

Games for CHANGE: High School Students' Learning Experiences and Motivation to
Learn Climate Change Science through Educational Computer Games

by

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DEDICATION

This dissertation is dedicated to my amazing son, Musab, who was born during the process, and to my lovely wife, Esra, who has always encouraged me even when I did not want to be encouraged. I am so grateful to have you both in my life.

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ABSTRACT

The purpose of this study is to explore high school students' perceptions of learning climate change science through educational computer games. Further, it is aimed to investigate what roles educational computer games play in motivating students to learn climate change science. A qualitative case research design is used in this research to better understand and describe how educational computer games influence students' perceptions of learning the climate change science and what roles these games play in motivating them to learn climate change science in the learning environment. A purposefully selected a high school teacher and her eight students are the study participants. A series of student and teacher interviews are used as a main source of data. Both deductive and inductive approaches are used to analyze the data using Gee's principles about how games teach and Keller's ARCS Theory of Motivation Model. The analysis of the data revealed that the educational computer games increased the students' perceptions of learning climate change science. The findings also showed that the games have different characteristics to improve the students' perceptions to learn climate change science. Interactivity, providing different learning styles, role playing, challenging, creating a realistic environment, and providing visual experiences to learn were the specific characteristics of the games used in this study. In addition, the analysis of the data revealed that the educational computer games increased the students' motivation to learn climate change science. The findings showed that the games play various roles in motivating the students to learn. These roles were creating an engaging, interesting, focused learning environment; providing real-world connections and worth knowing information; and presenting the content in a challenging, but a fun way.

CHAPTER I: INTRODUCTION

Background of the Study

There is an international consensus among scientists that climate change is one of the most significant challenges we face in today's world (IPCC, 2013). Climate change is seen by educators and policy makers as an important concept to teach in secondary level science. It is included in the Next Generation Science Standards (NGSS), such as for Earth and Space Science and Life Science courses (NGSS, 2013). However, it is still a controversial issue. Despite a consensus among scientists, there are many non-scientists who challenge whether human-caused climate change is real (McCright & Dunlap, 2011).

Climate change is a complex topic to teach. It requires knowledge of a wide range of science domains (Ekborg & Areskoug, 2006), with topics that are often taught in a disjointed way. With its long timeframe (larger effects 10s-100s years into the future), students often cannot make a personal connection to climate change. Further, climate change science is a complex topic, with many variables inter-relating over time. This complexity causes the lack of motivation for students. Not only is motivation a crucial factor for success in an academic discipline (Rodgers & Withrow-Thorton, 2005), lack of motivation decreases the quality of learning and discourages students from making an effort to continue learning (Keller, 1983). Teachers need to provide an effective teaching method and instructional materials for stimulating students' learning experience and motivation in the learning environment. However, the

complexity, and other factors, make the teachers job of motivating the learning of climate change a challenge (Luterbach & Reigeluth, 1994).

To address these types of challenges, game-based learning may provide a more learner-centered, easy, enjoyable, interesting learning environment for students (Kafai, 2001; Prensky, 2003). Game-based learning is defined as “the innovative learning approach derived from the use of computer games that possess educational value or different kinds of software applications that use games for learning and education purposes such as learning support, teaching enhancement, assessment and evaluation of learners” (Connolly, Stansfield, & Boyle, 2009, p. 3). Game-based learning has gained increasing interest from educators and researchers because it has the potential to improve motivation and fundamentally change the way new generations acquire knowledge (Gee, 2003). This increased interest in use of games for educational purposes has led educators and researchers to investigate the relationship between games and learning, and how games can increase students’ motivation and teach them a specific concept (Chmiel, 2015). Educational games, known as Serious Games, have been developed for people to teach certain concepts while entertaining them at the same time. According to Squire (2005), educational games allow for new types of interactions that permit people to be a part of complex systems, while often learning through self-expression. Squire feels that educators need to have a better understanding of how gaming affects students’ perceptions of learning and motivation to learn.

Prensky (2001), in his book called Digital Game-Based Learning, addresses the reason why games can motivate students to learn, while education frequently does not. He talks about a combination of twelve elements that make computer games one of the most engaging tools in the history of humankind. One of the most significant elements he states is “fun” factor of computer games. Prensky (2001) thinks that games are fun and they provide learners enjoyment and

pleasure. Fun value of the computer games provides motivational appeal for the learners (Malone, 1981); because fun is a great motivator that makes the learners intrinsically motivated to engage in learning activities. Another important element that motivates learners is “goals or objectives” of computer games. All computer games must have some goals or objectives that can be achievable through the gameplay. Achieving the goals in the game makes the learners motivated because we are goal-oriented species (Prensky, 2001). Goals push us to try hard and win the game. “Interaction” is another factor that he mentions in his book. Computer games give learners opportunity to create an interactive learning environment where they learn by doing. In this essence, students’ active participation is promoted. In addition to this, he mentions that “outcomes and feedback” is another important factor that increases learners’ engagement and motivation. Computer games give copious feedback to ensure that the players are moving closer to and not further away from the goal of the game. Furthermore, outcomes (winning and losing conditions in the games) give the players opportunities to measure progress against the goals. Prensky (2001) also talks about “conflict, competition, and challenge” elements of the computer games. Computer games have a full problem that need to be solved by the players. Conflict, competition, and challenge are basically problems in a game that players try to solve. These elements are great factors for learners to get excited and fully motivated to learn.

In a similar way, Gee (2005) states that in order to be so deeply motivating, games have to be designed to trigger player learning. He mentions that good game designers have mastered motivation to learn, by making use of a set of thirteen principles of good learning design, dividing them into three categories. In his first category, called empowered learners, he states that nobody learns anything unless they choose to do so, and what they choose to learn, is based on what matters to them and what is useful to them. In his second category, called problem

solving, he thinks that in today's school environment, students learn disconnected facts in order to pass the tests, but they do not conduct real problem solving. Games are effective tools for supporting problem-based learning. In his last category, called understanding, he believes that good games create an environment for learners to have deep understanding that can last a lifetime and prepare them for future learning.

