the flow survey results indicated that the concepts of time distortion and loss of self-consciousness were not distinctive enough for 5th graders. Students' focus group interview responses also revealed that, even though they did reported things that could be categorized as time distortion and loss of self-consciousness (e.g., they did not hear anyone talking), they did not seem to completely understand the differences between these two different concepts. For example, when asked about their feeling about time, one boy in the solo player group said, " It (time)

kind of went very fast because it is like there is no one around you… there is no time…and you are just having so much fun." When a student's response indicated that he or she shut him or herself off from the outside world (e.g., they felt there was no one around in the gameplay room), he or she was experiencing the feeling of loss of self-consciousness. However, this boy mentioned the sense of loss of self-consciousness when he was only asked about his feeling about time. Also, another girl said that she was not worried about how well she was doing in the game; however, she explained that she had this feeling only because she knew "it was not a competition" (instead of reporting that it was because she was so into the game). Again, this might be due to their limited understanding of the concept of self-consciousness. Of course, this needs to be validated in future studies (especially with a larger sample size).

Besides the descriptive data reported above, detailed results based on the statistical analyses that were conducted to answer the two sub-questions of research question one are presented in the following sections.

Gender and flow experience. Preliminary univariate analyses of variances were conducted to examine whether gender differences existed on any of the 4 dependent variables (4 flow subscale mean scores). Results revealed that the effect of gender on the flow subscale of time distortion/loss of self-consciousness was only approaching significance, F (1, 71)=3.63, p= .061, with girls reporting a slightly higher sense of time distortion/loss of self-consciousness (M=4.13, SD= .45) than boys (M=3.89, SD= .58). The effect of gender on the flow subscale of autotelic experience was also approaching significance (F (1, 71)=3.67, p= .06), with girls reported a higher level of autotelic experience (M=4.71, SD= .41) than

boys (*M*=4.50, *SD*= .53). There was no a main effect for gender on the other two flow subscales (attention focus and sense of control). As reported earlier, students' focus group interview responses also failed to reveal any flow experience difference based on gender. Basically, girls and boys both reported high sense of concentration, self-control (even for the control of in-game characters, girls and boys reported similar feelings), time distortion and loss of self-consciousness, and autotelic experience.

Reading proficiency and flow experience. Simple regression analyses were conducted to examine the relationship between students' reading proficiency score (measured on a 4-point scale) and each of the 4 flow subscales. Results revealed that students' reading proficiency significantly predicted students' autotelic experience, R^2= .07, β = .13, t = 2.35, p = .02. It was also revealed that the effect of reading proficiency on students' attention focus was approaching significant, R^2= .05, β = .13, t = 1.86, p = .066. The effect of reading proficiency on students' sense of time distortion/loss of self-consciousness was also approaching significant, R^2= .05, β = .12, t = 1.83, p = .07.

Prior gaming experience and flow experience. Simple regression analyses were also conducted to examine the relationship between students' prior gaming experience and each of the 4 flow subscales. Results revealed that prior gaming experience did not predict any of the flow subscales.

Gameplay condition and flow experience. Next, analysis was conducted to examine flow experience differences based on the two different gameplay conditions. Based on the (marginally) significant effect of reading EOG score and gender on several of the low experience subscales revealed previously, an 2(Gameplay condition: solo and collaborative

players) *2(Gender: male and female) MANCOVA analysis controlling for the effect of reading EOG scores was conducted. The Levene's test indicated that the assumption of homogeneity of variance was not violated, $p>.05$. The results failed to reveal a main effect for gameplay condition. Again, as reported earlier, students' focus group interview responses also did not reveal much flow experience differences based on playing conditions. The only difference revealed in students' interview responses and reported previously was that students in the collaborative player group said they were more likely to be concentrated and have a high sense of time distortion/loss of self-consciousness when they were the game "drivers" instead of "planners". The statistical analysis failed to reveal a main effect for gender. However, a significant main effect of reading EOG score on the flow subscale of autotelic experience was revealed, $F(1, 68) = 4.21$, $p= .04$, partial eta squared = .06. Reading EOG score did not have a main effect on the other three flow subscales. No interaction between playing condition and reading EOG score was revealed.

Summary of finding for research question one. Overall, both the flow survey and focus group interviews demonstrated that most students experienced a high level of flow experience in the game-based science learning environment. However, students' flow experience did not differ based on gameplay conditions. Results indicated that students' reading proficiency did significantly impact their game flow experience, but gender and prior gaming experience did not have a significant impact on students' game flow experience.

Findings for Research Question Two

The second research question of this study was: What and how did different factors (i.e., game design features and peer interaction during gameplay) impact students' game flow

experience? In the following sections, both descriptive and statistical analyses findings are reported and compared with qualitative data from the focus group interviews.

Descriptives. Table 4.11 showed the mean and standard deviation of each of the 6 flow antecedents. These results (mean score of approaching or greater than 4 on a 5-point scale) indicated that students thought that the game was designed with desirable features.

Table 4.11

Descriptive Data for Flow Antecedents (N=73)

Flow antecedents	Mean	Std. Deviation
Challenge/skill balance	4.15	.56
Clear goal	4.04	.63
Immediate / useful feedback	3.82	.68
Playability	4.03	.65
Gamefulness	3.95	.56
Frame story	4.14	.54

As shown in the table, a mean score of 4.15 on a 5-point scale indicated that the challenge level of the game tasks was appropriate for the students. Students in the focus groups also reported that they liked the game because "it was in the middle" (meaning that it was neither too difficult nor too easy for them). This meant that there was an appropriate balance between the challenge provided by the game and students' perceived skills, supported by both quantitative and qualitative data. Besides, students in both gameplay conditions also reported that their skills improved on the second day of the gameplay, which helped them to meet the new and higher level challenges in the game.

As for the game design feature of clear goals, even though results from the flow survey indicated that students knew pretty clearly about the goals of the game (a mean score of 4.04 on a 5-point scale), their focus group interview results were not completely consistent. When asked students what they thought the goal of the game was (e.g., why they were doing all those missions in the game), most students (solo and collaborative players) either hesitated or said that they just wanted to complete the quests. Only three students (two collaborative players and one solo player) were able to articulate that the goal of the game was to help the people on the island and to get better in science content. In the follow-up questions that asked them how they knew the goals of the game, students mentioned that the game background story video presented to them before gameplay was very helpful.

For the game design feature of clear and immediate feedback, an overall mean score of approaching 4 also indicated that students perceived this to be a desirable feature of the game. When asked whether they thought the game did a good job in telling them when they did something right or wrong, all students in the focus groups gave a positive answer. Specifically, as reported earlier, some students reported that they enjoyed CRYSTAL ISLAND because the feedback provided by the game was very encouraging. For example, one student in the solo player group commented that, "… When you get the answer right, it says excellent…and if you get it wrong, it says try again later…" Two other students in the collaborative player group explicitly explained that they would give the CRYSTAL ISLAND game a 10 on a rating scale of 1 to 10 because the game told them when they did something wrong.

The focus group interviews also revealed that students easily learned how to play the game and that they quickly understood the playing rules without any difficulty, an indicator of good playability of the game. This was also consistent with findings from the flow antecedent survey items (a mean score of greater than 4), as shown in the table above. All 10 students interviewed reported that the game tutorial was very helpful in teaching them how to play the game, including how to use different keyboard combinations and shortcuts to control the game characters.

For the game design feature of gamefulness, a mean score of very close to 4 (3.95 exactly) also indicated that this was a desirable feature of the CRYSTAL ISLAND game design. Actually, when students were asked about their general gameplay experience and why they had such feelings, both solo and collaborative players mentioned features that could be categorized as high gamefulness. For example, one boy in the solo player group reported that the CRYSTAL ISLAND game was more fun than other games that he had played before because "it had different levels", meaning that the game was nonlinear—an important feature of high gamefulness. Another girl in the collaborative player group also said that she enjoyed playing the CRYSTAL ISLAND game because she could use the sand dollars (earned external in-game rewards) to buy things she needed, another indicator of high gamefulness. Besides, when asked other more direct and specific questions about gamefulness (e.g., whether they were able to play the game in different ways), all students interviewed gave a positive answer as well.

The high mean score for game frame story was also supported by students' focus group interview responses. It was apparent from students' responses that they enjoyed the

game background story video presented to them on the big screen right before they started the game tutorial. As reported earlier, students from both focus groups said that the game background story was not only very "cool" but also very helpful in telling them what happened in the game and what they needed to do.

Finally, for students' perception of their peer interactions during gameplay, which had a mean score of 4.21 based on students' self-reports in the flow survey, results from the collaborative player focus group interview were mixed. Specifically, some students reported that they enjoyed playing the Crystal Island game because they got to play with a partner and this allowed them a chance to help each other, but some others did not think the same way. There was one girl who reported that she felt her partner was "kind of annoying" because they constantly disagreed on gameplay actions and decisions. Besides, when asked whether they would like to play with a partner in the future, 2 students said they would like a different partner. Also interestingly, all 5 collaborative players said that actually they would rather be a "shark" (solo player) because they thought playing individually was "faster" than when they had to "tell their partner what to do".

To examine how each of these game design features as reported above impacted students' game flow experience, I ran separate multiple regressions. The goal was to examine whether the 6 game design factors significantly predicted each of the 4 game flow experience subscales. The results are presented in the following sections and were organized based on each flow subscale.

Game design features and attention focus. Results of the multiple regression showed that the 6 flow antecedents/game design features explained 30.4% of the total

variance in student attention focus (R^2= .30, F (6, 66)=4.81, p < .01). It was also found that challenge/skill balance significantly predicted students' attention focus (see Table 4.12). The importance of the balance between challenge and perceived skills was supported by students' focus group interview responses. When asked about general gameplay questions such as other games that they had played before and what they liked about those games, five students (two collaborative and three solo player) mentioned the challenges provided by the game. For example, when asked to rate the game they played before on a scale of 1 to 10, a boy in the solo player group said that the game was fun but he would only give it a 6. He explained this by saying that, "… I know I said I like challenges…but it can get really frustrating…" When asked to compare the CRYSTAL ISLAND game with the game he mentioned, he said that the CRYSTAL ISLAND game would definitely be a 10 because it was not too difficult. Similarly, a boy in the collaborative player group commented, "I think it (the CRYSTAL ISLAND game) would be a little bit better than my game because usually I get frustrated when it gets too difficult but this game I don't get frustrated". Moreover, when asked more specific questions about the challenges provided by the CRYSTAL ISLAND game, all students interviewed agreed that this was a very important reason why they had the enjoyable gameplay experience.

Table 4.12

Multiple regression of game design features on students' attention focus

Variables	B	t	Sig. (p)
Challenge/skill balance	.29	2.26	.027
Playability	.10	.98	.33
Gamefulness	.21	1.64	.11
Clear goals	.05	.38	.71
Immediate and unambiguous feedback	.08	.81	.42
Game frame story	-.003	-.02	.98

Game design features and sense of control. Results of the multiple regression showed that the 6 flow antecedents/game design features explained 44.5% of the total variance in students' sense of control (R^2= .45, F (6, 66)=8.83, p < .01). It was also found that the playability of the game significantly predicted students' sense of control during gameplay (see Table 4.13). In the focus group interviews, even though students did not mention things related to the concept of playability when they were asked general prior gameplay experience, they did reported that it was easy for them to understand the game on the screen (i.e., interface design) and learn how to play the game. This, according to the students, was also very important for their enjoyable gameplay experience in the CRYSTAL ISLAND game environment.

Table 4.13

Multiple regression of game design features on student sense of control

Variables	B	t	Sig. (p)
Challenge/skill balance	.09	.63	.53
Playability	.48	4.02	.00
Gamefulness	-.02	-.16	.87
Clear goals	.18	1.37	.18
Immediate and unambiguous feedback	.10	.91	.37
Game frame story	.24	1.60	.11

Game design features and time distortion/loss of self-consciousness. Results of the multiple regression showed that the 6 flow antecedents/game design features explained 41.1% of the total variance in students' sense of control (R^2= .41, F (6, 66)=7.68, p < .01). The game design features of gamefulness and game background story both significantly predicted students' sense of time distortion and loss of self-consciousness during gameplay (see Table 4.14).

Table 4.14

Multiple regression of game design features on time distortion and loss of self-consciousness

Variables	B	t	Sig. (p)
Challenge/skill balance	.13	1.13	.26
Playability	.01	4.02	.92
Gamefulness	.23	2.11	.04
Clear goals	.09	.84	.40
Immediate and unambiguous feedback	.05	.62	.54
Game frame story	.30	2.65	.01

The impact of gamefulness on students' enjoyable gameplay experience was also reflected in their focus group interview responses. For example, as mentioned earlier, when students were asked what they liked about the CRYSTAL ISLAND game and what they did in the game that they thought was fun, both solo and collaborative players mentioned aspects related to the concept of gamefulness. For example, two solo players mentioned that they liked the CRYSTAL ISLAND game because it had different levels and that they could buy stuff using the external rewards (i.e., sand dollars). These two things, both are features of a game with high gamefulness, were also emphasized by another two collaborative players. Student focus group interview data also supported the quantitative results in that students in both gameplay conditions mentioned that the game background story video was very interesting and that was also one of the reasons why they found the game to be engaging and fun.

Game design features and autotelic experience. Results of the multiple regression showed that the 6 flow antecedents/game design features explained 35.4% of the total variance in students' sense of control (R^2= .354, F (6, 66)=6.04, p< .01). It was also found that the playability of the game (β = .19, t = 2.23, p = .029) and game frame story (β = .31, t = 2.87, p = .006) both significantly predicted students' sense of autotelic experience during gameplay. Qualitative focus group interview data also revealed that students considered these two features of game design to be very important. Like playability of the CRYSTAL ISLAND game as discussed above, students also reported in the focus group interviews that the game has a very interesting and engaging background story, which they believed was also one of the reasons they enjoyed the game.

Table 4.15

Multiple regression of game design features on students' autotelic experience

Variables	*B*	*t*	Sig. (*p*)
Challenge/skill balance	.19	1.78	.08
Playability	.19	2.23	.03
Gamefulness	-.06	-.55	.59
Clear goals	.07	.71	.48
Immediate and unambiguous feedback	-.08	-1.00	.32
Game frame story	.31	2.87	.01

Peer interaction and flow experience. For students in the collaborative gameplay condition, simple regression analyses were conducted to examine whether their perception of peer interaction during gameplay impacted their flow experience (4 simple regression analyses were conducted, one for each flow subscale). Results showed that students' perception of peer interaction did not predict any of the 4 flow subscales. However, when students' reading EOG score was added to the regression model, the multiple regression (with perception of peer interaction and reading EOG score as two predictors) results revealed that students' peer interaction and reading EOG score combined explained 14% of variance in students' sense of time distortion/loss of self-consciousness (R^2= .14, F (2, 33)=2.68, *p*= .08). It was also found that the impact of peer interaction on students' sense of time distortion and loss of self-consciousness was approaching significance, β = .41, t = 1.90, *p* = .066. Again, as discussed previously, peer interaction was also emphasized by a couple of students in the collaborative player focus group interview, even though students' perceptions of peer interaction during gameplay were not always positive.

Summary of findings for research question two. The results revealed that the CRYSTAL ISLAND science learning game was well designed with fairly good features, as showed in student responses to the flow antecedent questions and their focus group interviews. These game design features had a positive impact on students' game flow experience. Beside, students' perception of peer interactions during gameplay also had marginally significant impact on their game flow experience.

Findings for Research Question Three

The 3rd research question of this study was: How did different students' game flow experience impacted students' science content learning and science learning attitude changes?

Originally, it was proposed that flow experience would be divided into 3 levels (i.e., low, medium, and high flow experience levels) to examine whether differences existed in students' science content learning gains and science learning attitude changes based on different flow experience levels. However, the analysis results revealed that the majority of students had high flow experience (over 4 on a 5-point scale; see the findings for research question one above) and very few of them had low flow experience. Since there was such a big difference in the subgroup sample sizes, it did not make sense to look at flow experience as 3 different levels. Therefore, each of the flow experience subscales had to be treated as an interval variable. Based on this decision, the 4 flow experience subscales were used as independent variables to examine how they predicted students' science content learning gains and science learning attitude changes (residual gain scores; see discussion previously).

In the following sections, findings of the relationship between flow experience and science content learning gains and science learning attitude changes are reported.

Science content learning gains. First, to examine group differences in science content learning gains from pre- to post-test, as indicated by increases in correct responses to the 26 test items, a 2 (Condition: single player, collaborative) x 2 (Time: pre, post) repeated measures analysis of variance (RM-ANOVA) was conducted. The RM-ANOVA revealed a main effect of test, indicating that students demonstrated significant increases in correct responses to the content test from pre- ($M = 14.64$, $SD = 4.97$) to post-test ($M = 15.74$, $SD = 5.41$), collapsed across playing condition F (1,71) = 5.26, $p = .03$, partial eta squared = .07. Meanwhile, the RM-ANOVA failed to reveal a main effect of condition, indicating that the single player ($M = 15.24$, $SD = 5.63$) and collaborative players ($M = 16.25$, $SD = 5.21$) did not differ significantly in terms of learning gains from pre- to post-content-knowledge test, F (1, 71) = .01, $p = .93$, partial eta squared = .00.

Flow experience and science content learning gains. Next, residual gain scores from pre to post science content test for all students were calculated. A multiple regression analysis was then conducted to examine how flow experience predicted science learning gains (residual gains). Results indicated that, among the 4 flow subscales, the effect of the flow subscale of sense of control on students' residual science learning gains was approaching significant, b=-1.40, t (68)= -1.91, p= .06, meaning that students who felt a higher level of sense of control actually tended to have lower content learning gains. The effect of the other 3 flow subscales did not significantly predict science content learning gains.

Science learning attitude change. To examine how flow experience impacted students' science learning attitude changes, the same procedures as described above were

gone through**.** First, to examine group differences in science learning attitude changes from pre- to post-surveys, a 2 (Condition: single player, collaborative) x 2 (Time: pre, post) repeated measures analysis of variance (RM-ANOVA) was conducted. The RM-ANOVA failed to reveal a main effect of test, meaning that students across the two gameplay conditions did not show changes in their science learning attitude. The RM-ANOVA also failed to reveal a main effect of gameplay condition or the interaction between time and gameplay condition.

Flow experience and science learning attitude change. Again, after the RM-ANOVA, residual gain (change) scores from pre to post science learning attitude survey for all students across the two gameplay conditions were calculated. A multiple regression analysis was then conducted to examine how flow experience predicted science attitude changes (residual gains/changes). Results indicated that none of the 4 flow subscales significantly predicted students' science learning attitude changes.

CHAPTER FIVE: DISCUSSION

This study used an embedded mixed method design to answer the following three research questions:

- To what extent did 5th graders in an urban elementary school in the Southeastern U.S experience game flow while playing the CRYSTAL ISLAND game, as reflected in the flow scale and focus group interview?

  - What were the differences in students' game flow experience based on two different playing approaches (solo and face-to-face collaborative playing)?

  - What were the differences in students' game flow experience based on individual differences?

- What and how did different factors (game design features and peer interaction) impact students' game flow experience?

- What was the impact of students' game flow experience on their science content learning gains and science learning attitude changes?

The final sample included 73 5th graders who completed all of the pre and post measures, including the science content test, science learning attitude survey, and the adapted game flow survey. The adapted game flow survey queried students about their self-perception of their emotion and subject gameplay experience in the game-based science learning environment. The flow survey also included items to examine students' perceptions of major game design features as well as their perceptions of peer interaction during collaborative gameplay. In chapter four, I first addressed issues related to reliability and validity for the adapted game flow survey and the science learning attitude survey. This was

followed by detailed presentation and comparison of the results from the surveys and focus group interviews, which answered all the 3 research questions guiding this current study.

In this chapter, I first discuss findings reported in the previous chapter, including findings from the survey validation processes and their implications. Following this, the discussion is organized into three main sections based on the three research questions: (a) flow experience in the CRYSTAL ISLAND game environment; (b) impact of key game design features as well as students' perceptions of peer interactions on their game flow experience; and (c) relationship between flow experience and science learning outcomes as measured by students' science content learning gains and changes in their attitude towards science. Recommendations for future research and implications for educational game designers, researchers and classroom teachers are also proposed where appropriate.

Validation of Adapted Flow Survey and Science Attitude Survey

Validation of Adapted Flow Experience Survey

Overall, findings from the validation analyses of the adapted game flow survey, including the EFA analysis results and the descriptive data such as reliability for each subscale, item-total correlation, and inter-item correlation, indicated that the adapted survey provided an acceptable measure of 5th graders' flow experience in the game environment. On the other hand, some problematic items were also identified during the validation process, indicating that these items warrant further work. Specifically, for the 15 adapted items measuring students' flow experience, one item in the subscale of attention focus had double loading on two factors, with higher loading on the non-theorized factor. Two other items in the subscale of time distortion and loss of self-consciousness also had double loading, even

though both with higher loading on their respective theorized factor. Besides, for the 18 adapted items measuring the 6 game design features, 3 items were also identified as problematic. These included one item in the subscale of unambiguous feedback that had double loading on two factors, with higher loading on the non-theorized factor, and one item from the subscale of clear goals that also had double loading (even though with higher loading on the theorized factor). There was also an item in the subscale of unambiguous feedback that had a loading value of greater than 1. There might be several reasons for these results (e.g., the analyses were based on a small sample size, and there were only 3 items measuring each subscale). It might also be possible that the items themselves were problematic (e.g., unclear wording). These findings indicated that the adapted survey needs to be further explored and that future work is warranted.

The validation results also revealed that flow experience was not represented in the same way for students in different age groups. Theoretically, flow experience for adults (e.g., college students) consists of 5 dimensions, including total concentration, sense of control, time distortion, loss of self-consciousness, and autotelic experience. However, results from the exploratory factor analysis indicated that flow experience in the game-based learning environment did not function as theorized for younger populations (i.e., 5th graders). Only 4 dimensions of flow experience were identified from the exploratory factor analysis. There are a few reasons as to why this may have happened. First, while the concepts of time distortion and loss of self-consciousness were distinct for older students (e.g., college students), students in this current study might be too young to clearly differentiate between the two

concepts. As discussed in the previous chapter, this was also supported by data from students' focus group interview.

In fact, both the EFA analysis and the focus group interview results were different from students' written responses to the open-ended question at the end of the flow survey. For the question "how did you feel when you were playing the CRYSTAL ISLAND game", many students wrote about feelings that could be categorized as loss of self-consciousness. For example, students wrote that playing the CRYSTAL ISLAND game helped them "forget about unhappy things in my life" and that they "still enjoyed playing the game even when they were unhappy." At first look, it seemed that students understood the concept of loss of self-consciousness; however, closer examination of the flow survey items and students' written responses revealed that the language used in the flow survey questions might have possibly influenced students' written responses. For example, one Likert-scale item in the flow survey asking students about the feeling of loss of self-consciousness was " When I was playing the CRYSTAL ISLAND game, I forgot about unhappy things in my life." Therefore, it was highly possible that even if students did not clearly understand the concept being asked, they were able to express it in an accurate way. Nevertheless, it was also possible that some students did understand the concept of self-consciousness. Therefore, this issue warrants further exploration.

Secondly, as was also mentioned earlier, the study was based on a relatively small sample size (n=73) and this might have impacted the results of the EFA analysis. Researchers have pointed out that in order to produce reliable and stable EFA results, a relatively large sample size is needed (e.g., Dewinter, Dodou & Wieringa, 2009). As a result, this adapted

survey needs to be further validated with a larger sample size (e.g., the conventional 1: 10 ratio) to see how the results would be potentially different.

Third, the number of items used to measure each of the 5 theorized flow experience subscales was very small (only 3 items each), which might also have prevented the EFA analysis to yield stable results. This indicates that more items need to be written and developed for each flow experience subscale.

Fourth, it might be possible that the wording of the items, especially items measuring the dimensions of time distortion and loss of self-consciousness, was confusing for students to understand what was being asked. As mentioned earlier, some items from these two original flow subscales had double loading. This might also have impacted the EFA analysis results.

Validation of Science Attitude Survey

The validation analyses of the science learning attitude survey also produced similar results with the validation results for the adapted flow experience survey in that some poor items were identified and that the construct of science learning attitude did not have exactly the same number of dimensions for students in this present study. The overall findings, including data from the reliability and correlation analyses indicated that the science learning attitude provided an appropriate measure of 5th graders' science learning attitude, supporting the claims made by the authors who developed the survey (Weinburgh & Steele, 2000). In this current study, however, the validation process also identified some problematic items that need to be further explored. These included 6 items that demonstrated non-normal distributions and had very low correlations with other items in the same subscale. Also

identified as problematic were several other items that had double loading on more than one factor, including 2 items in the subscale of anxiety about science and 1 item in the subscale of self-concept of science (see Chapter 4 for details). In the final EFA output, there was also one item in the subscale of desire to learn science that had a loading value of over 1. Again, these results indicate that further work is warranted for these items.

Meanwhile, findings from this current study also revealed one major difference from the results of a previous study conducted by the creators of this survey. As reported earlier, the EFA analysis only extracted 4 dimensions for the science learning attitude survey instead of the theorized 5 dimensions. Specifically, items measuring the subscales of anxiety about science and self-concept of science loaded on the same factor. It is important to note that the science learning attitude survey administrated to the 5th graders in my study was the same as the original survey, in that the items were not reworded since the original survey was developed to be used with K-5 students and the readability was also within appropriate range as demonstrated by the authors. There might be several similar reasons as were discussed earlier. For example, like the adapted flow experience survey, my sample size was too small to produce stable EFA results. Taken together, the findings indicate that the validity and reliability of the science learning attitude survey also needs to be explored extensively in future studies. Future studies with a larger sample size might be particularly helpful in validating the survey.

Flow Experience in the Crystal Island Game Environment

In the following sections, findings related to research question one are discussed. Specifically, I discuss students' overall game flow experience while interacting the Crystal

ISLAND game, and the impact of different gameplay conditions and students' personal characters (i.e., gender, reading proficiency, and prior gaming experience) on their flow experience.

Effectiveness of the CRYSTAL ISLAND Game in Supporting Flow Experience

Overall, the results revealed that the CRYSTAL ISLAND game was able to arouse students' game-based learning interest, in that most of the students in the focus group interviews reported that the game was both "educational" and "fun." The adapted game flow survey provided a more direct measure of students' self-perception of their gameplay experience. The fact that all of the 4 flow experience dimensions had a mean in the high range (e.g., greater than 4 on a 5-point scale) indicated that the CRYSTAL ISLAND game afforded the students an enjoyable game flow experience. This was confirmed by the qualitative data derived directly from student focus group interviews. The focus group interviews helped to understand students' responses to the flow survey questions by providing more in-depth information related to how exactly they felt while they played the game as well as what they thought had contributed to or impeded their enjoyable gameplay experience.

These findings were consistent with results from previously published game flow studies. For example, in their game flow experience studies with college students (Kiili, 2005) and elementary students (Inal & Cagitay, 2007), the authors found that students, regardless of their age and grade levels, experienced flow during gameplay. Findings from this current study also supported the claim that flow experience is very likely to occur during the course of positive human-computer interactions in the computer-mediated environments, including

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in the virtual game environment. In addition, this present study also extended our bigger understanding of game flow experience with upper elementary school students by collecting and analyzing data from two different sources (i.e., survey and focus group interviews). In particularly, the focus group interviews produced data that helped to confirm and understand student responses to the survey questions, thus leading to a more holistic picture of student gameplay experience and reactions.

To reiterate, students in this study had the highest mean for the dimension of autotelic experience, and this was supported by their focus group interview data. This indicated that students experienced a high level of enjoyment while they were playing the CRYSTAL ISLAND game and that this enjoyment was driven by their intrinsic motivation derived from playing the game as opposed to being driven primarily by extrinsic motivators such as external rewards. This finding has important implications in that intrinsic motivation is one important reason for students' continuous engagement in learning.

Students' subjective gameplay experience in the CRYSTAL ISLAND game environment was also characterized as complete attention focus on the game, supported by both a high mean score (greater than 4) for this subscale and students' focus group interview statements that they were so focused on the game that they could not move their eyes away from the computer screen. A mean in the high range (greater than 4) for the subscale of time distortion and loss of self-consciousness also indicated that students forgot about time and that their sense of self seemed to disappear when they experienced the peak moment of engagement during gameplay. The statements provided by students during the focus group interviews also revealed that one of the most significant characteristics of the experience of time distortion

and loss of self-consciousness was students' tendency to ignore other students (e.g., not feeling like to stop the game to response to their peers' questions) when they were enjoying playing the game.

Finally, although the statistical data indicated that students felt in pretty good control of their own playing actions in the game, data from the focus group interviews also revealed other very useful information related to additional aspects of game control. In particular, students' interview responses indicated that experiencing difficulty in controlling the game characters and moving around freely in the game environment negatively impacted their enjoyable gameplay experience. This finding is very important in that it implies that the sophistication of character control in the game environment needs further development. Since this supplementary information would never have been found with a pure quantitative study, it also suggested that future studies of students' game flow experience could benefit from a mixed method research design.

Impact of Gameplay Approaches on Flow Experience

Findings from both the statistical analysis of the adapted flow survey and students' focus group interviews failed to reveal game flow experience differences based on playing conditions. In short, students in both the solo and collaborative gameplay conditions experienced high flow experience, as supported by the quantitative and qualitative data sets. However, students' oral statements that they were more concentrated in the game when they were game "drivers" indicated that playing the game individually might have some potential benefits in terms of supporting playful learning experience. However, as pointed out previously, the conclusions were made based on data from a small sample of 5th graders and

so might not be readily generalizable to other populations (e.g., different age groups) or other research contexts. Since the issue of collaborative gameplay and its impact on students' learning experience in the game environment has rarely been explored, more research in this area is needed to contribute to a better understanding of the issue. Research in this field is important because it might provide potential empirical data that will help educators and researchers to better understand under what contexts (e.g., gameplay approaches) gameplay could better facilitate student engagement and enjoyment. It will also provide information that will help teachers who want to incorporate game-based learning in their classrooms with their decision making process (e.g., whether students should play the game individually or collaboratively). For example, if future studies confirm that collaborative gameplay is not more effective than solo gameplay, then teachers would decide to go with solo gameplay since collaborative gameplay involves more complex procedures (e.g., extra steps in student assignment and facilitating of the collaborating process).

Impact of Student Characters on Flow Experience

Besides the impact of gameplay conditions, this study also examined student personal characters and potential impact on their game flow experience in the CRYSTAL ISLAND game environment. Variables examined included student gender, prior gaming experience, and reading proficiency as measures by reading EOG scale scores (on a 4-point scale).

As for the impact of gender on game flow experience, findings from this current study were contradictory to existing studies. For example, in a qualitative game flow experience study with 3rd graders, Inal and Cagiltay (2007) observed that boys were more focused than girls during gameplay. In contrast, this study found that gender had a marginally

significant impact on the flow experience subscales of autotelic experience and time distortion and loss of self-consciousness, with girls receiving a higher mean score for both of these two subscales. Besides, gender was not found to have significant impact on students' flow experience subscales of attention focus (or sense of control).

One possible explanation for the differences revealed here was related to the research design and data collection instruments used. In the study of Inal and Cagiltay (2007), students' flow experience data was collected by using structured interviews based on the game flow survey developed by Kiili (2005) as well as by using field observations. However, in my study, data was obtained from statistical analysis of the flow survey results and students' focus group interviews, neither of which revealed flow experience differences based on gender. Preliminary findings from this current study implied that the CRYSTAL ISLAND game was effective in supporting all students' flow experience, regardless of their gender.

On the hand other, since statistical analysis revealed that girls in this study had a higher average score for the flow experience subscales of autotelic experience and time distortion / loss of self-consciousness, possibly because girls prefer games with a rich frame story such as CRYSTAL ISLAND while boys might find other types of games such as action / adventure games more appealing, the impact of gender on students' gameplay experience warrants more exploration. In particular, since this quantitative finding was not confirmed by student focus group interview data, the issue of whether (and why) the game had a different impact on student playing experience deserves future exploration.

Note that the impact of students' ethnic background (i.e., race) on their game flow experience was not examined because most of the students reported that they were White Americans and very few belonged to other ethnic groups (see Chapter 3). Therefore, it did not make sense to conduct ANOVAs to examine group difference in flow experience based on race. However, data from student focus group interviews indicated that flow experience did not differ based on race, supported by the evidence that all students, regardless of their race, provided statements showing that they all experienced high flow experience during gameplay.

The statistical data from the adapted flow survey also did not reveal a significant impact of students' prior gaming experience on their self-reported flow experience in the CRYSTAL ISLAND game environment, indicating that the game was able to support students' enjoyable science learning experience, no matter they had much prior experience with gameplay or not. This might also indicate that the occurrence of flow experience in the game experience does not depend on how much prior experience the players have had.

However, students' reading proficiency was found to be an important indicator of their flow experience, with students with higher reading proficiency reporting a higher level of flow experience, especially for the subscale of autotelic experience. This was not surprising in view of the fact that the CRYSTAL ISLAND game is a narrative-centered science learning game which requires students to have a certain level of reading proficiency in order to understand the in-game written instructions and resources provided to assist them with the quests.

On the other hand, I had expected that there might have been an interaction between reading proficiency and gameplay approaches. Specifically, I had assumed that students with lower reading proficiency might benefit from playing with a partner (e. g., getting help from a peer), which might in turn enable them to experience a higher level of game flow than they would if they played individually. It was also assumed that the flow experience of students with higher reading proficiency might be negatively impacted by having to play with a partner. These prior assumptions were not supported by the findings. As reported in the statistical results, the analysis failed to reveal an interaction between these two variables. Nevertheless, the findings, especially the finding that reading proficiency had a positive impact on students' flow experience, are very important because it implied that educational game designers should take into account students' language ability with an effort to provide students with different language proficiency levels a highly enjoyable virtual learning experience. This also implies that appropriate scaffolding is necessary to better facilitate student engagement in the virtual learning environment, especially for those with lower or limited reading proficiency.

Again, for similar reasons that were discussed previously, the findings might not be generalized to other contexts or populations. To further explore this issue, an additional series of empirical studies are clearly needed. Research in this area is especially important since no previous literature exists that have examined the relationship between reading proficiency and flow experience in the game environment, even though there have been some studies which examined the impact of gameplay on students' learning outcomes such as language development. Also worthy of further investigation is an examination of how

students' ability to read and comprehend information and resources presented in a multimedia format in the game (e.g., graphics and explanatory video clips) impact their gameplay experience. The CRYSTAL ISLAND game incorporates a great deal of such reading materials; however, students' reading ability was examined only in terms of their reading EOG scores, one limitation of the current study. As reading in an online or virtual environment becomes more popular, research in this area will greatly contribute to literature in the field.

Impact of Game Design and Peer Interaction on Students' Flow Experience

The second research question asked about key game design features and their impact on students' flow experience. Also examined was student perceptions of their peer interaction during collaborative gameplay and how this impacted students' game flow experience. In the following sections, findings related to this research question are discussed.

Student Perceptions of the CRYSTAL ISLAND Game Design Features

Overall, the statistical data revealed that all 6 game design features had a mean of greater than or approaching 4 on a 5-point scale, indicating that the game was perceived by the 5th graders to be well designed with desirable features. Students' statements in the focus group interviews supported the quantitative findings in general, even though some slight differences were also revealed, as reported previously in Chapter 4.

In particular, for the game design features of a balance between challenge and perceived skills, gamefulness, and game frame story, both statistical and qualitative data was consistent. The findings that the mean for each of these three factors were all very close to or greater than 4, meaning that these were all desirable features of the game, were supported by

students' focus group interview statements. For the other 3 game design features, including clear goals, unambiguous feedback, and playability, data from the two sources were not entirely consistent.

For example, for the game design feature of clear goals, even though the mean was over 4 (4.04) on a 5-point scale (in the high range), most students reported during the focus group interviews that they felt "confused" at some point about the goal of the game. There might be at least two reasons as to why this was the case. First, it might be that the students in the focus group interviews might not be representative of all student participants. It might also imply that the CRYSTAL ISLAND game needs to be further developed to provide a clearer overarching goal for all players (Note: The CRYSTAL ISLAND game currently is still under development and refinements are still being made).

Similarly, for the game design feature of unambiguous feedback, it was unexpected that findings from the statistical data would differ from the qualitative interview data. While the mean for unambiguous feedback was the lowest among all 6 game design features examined in the survey, students' oral statements indicated that several of them spoke highly of this feature of the CRYSTAL ISLAND game. For example, some students mentioned that they enjoyed the game because the feedback provided by the game was very encouraging and clear. Again, this might be due to the same reason that was mentioned above for the design feature of clear goals. For example, students in the focus group interviews were not representative of all students, or that the game still needs to be further refined so that the feedback provided would be effective for all students. It might also be possible that students did not really know or understand that the encouraging comments provided by the game were

called "feedback" (the word I used in the interview questions), and so they scored it low on the adapted game flow survey. This implied that the interview questions might need to be revised or reworded.

Finally, for the game design feature of good playability, even though a mean score of 4.03 indicated that this was also perceived by the students to be a desirable feature of the game, data from the focus group interviews revealed some additional game playability features that need to be improved. Specifically, as reported in the previous chapter, some students commented that they felt frustrated with the game character control and movement in the game. Therefore, this is a limitation of the game design and improving this feature will potentially provide students with an even better playing experience.

Impact of Game Design Features on Flow Experience

In terms of factors predicting students' game flow experience, the regression analyses revealed that all but 2 of the 6 game design features examined in the flow experience survey significantly predicted students' flow experience. These included a balance between challenge and perceived skills, playability, gamefulness, and game frame story. Among these four predictors, a balance between challenge and skills, and gamefulness, received most emphasis and were mentioned by the students most frequently in the focus group interviews than the other factors (see Chapter 4), indicating that these might be the most important and desirable game design features that game players look for.

In short, findings from this current study were consistent with existing studies in that the game design features of a balance between challenge and perceived skills, playability, and gamefulness were also found by other researchers to significantly predict flow

experience in the computer-mediated learning environments, including in the educational game environments (e.g., Inal & Cagiltay, 2007; Kiili & Lainema, 2008; Webster, Trevino, & Ryan, 1993). However, for the game design feature of game frame story, even though it was also found to be an important flow experience predictor in this current study, it was not the case for other studies in the field. In a study investigating college students' game flow experience and its impacting factors, game frame story was not found to be directly correlated with undergraduate students' game flow experience (Kiili, 2005). The author explained that this was due to the fact that the game used in the study did not have a very clear background story. This also helped to explain why my current study had different findings in terms of this issue. Actually, the importance of a clear game background story found in this current study was supported by the fact the CRYSTAL ISLAND game had a clear background story. This background story was presented to the students in the format of a 3-minute video clip before gameplay. Students' responses to both the survey and focus group interview questions indicated that they thought the background story was not only very engaging but also very helpful.

All of the above-mentioned findings have significant implications for educational game designers. Taken together, the results indicated that in order to facilitate students' playful learning experience, it is important to design an educational game with all these desirable features. First, the difficulty level of the game should be appropriate to avoid making students feel frustrated; conversely, it should not be too easy, otherwise students will easily become bored. Secondly, it is important that a well-designed educational game should include a game interface that is easy to navigate and that doesn't put too much unnecessary

cognitive load on students' part. The rules of gameplay should also be easy to understand. Besides, good playability also means that it should be easy for students to control the game characters (see discussion above) so that they can experience a higher sense of control over the game environment. Third, an educational game should be designed in such as way that it really feels like a game (i.e., high gamefulness). This means that the game should be non-linear and should allow students opportunities to make decisions of their own playing actions to make progress in the game. While providing certain external in-game rewards (e.g., sand dollars in the CRYSTAL ISLAND game) is also a feature that all students enjoy, high gamefulness also means that students should be able to use the external rewards in different and meaningful ways. Finally, providing students with a clear background story is also important to be taken into consideration during the game design process.

It is also important to note that while not supported by the regression analyses in the current study, the game design features of clear goals and unambiguous feedback were both found to be important predictors of students' game flow experience in previous studies, including the several studies cited above. Clear goals and unambiguous feedback may not have been a significant predictor in this current study due to the fact that the game was still at a developmental stage at the time of study. Therefore, the lack of statistical evidence that these two factors significantly predicted students' game flow experience might be due to certain game design limitations that are currently being refined as oppose to their unimportance for predicting students' game flow experience (Zheng, Meluso, & Spires, 2011). Students' statements from the focus group interviews supported this assumption. As reported previously in Chapter 4, when asked which of the game design features were

important reasons why they had enjoyed the game so much, all students from the two focus groups reported that all of the game design features examined were important. Apparently, the impact of key game design features on players' flow experience needs to be further investigated and validated.

Impact of Peer Interaction on Game Flow Experience

Overall, a mean of over 4 on a 5-point scale indicated that students in the collaborative player group had pleasant experiences playing with their partners. Students' focus group interview statements both supported and contradicted this statistical finding. On one hand, 4 of the 5 collaborative players in the focus group reported that playing with a partner was pleasant and helpful experience. There was one student who explicitly reported that she enjoyed the game because she got to play with a partner and that they were able to help each other. This indicated that students' did appreciate the opportunity of meaningful and enjoyable interaction with peers in the virtual learning environment, consistent with findings from a study conducted by Morgan and Ellis (2006). On the other hand, despite the sense of satisfaction experienced while playing the game collaboratively with a peer, all 5 students expressed that they would rather play the game individually, possibly because they all wanted more time to be the "driver" instead of the "planner". Also, one girl commented that she did not like her partner due to gameplay decision disagreements. In accordance with these different statements, it was apparent that even though students felt good playing with a partner, playing individually was more appealing to them. This finding is important, as it will inform future teaching practice as educational games are more commomly integrated into the classroom.

I had assumed that peer interaction would be a significant predictor of students' flow experience. Theoretically, students who have more favorable peer interaction experiences are supposed to also have more enjoyable gameplay experience in general. However, this assumption was not completely supported by the statistical data from the regression analysis. To reiterate, the simple linear regression failed to reveal a significant impact of peer interaction on game flow experience.

Meanwhile, the multiple regression analysis showed that the impact of peer interaction on students' game flow experience (for the subscale of time distortion and loss of self-consciousness) was approaching significance when controlled for the impact of their reading EOG scores (see Chapter 4). This finding indicated that, even though there was not a main effect of gameplay condition (e.g., solo and collaborative gameplay) on flow experience (see discussion above), within the collaborative gameplay condition only, favorable peer interaction experience seemed to be able to make potential contribution to students' game flow experience, especially for those with lower or limited reading proficiency. Therefore, the issue of peer interaction during collaborative gameplay is worthy of more investigation. Specifically, due to the potential benefit of positive peer interaction, more research should be conducted to help answer the question of what we can do during the research process (e.g., partner assignment) to ensure that all collaborative players have more enjoyable peer interaction experience. This will in tern help/make collaborative gameplay more effective.

Again, it is important to note that the findings reported here were based on a small sample of 5th graders, thus limiting its generalizability to other contexts and populations.

Research examining the impact of peer interaction during the computer-mediated learning process is worthy of extensive further investigation since social interaction is believed to be at the core of any meaningful learning experience.

Impact of Game Flow Experience on Students' Science Learning Outcomes

The third question asked about the impact of game flow experience on students' science learning outcomes, including science content learning gains and science attitude changes, both measured with the pre and post tests/surveys.

Gameplay and Science Learning Outcomes

Science content learning gains. For science content learning gains, findings revealed that across gameplay conditions, students made significant learning gains; there was no difference between the two gameplay groups. These findings were consistent with findings in other studies (e.g., Meluso, et al., 2011). However, the findings were contradictory to findings reported by other researchers. For example, Foster (2008) found that students who played the game with a partner overcame more misconceptions about microbiology than those who played the game individually.

The findings of this current study that collaborative game players did not make higher learning gains were not surprising considering what I observed during data collection. Shih et al. (2010) indicated that, even though peer collaboration has the potential to improve student learning, the effectiveness of collaboration also depends on the collaboration strategies and models. In order for collaboration to contribute to new learning, students need to engage in meaningful discussion and idea exchanges with each other.

However, during the gameplay process, it was observed that some students in the collaborative gameplay conditions did not engage in active and meaningful interactions and collaborations with his or her peer. For example, I observed that some students just sat quietly besides their peer and watched their peer played the game instead of providing constructive ideas to contribute to the gameplay. There were indeed some students who were actively engaged in discussing with their partners, but the content of their conversation was not related to learning. Instead, oftentimes students were talking about other things such as funny characters in the game and funny gameplay actions such as jumping up and down the hill in the game.

This indicated that a clear role and a common goal should also be set for collaborative game players in order for meaningful and active collaboration to occur, thus leading to new knowledge construction (e. g., Hämäläinen, Manninen, Järvelä, & Häkkinen, 2006). Before the gameplay, even though students were instructed to work as best as they could to finish the learning quests together, there was not a clearly defined role for each of the two students in a dyad. As a result, this might result in vague roles and respective responsibilities for some students in the dyads. In future studies of collaborative gameplay, students need to be more explicitly instructed as to how to engage in active acquisition of information and knowledge together with a partner. Besides, research has found that collaborative gameplay would be more effective only when the collaboration among game players were enjoyable. However, as reported previously, some students reported that they did not enjoy playing with their partner. This might also explain why the collaborative players did not learn better than solo players.

Taken together, the first implication of these findings is that the CRYSTAL ISLAND game has the potential to contribute to science learning in 5th graders. A second value is that the findings provided important information regarding how collaborative gameplay could be further structured to scaffold student content learning in the game environment. With appropriate scaffolding, the potential of collaborative game-based learning may be revealed.

Science learning attitude changes. Even though students across two gameplay conditions made significant content learning gains, statistical analysis failed to reveal any changes in students' science learning attitude as a result of playing the game. This might be due to the fact that students only interacted with the CRYSTAL ISLAND game for 3 days, with appropriately 40-50 minutes on each day. This time frame might be too short for students to develop a more positive attitude towards science learning. The results might also be related to potential limitations in the science learning attitude survey used in the study. As a result, even though no positive findings were revealed, the results did provide important information regarding further research design enhancement and instrument refinement for better outcomes. If possible, students should be allowed more time to interact with the game in future studies. In addition, as also pointed out previously, the science learning attitude survey needs to be further developed and validated with a larger sample size.

Impact of Flow Experience on Science Learning Outcomes

Previous studies have revealed that the impact of flow experience on learning outcomes were mixed. For example, some studies have found that flow experience, which has often been referred to as an optical enjoyment experience, were able to lead to optimal performance (e.g. Kiili, 2005; Hsu & Lu, 2006; Ghani, 1991; Skadberg & Kimmel, 2004).

Some other studies, however, did not find a positive relationship between flow experience and learning outcomes (e.g., Lee and Kwon31; Killi and Lainema, 2008; Moreno, et al., 2004). For example, Moreno and her colleagues (2004) found that higher level of immersion did not result in middle school students' better performance in tests of knowledge retention and transfer. In this current study, higher game flow experience was also not found to lead to higher science content learning gains or science learning attitude changes. Particularly, it was surprising that students' sense of control (one of the 4 flow experience subscales) was found to be negatively associated with science content residual learning gain scores.

There are several possible reasons as to why this happened. First, as mentioned earlier, students played the game for only a very limited amount of time (40 minutes each day for a row of 3 days). This may have limited the possibility to observe the actual impact of game flow experience on learning outcomes such as content learning gains. For example, in the study where Kiili (2005) found a positive correlation between undergraduate students' game flow experience and their computer science content learning gains, students played the game for a total of about 30 hours, much longer than in my study. Therefore, it is reasonable to predict that the results might be different if students get to play the game for a longer time in future studies. The issue is worth more studies. Second, the results of this current study might also imply that in order for students to make more learning gains, appropriate content area scaffolding should be provided (Moreno, et al, 2004). This is particularly important in view of what researchers have claimed about the relationship between positive emotion and effective learning in the game environment. Graesser and his colleagues (2009) pointed out that there is often a tradeoff between deep learning and students' positive emotion during the

learning process in the virtual learning environment, a 3rd possible explanation of the negative findings reported in this current study. Oftentimes, students experience deep enjoyment and satisfaction interacting with certain learning software (i.e., an educational game in this case), but this doesn't translate into their better performance or behaviors probably because their attention has been focused entirely on the entertainment aspect of the game that they forget about the content. As a result, a certain degree of scaffolding or guidance from the teacher or from the gameplay facilitator might help to redirect students' attention to the learning aspect of the game while having fun at the same time. For example, the data collection facilitators should explain to the students at the very beginning of the gameplay sessions the importance of focusing on the gameplay tasks. During the gameplay process, the facilitators should also wander around in the gameplay room to monitor student gameplay behaviors. Once undesirable gameplay behaviors (e.g., just having fun in the game by jumping around without doing nothing related to learning) are observed, the facilitators should point out and correct them.

The finding that students' self-reported sense of control was negatively associated with science content learning gains has great implications for game design as well. A sense of control indicates that the degree of freedom given to students made them feel that they are in good control of the playing actions that they take and the strategies that they use to perform a task (Sweetser & Wyeth, 2005). A well-designed game should always give students some degree of freedom and autonomy. However, there is also the issue of balance between freedom and self-control, especially for younger children such as elementary school students. Apparently, 5th graders in my study were able to control their pace of playing and

their playing strategies. However, without appropriate monitoring or guiding mechanism, it is possible that this will lead to results opposed to what we as educators and educational game designers want to see (e.g., higher learning gains), especially when students make their own decisions to perform off-task gameplay actions (e.g., simply wandering around on the island without actively seeking useful learning information). As a result, it is important to take into account the degree of autonomy and control that we want to offer to students so that a good balance might be achieved.

Conclusion

The study employed a mixed methods research design to examine 5th graders' flow experience in the CRYSTAL ISLAND game environment, the game design features that impacted their game flow experience, and how the flow experience in turn impacted their science content learning outcomes. The results illustrated that using a mixed methods research design provided a good vehicle to examine students' subject gameplay experience in the virtual environment. The value of mixed methods research design was especially apparent when the participants are younger (i.e., upper elementary school students), as it provided a chance for the researcher to collect in-depth data and to highlight similarities and differences in students' quantitative and qualitative responses. In particular, flow experience is a complex concept, especially for 5th graders. Therefore, using a mixed methods research design has great value.

The findings from the adapted flow experience survey and the science attitude survey also revealed that, while the surveys provided a satisfactory measure of students' flow experience in the game environment as well as science learning attitude, both surveys need to be further refined in future studies. However, both statistical and focus group interview data

indicated that flow experience theory provided a new lens for educational game researchers to examine the issue of student emotion and playful science learning experience in the game environments.

The findings that students across playing conditions reported high flow experience in the CRYSTAL ISLAND game environment and that they made significant science content learning gains have important implications for educational researchers and classroom teachers. Specifically, the findings collectively implied that well designed educational games have the potential of providing a science content learning environment that is both engaging and effective for elementary school students. However, the issue of gameplay and its impact on upper elementary students' attitude towards science learning should be further explored in more empirical studies. Additionally, the impact of collaborative gameplay, including students' perception of their peer interactions, on their enjoyable game flow experience and on their science learning outcomes, also requires more investigation. Effective strategies that could potentially improve the effectiveness of peer collaboration in the virtual learning environment should be explored to make full potential of the strengths of peer collaboration and interaction.

Both statistical and qualitative findings from this study also have great implications for educational game designers in that it revealed important game design features that impacted students' game flow experience. Future educational game designs that integrate the principles of flow experience theory will greatly improve the effectiveness of the game in supporting students' positive learning experience, especially in the science education areas. Moreover, the study also revealed certain student personal characters such as their reading

proficiency that have a positive impact on students' game flow experience in the CRYSTAL ISLAND game environment. The findings will also inform effective game design practice as they provided valuable information regarding how educational games should be designed in order to facilitate a higher level of deep engagement for all student populations. By doing this, we will be able to reach out to a much larger population of students, especially those who don't usually demonstrate interest in science content.

As also pointed out previously, it is important to note that the study reported here is based on a relatively small sample size; future studies should be conducted with a larger sample size to better understand the phenomenon of flow theory within the game-based learning context. Besides, the results may not be applicable to different student populations (e.g., students in urban or rural areas, or students of other ages). Future studies that explore a variety of student populations will provide important contributions to the field.

Finally, as discussed previously, the focus group interviews disclosed very important supplementary information regarding students' flow experience in the CRYSTAL ISLAND game environment. This information could have not been able to be obtained had the present study employed a pure quantitative approach. This suggests that future studies employing a mixed method design will help to capture the phenomenon better.

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APPENDICES

APPENDIX A: Informed Consent Form

We are asking your child to participate in a research study. The purpose of this study is to examine the effectiveness of a new science learning computer software program that is engaging as well as effective for student learning.

INFORMATION

Your child will use the software program as part of his/her regular science curriculum. If you allow your child to participate in the study, s/he will be asked to play with the software and complete some questionnaires and knowledge assessments related to the use and effectiveness of the software. Your child will also be videotaped while playing and in a follow-up interview which ask them about their playing experience. Participation in the project should take approximately 3 hours.

RISKS

There should be no risks to your child from this research. No information will be recorded that may be embarrassing or uncomfortable.

BENEFITS

Your child may benefit from participation by using the computer software and learning science in a new, hopefully more engaging, manner.

CONFIDENTIALITY

The information in the study records will be kept strictly confidential. Information will be collected directly from the computer software and stored securely in computer files that are password protected. Information will not be connected to subjects' identities. Videotapes will be destroyed at the end of the research. No reference will be made in oral or written reports which could link you to the study.

CONTACT

If you have questions at any time, you may contact the researcher, Meixun Zheng, at 919-515-8507. If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact the Chair of the NCSU IRB for the Use of Human Subjects in Research Committee, at 919-515-4514 or Mr. Matt Zingraff, at 919-513-1834.

PARTICIPATION

Your child's participation in this study is voluntary. While the use of the software is a part of your child's classwork, the other aspects of the research, completing the questionnaires, and allowing the release of class information are voluntary. You may decline participation without affecting your child's grades. If you decide to participate, you or your child may withdraw from the study at any time without penalty.

CONSENT

"I have read and understand the above information. I have received a copy of this form. My child has permission to participate in this study with the understanding that he/she may withdraw at any time. My child has read the above information and agrees to participate with the understanding that s/he may withdraw at any time."

Parent's signature_____   Date _____

Subject's signature _____   Date _____

Investigator's signature_____   Date _____

APPENDIX B: Adapted Game Flow Experience Survey

Please answer the following questions in relation to your CRYSTAL ISLAND game playing experience. Think about what kind of feelings you experienced during playing and choose the answer that best describes your feeling. There is NO correct or wrong answer.

Strongly agree=5, Strongly disagree=1

Flow Experience Items

1. The CRYSTAL ISLAND game really grabbed my attention.

2. It was easy for me to pay all my attention to the game.

3. I was completely concentrated in playing the game.

4. It was easy for me to control my playing actions in the game.

5. I was able to decide on my own playing actions and made progress in the game.

6. I was in good control of my playing actions.

7. When I was playing, I did not care about what others thought about how well I was playing.

8. I just kept playing and was not worried about how well I was doing.

9. While I was playing the CRYSTAL ISLAND game, I forgot about unhappy things.

10. While I was playing the CRYSTAL ISLAND game, I felt time seemed to go in an unusual way (either much faster or slower than usual).

11. During gameplay, I forgot about time because I really got into the game.

12. During gameplay, the time seemed to pass very fast. Suddenly, the playing session was almost over.

13. I really enjoyed playing the CRYSTAL ISLAND game.

14. I liked the feeling of playing and want to play it again.

15. I enjoyed playing the CRYSTAL ISLAND game because it made me feel good.

Flow Antecedent Items

1. The game tasks were challenging, but I had the skills to meet the challenge.

2. The difficult level of the game equaled to my skill level.

3. As I played the game, my skills got improved and so I was able to complete more difficult tasks.

4. I understood the game on the screen quickly and knew what to do without having to think.

5. I learned how to lay the game very easily.

6. It was easy for me to understand how to play the game.

7. The game did not get any more difficult as I played.

8. I was able to play in many different ways.

9. I could use the rewards (i.e., sand dollars) I gained later when I did other tasks.

10. I knew clearly what I needed to do in the game.

11. The goal of the game was very clear to me.

12. I understood the goal of the game from the very beginning.

13. The feedback given by the game helped me know how well I was doing in the game.

14. The game provided quick feedback of how well I was playing.

15. The feedback that the game provided was very helpful.

16. The game background story was part of the reason why I liked playing the game.

17. The game story made it easier for me to understand what happened in the game.

18. The game story helped me to understand what I needed to do in the game.

19. I enjoyed playing the game with my partner.

20. My partner helped me to do better in the game.

21. I would like to play the game with my partner gain.

APPENDIX C: Science Attitude Survey

We are interested in knowing how you feel about science. Please read the following statements carefully and choose the number that BEST describes your feeling about science learning. There is NO right or wrong answer. It is important to answer all of the items. Thank you!!

Strongly agree=5, Strong disagree=1

---

1. Science is useful in helping to solve the problems in daily life.
2. Science is helpful in understanding today's world.
3. Science is of great importance to a country's development.
4. Most people should study some science.
5. It is important to know science in order to get a good job.
6. I would like to do some extra or un-assigned reading in science.
7. Sometimes I read ahead in our science book.
8. I have a real desire to learn science.
9. I like the challenge of science assignments.
10. It is important to me to understand the work I do in science class.
11. Science is easy for me.
12. I usually understand what we are talking about in science.
13. I don't do very well in science.
14. No matter how hard I try, I can not understand science.
15. I often think, "I can not do this," when a science assignment seems hard.
16. When I hear the word science, I have a feeling of dislike.
17. It makes me nervous to even think about doing science.
18. It scares me to have to take a science class.
19. I have a good feeling toward science.
20. I feel tense when someone talks to me about science.
21. Science is one of my favorite subjects.

22. Science is something that I enjoy very much.

23. Science teachers make science interesting.

24. Science teachers present materials in a clear way.

25. Science teachers are willing to give us individual help.

APPENDIX D: Focus Group Interview Protocol

Part One: What was Fun?

General Gameplay Experience

1. Have you ever played a game that you think was very fun before?

2. On a scale from 0-10, what do you think the game you mentioned just now would be?

3. What about the CRYSTAL ISLAND game as compared with the game that you told me just now? Why?

4. On a scale from 0-10, what do you think the CRYSTAL ISLAND game would be? Why?

5. What did you do in the game that you think was fun?

6. How did you fell when you played the CRYSTAL ISLAND game?

Specific Game Flow Experience

1. Concentration: Did you pay all your attention to the game?

2. Time distortion: When you were playing the CRYSTAL ISLAND game, what was your feeling about time? Did you feel that time went very fast?

3. Sense of control: Did you feel you were able to easily control your own playing actions? Follow-up: What made it easy/difficult for you to control your playing actions?

4. Loss of self-consciousness: When you were playing the CRYSTAL ISLAND game, did you worry about that you may not complete a quest or worry about you may fail the game? Did you worry about what your friends may think about how you were doing in the game? Sometimes you may have unhappy things such as having tons of schoolwork or having tests to take. Did you think playing the game helped you forget about the unhappy things?

5. Autotelic experience: Do you think playing the CRYSTAL ISLAND game make you feel good? Do you think you enjoyed playing the CRYSTAL ISLAND game so much that you would like to play it again in the future?

Flow Antecedents

General: What do you think have made you enjoyed playing the game?

1. Playability: Was it easy for you to learn how to play the game?

2. Game Frame story: Did you like the background story of the game? Did you think the background story was helpful? Why?

3. Goal: Do you know the goal of the game? Could you tell me what the goal of the CRYSTAL ISLAND game is? (*Follow up*: How did you know this?)

4. Challenge and skill balance: How did you think about the playing tasks? Do you think they were too easy or too difficult for you?

   Follow up: Which one was (too/very) easy? Which one was (too/very) difficult?

5. Feedback: Did you think the feedback given by the game is useful? Why?

6. Gamefulness: Were you able to play the game in different ways?

   Were you able to use your sand dollars in the game?

   Follow up: Do you like the way in which you could use the sand dollars (e. g., buying stuff from the trade post)?

7. Peer interaction: Did you enjoy playing with your partner? Why?

   Do you think playing with a partner helped you do better in the game?

   Do you want to play with your partner again? Why?

Summary: Of all these things that we talked about just now, which do you think is the most important reasons why you enjoyed the CRYSTAL ISLAND game?

Part2: What was Not Fun?

1. Have u ever played a game that was boring and not fun?

2. Why do you think it was boring? What was wrong with the game?

3. Was there any time that you felt bored and not fun when you played the CRYSTAL ISLAND game? Could you tell me some examples?

4. What would you like to be added to the CRYSTAL ISLAND game to make it more fun?

Part 3: Summary

"Think about when you play sports in a team with your friends (e.g., baseball and soccer). You enjoyed it so much that you think you could play it for a whole day. You felt that you did

not want to stop and you could not hear anyone talking (calling your name). You were having so much fun that you even forgot about your lunch or dinner."

1. Have you ever felt this way when you play sports?
2. Did this happen to you when you played ci-5?
3. How was the CRYSTAL ISLAND game compared to that? Was there anything similar or different?

Concluding Question:

Is there anything that you could like to tell me about the CRYSTAL ISLAND game?

APPENDIX E: Pre Science Content Test

Thank you for helping us today. Please answer all of the questions as best as you can. If you have any questions, raise your hand and someone will come and help you.

*1. Are you a boy or a girl?

◯ Boy

◯ Girl

*2. Which of the following best describes your race?

◯ American Indian/Alaska native

◯ Asian American/Asian/Pacific Islander

◯ Black/African American

◯ Hispanic/Latino

◯ White

◯ Other

*3. How old are you?

◯ 9

◯ 10

◯ 11

◯ 12

◯ 13

*4. How do you feel about the following:

	Really dislike	Dislike a little	Neither like nor dislike	Like a little	Really like
Video games	◯	◯	◯	◯	◯
Computers	◯	◯	◯	◯	◯
Science	◯	◯	◯	◯	◯

*5. How GOOD are you at the following:

	1 Not very good	2	3 Average	4	5 Very good
Video games	◯	◯	◯	◯	◯
Computers	◯	◯	◯	◯	◯
Science	◯	◯	◯	◯	◯

*6. How much time do you spend doing the following:

	1 None at all	2	3 Some time	4	5 A lot of time
Play video games	◯	◯	◯	◯	◯
Use the computer	◯	◯	◯	◯	◯
Do science homework	◯	◯	◯	◯	◯

✳7. Please indicate how much the following statements are like you.

	Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree
I am sure that I can learn science.	○	○	○	○	○
I can get a good grade in science.	○	○	○	○	○
I am sure I could do middle school science.	○	○	○	○	○
I have a lot of self-confidence when it comes to science.	○	○	○	○	○
I am not the type to do well in science.	○	○	○	○	○
It takes me a long time to learn new things in science.	○	○	○	○	○
Even before I begin a new topic in science, I feel confident I'll be able to understand it.	○	○	○	○	○
I think I have good skills and strategies to learn science.	○	○	○	○	○

✳8. Which of the following is NOT a model?

○ a globe

○ a doll

○ a waterfall

○ a map

✳9. Which of the following is a person who makes maps?

○ Geographer

○ Surveyor

○ Cartographer

○ Volcanologist

✳10. Which is the MOST accurate way to locate an EXACT position on a map?

○ Scan the map visually.

○ Use the map key.

○ Use the compass rose.

○ Use the map grid.

Use this map to answer the following questions.

✱11. The bridges on the map are located in which coordinates?

○ C-4, E-4

○ E-4, B-4

○ D-8, C-10

○ C-4, E-3

Use this map to answer the following questions.

★ 12. What activity should a camper be able to do at C-5?

◯ Horseback riding

◯ Mountain climbing

◯ Snow skiing

◯ Canoeing

Use this map to answer the following questions.
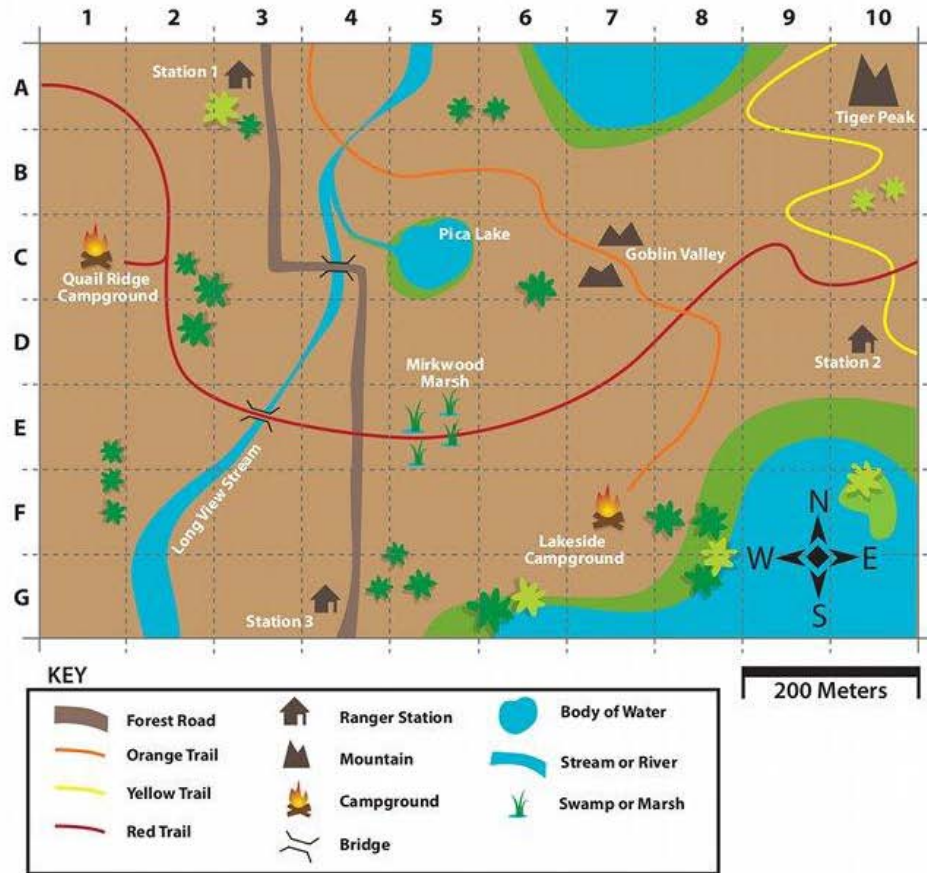

13. From Ranger Station 3, travel north for 400 meters and then east for 100 meters. Where are you?

◯ Mirkwood Marsh

◯ Goblin Valley

◯ Pica Lake

◯ Ranger Station 2

Once again, use this map to answer the following questions.

KEY

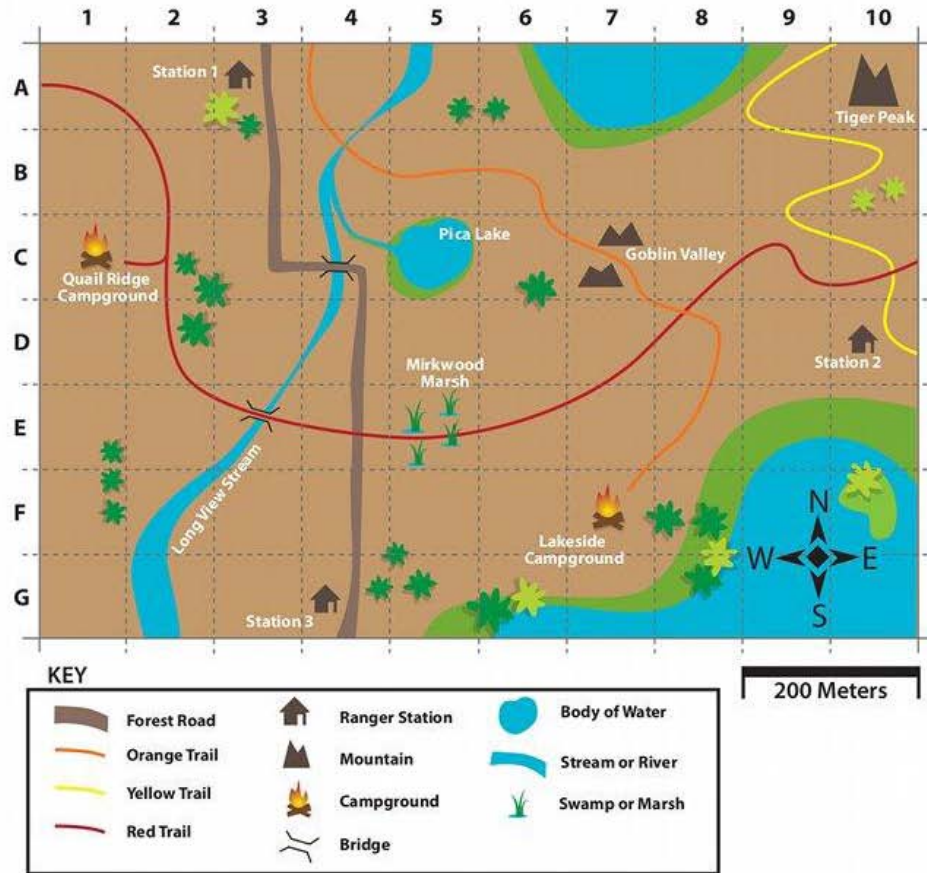|				
Forest Road		Ranger Station		Body of Water
Orange Trail		Mountain		Stream or River
Yellow Trail		Campground		Swamp or Marsh
Red Trail		Bridge		

✳14. You need to get from Ranger Station 1 to Ranger Station 3. About how many meters long would this hike be if you stay on the road?

○ 1000 meters

○ 1600 meters

○ 1200 meters

○ 700 meters

15. About 200 meters southeast of the Quail Ridge Campground is what landmark?

○ Ranger Station 1

○ Pica Lake

○ Ranger Station 3

○ Long View Stream Bridge

Once again, use this map to answer the following questions.

KEY

Forest Road	Ranger Station	Body of Water
Orange Trail	Mountain	Stream or River
Yellow Trail	Campground	Swamp or Marsh
Red Trail	Bridge	

＊16. Which of the following is located southeast of Pica lake?

○ Mirkwood Marsh

○ Longview Stream

○ Goblin Valley

○ Lakeside Campground

Use the illustration below to answer the following questions.

* 17. Where is a tributary shown in the illustration?

◯ A
◯ B
◯ C
◯ D
◯ E

Use the illustration below to answer the following questions.

* 18. On the illustration, the letter C represents a

- ◯ waterfall
- ◯ plateau
- ◯ delta
- ◯ tributary

Use the illustration below to answer the following questions.

＊19. In which location has a delta formed?

◯ A
◯ B
◯ C
◯ D
◯ E

✳20. In the box next to each definition, select the word that best fits that definition.

Landform

Definition	
Fan-shaped deposit of materials at the mouth of a stream or river.	[ ]
A large, nearly level area that has been lifted above the surrounding area.	[ ]
A stream that flows to a larger stream or other body of water.	[ ]
Wall across a river that holds back water, creating a reservoir or lake.	[ ]

✳21. Use all of the clues provided, and the map below, to help you solve the problem. When you have the solution to the problem, please write your answer in the space provided.

Florida contains many forests and wilderness areas, which are located throughout the state. Your problem is to find the correct national forest from the clues given.

• The area you are trying to find is in the northern part of the state.
• It is located about 100 miles from another national forest.
• It is west of the town of Jacksonville.
• It is west of a marine/wildlife reserve.
• It is about 75 miles west of the Suwannee River

**Please write the name of the correct national forest in the space below.**

[ ]

22. Teachers use models to help students make sense of their observations, and understand abstract ideas through the visualisation of:
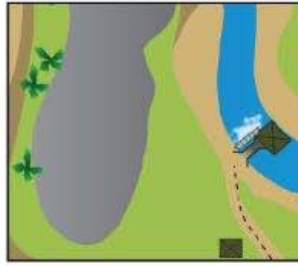
◯ Objects that are too big to be easily seen.

◯ Objects that are too small to be easily seen.

◯ Processes that cannot easily be seen or observed.

◯ All of the above.

◯ None of the above.
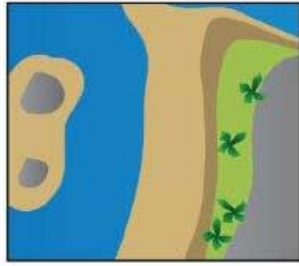
✱ 23. Which top-down map view most closely matches the actual island photo underneath?

◯ A

◯ B

◯ C

◯ None of the above.

✱ 24. Effective problem solving requires four steps that are done in a certain order. Please number the four primary problem solving steps in the correct order.

Please select the correct option from each drop-down menu.

Step 1	[ ]
Step 2	[ ]
Step 3	[ ]
Step 4	[ ]

✱25. Imagine that you were asked to create a school map for a new student at your school. In what order would you complete the following steps?

Please select the correct option from each drop-down menu.

I would draw my map as I walked from one class to the next.	[ ]
I would make a plan by listing the things I needed to do to make my map.	[ ]
I would think about whether I understood the assignment and I would ask questions if needed.	[ ]
I would look at my map and decide whether my map would work or whether I needed to change something on it.	[ ]

✱26. Please choose the answer that best describes your feeling.

	Strongly Disagree	Disagree	Not sure	Agree	Strongly Agree
Science is useful in helping to solve the problems in daily life.	○	○	○	○	○
Science is something that I enjoy very much.	○	○	○	○	○
I would like to do some extra reading in science.	○	○	○	○	○
Science is easy for me.	○	○	○	○	○
When I hear the word science, I have a feeling of dislike.	○	○	○	○	○
Most people should study some science.	○	○	○	○	○
Sometimes I read ahead in our science book.	○	○	○	○	○
Science is helpful in understanding today's world.	○	○	○	○	○
I usually understand what we are talking about in science.	○	○	○	○	○

✱27. Please choose the answer that best describes your feeling.

	Strongly Disagree	Disagree	Not sure	Agree	Strongly Agree
Science teachers make science interesting.	○	○	○	○	○
No matter how hard I try, I can not understand science.	○	○	○	○	○
I feel tense when someone talks to me about science.	○	○	○	○	○
Science teachers present materials in a clear way.	○	○	○	○	○
I often think, "I can not do this," when a science assignment seems hard.	○	○	○	○	○
Science is of great importance to a country's development.	○	○	○	○	○
It is important to know science in order to get a good job.	○	○	○	○	○
I like the challenge of science assignments.	○	○	○	○	○

APPENDIX F: Pattern Matrix for Flow Experience Items (1st)

	Factor			
	1	2	3	4
The CRYSTAL ISLAND game really grabbed my attention.			.848	
It was easy for me to pay all my attention to the game.			.746	
I was completely concentrated in playing the game.		.476	.408	
It was easy for me to control my playing actions in the game.	.853			
I was able to decide on my own playing actions and made progress in the game.	.677			
I was in good control of my playing actions.	.758			
When I was playing, I did not care about what others thought about how well I was playing.		.561		
I just kept playing and was not worried about how well I was doing.		.538		
While I was playing the CRYSTAL ISLAND game, I forgot about unhappy things in my life.		.482		
While I was playing the CRYSTAL ISLAND game, I felt time seemed to go in an unusual way (either went much faster or slower than usual).		.677		
During playing, I forgot about time because I really got into the game.		.500		.415
During playing, the time seemed to pass very fast. Suddenly, the playing session was almost over.		.609		
I really enjoyed playing the CRYSTAL ISLAND game.				.785
I liked the feeling of playing and want to play it again.				.779
I enjoyed playing the game because it made me feel good.				.387

APPENDIX G: New Pattern Matrix for Flow Experience Items (2ⁿᵈ)

	Factor			
	1	2	3	4
The CRYSTAL ISLAND game really grabbed my attention.				.874
It was easy for me to pay all my attention to the game.				.663
It was easy for me to control my playing actions in the game.	.869			
I was able to decide on my own playing actions and made progress in the game.	.690			
I was in good control of my playing actions.	.747			
When I was playing, I did not care about what others thought about how well I was playing.		.491		
I just kept playing and was not worried about how well I was doing.	.309	.453		
While I was playing the CRYSTAL ISLAND game, I forgot about unhappy things in my life.		.446		
While I was playing the CRYSTAL ISLAND game, I felt time seemed to go in an unusual way (either went much faster or slower than usual).		.750		
During playing, I forgot about time because I really got into the game.		.534	.391	
During playing, the time seemed to pass very fast. Suddenly, the playing session was almost over.		.669		
I really enjoyed playing the CRYSTAL ISLAND game.			.838	
I liked the feeling of playing and want to play it again.			.750	

I enjoyed playing the game because it made me feel good.			.470	

APPENDIX H: Pattern Matrix for Flow Antecedent Items (1st)

	Factor					
	1	2	3	4	5	6
The game tasks were challenging, but I believe I had the skills to meet the challenge.						.780
The difficulty level of the game equaled to my skill level.						.404
As I played the game, my skills got improved and so I was able to complete more difficult tasks.						.572
I understood the game on the screen quickly and knew what to do without having to think.	.658					
I learned how to play the game very easily.	.801					
It was easy for me to understand how to play the game.	.823					
The game did not get any more difficult as I played.					.396	
I was able to play in many different ways.					.947	
I could use the rewards (e.g., sand dollars) I gained later when I did other tasks.					.498	
I knew clearly what I needed to do in the game.				.946		
The goals of the game were very clearly.				.438		

I understood the goal of the game from the very beginning.	.348		.734			
The feedback given by the game helped me know how well I was doing in the game.		1.059				
The game provided quick feedback of how I well I was playing.		.672				
The feedback that the game provided was very useful.	.376	.366				
The game background story was part of the reason why I liked playing the game.	.683					
The game story made it easier for me to understand what happened in the game.	.647					
The game story helped me to understand what I needed to do in the game.	.726					

APPENDIX I: Pattern Matrix for Flow Antecedent Items (2nd)

	Factor					
	1	2	3	4	5	6
The game tasks were challenging, but I believe I had the skills to meet the challenge.						.804
The difficulty level of the game equaled to my skill level.						.390
As I played the game, my skills got improved and so I was able to complete more difficult tasks.						.552
I understood the game on the screen quickly and knew what to do without having to think.	.670					
I learned how to play the game very easily.	.715					
It was easy for me to understand how to play the game.	.870					
The game did not get any more difficult as I played.					.368	
I was able to play in many different ways.					.984	
I could use the rewards (e.g., sand dollars) I gained later when I did other tasks.					.467	
I knew clearly what I needed to do in the game.		.986				
The goals of the game were very clearly.		.460				
I understood the goal of the game from the very beginning.		.733	.343			

The feedback given by the game helped me know how well I was doing in the game.				1.041		
The game provided quick feedback of how I well I was playing.				.670		
The game background story was part of the reason why I liked playing the game.			.672			
The game story made it easier for me to understand what happened in the game.			.579			
The game story helped me to understand what I needed to do in the game.			.726			

APPENDIX J: Pattern Matrix for Science Attitude Survey (1st)

	Factor				
	1	2	3	4	5
Science is useful in helping to solve the problems in daily life.			.444		
Science is helpful in understanding today's world.			.601		
Science is of great importance to a country's development.			.774		
It is important to know science in order to get a good job.			.599		
Science is something that I enjoy very much.		.703			
I would like to do some extra reading in science.		.734			
I like the challenge of science assignments.		.446			
Science is one of my favorite subjects.		.639			
I have a real desire to learn science.		.563			
Science teachers make science interesting.				.942	
Science teachers present materials in a clear way.				.483	
Science teachers are willing to give us individual help.				.490	
When I hear the word science, I have a feeling of dislike.	.473				.721
I feel tense when someone talks to me about science.	.537				
It makes me nervous to even think about doing science.	.678				.392

Science is easy for me.	.325	.816			-.332
No matter how hard I try, I can not understand science.	.827				
I often think, "I can not do this," when a science assignment seems hard.	.587				
I don't do very well in science.	.769				

APPENDIX K: Pattern Matrix for Science Learning Attitude Survey (2nd)

	Factor			
	1	2	3	4
Science is useful in helping to solve the problems in daily life.			.393	
Science is helpful in understanding today's world.			.601	
Science is of great importance to a country's development.			.743	
It is important to know science in order to get a good job.			.549	
Science is something that I enjoy very much.		1.003		
I would like to do some extra reading in science.		.500		
I like the challenge of science assignments.		.413		
Science is one of my favorite subjects.		.605		
I have a real desire to learn science.		.536		
Science teachers make science interesting.				.944
Science teachers present materials in a clear way.				.515
Science teachers are willing to give us individual help.				.477
I feel tense when someone talks to me about science.	.531			
It makes me nervous to even think about doing science.	.678			
No matter how hard I try, I can not understand science.	.879			

I often think, "I can not do this," when a science assignment seems hard.	.560			
I don't do very well in science.	.705			