Statement of the Problem

One of the major effects of climate change is increased sea level rise, which causes extreme weather events in the coastal areas (IPCC, 2013). A big percentage of Florida residents lives in coastal areas (Crosset, 2005) and they will be affected both by sea level rise and extreme weather events such as hurricane, severe floods, drought, etc. (Jollands, Bernier, & Golubiewski, 2007). Therefore, it is important that students become aware of these events and their effects, by learning the science behind climate change, and what can be done to mitigate the effects of Global Climate Change.

Due to the complexity of climate change science, students have a hard time understanding the effects of climate change and how to deal with the issues related to climate change (McCright & Dunlap, 2011). In addition, climate change science is a multidisciplinary topic that requires an overwhelming amount of information from different subject fields, such as geology, physics, ecology, marine science, and students need to be familiar with the information across all content areas (Ekborg & Areskoug, 2006). Further, students have misconceptions about global climate change and are not being prepared to make informed decisions regarding this complex phenomenon.

Educational computer games have great potentials to increase students' motivation and help students to become self-directed and self-motivated learners (Garris, Ahlers, & Driskell,

2002). Although educational computer games can be great tools for learning and motivating for younger generations, there is little consensus about the essential characteristics of these games. In other words, it is still unclear why games are seen as motivating and how motivational processes work and connect causally to instructional outcomes (Garris et al., 2002). Also, it is not clear how these games affect students' perceptions of learning in the learning environment.

Moreover, there are a lot of research studies have been done investigating the effects of educational computer games ((Connolly, Boyle, MacArthur, Hainey, & Boyle, 2012); (Wouters, van Nimwegen, van Oostendorp, & van der Spek, 2013)). Existing research studies do not directly focus on the learners' perceptions of learning and motivational effects of educational computer games in science learning. In addition, these research studies mostly employed quantitative and mixed method study designs. There is a gap in the literature given there is no pure qualitative research study focusing on high school students' perceptions of learning and their motivation to learn science through educational computer games. It is the goal of this research study to explore high school students' perceptions of learning climate change science through educational computer games and to investigate what roles these games play in motivating students to learn climate change science.

Purpose of the Study

The purpose of this study is to explore high school students' perceptions of learning climate change science through educational computer games. Further, it is aimed to investigate what roles educational computer games play in motivating students to learn climate change science.

Significance of the Study

Teaching high school students the effects of climate change is challenging because students have difficulty making a personal connection to the topic and difficulty conceiving its slow pace, larger effects of which will be seen 10s-100s years in to the future. Game-based learning could provide a learning environment for students to make personal connections, actively engage with specific topics, and get highly motivated to learn climate change science. However, it is still unclear how educational computer games affect students' perceptions of learning and what roles educational computer games play in motivating students in the learning environment. Furthermore, even though there are a lot of research studies done investigating effectiveness of educational computer games, there is a gap in the literature as there is no pure qualitative study that explores students' perceptions of learning and their motivation to learn climate change science through educational computer games. This study strives to fill the gap in the literature, providing deeper understanding of high school students' perceptions of learning and their motivation to learn climate change science.

Research Questions

Based upon the problem identified, to explore high school students' perception of learning climate change science through educational computer games and their motivation to learn using these games in climate change science learning, I proposed the following research questions;

- 1- What are the high school students' perceptions of learning climate change science through educational computer games?
- 2- According to high school students, what roles do educational computer games play in motivating them to learn climate change science?

Theoretical Foundations

Gee's Principles About How Games Teach

Gee (2005) described thirteen principles of effective learning systems design that triggers learning and makes the learners deeply motivated to learn. These principles of learning built into computer games are organized into three categories (see Table 1 below).

Table 1. Gee's Principles about how Games Teach (2005)

Empowered Learners	Problem Solving	Understanding
<ul style="list-style-type: none">• Co-design• Customize• Identity• Manipulation and Distributed Knowledge	<ul style="list-style-type: none">• Well-ordered Problems• Pleasantly Frustrating• Cycles of Expertise• Information 'On Demand' and 'Just in Time'• Fish Tanks• Sandboxes• Skills as Strategies	<ul style="list-style-type: none">• System Thinking• Meaning as Action Image

Empowered learners. In his first category, called empowered learners, Gee (2005) describes four principles:

- 1- Co-design:** In good learning, learners must be like active agents not passive consumers in the learning process. Computer games provide an environment where learners are taking an active role in the learning process, rather than making them passive consumers. While playing the games, learners are co-designing the game by making actions and decisions in the gameplay. Learners' actions and decisions affect the outcomes, and the way they solve problems in the games.

- 2- **Customize:** Gee (2005) states that nobody learns anything unless they choose to do so. In good computer games, learners have freedom to choose and customize their learning styles based upon their own personalities. These games allow learners to customize the difficulty level to solve problems in different ways.
- 3- **Identity:** In today's schools, learners do not make sense of the things that they are learning in the classroom. They always keep saying "why do we need to learn this information or where will we use it?," etc. Computer games are good at creating an identity for learners. For example, learners can take a role of a scientist to solve real world problems while playing the games. Games provide clear roles and clear goals to make sense of what learners are doing in the gameplay.
- 4- **Manipulation and distributed knowledge:** People feel empowered when they can manipulate the smart tools in interactive ways to grasp new knowledge. Computer games provide an environment where the players can manipulate the game-world in an enjoyable way. This manipulation helps learners to engage their body and mind in the gameplay and make them truly connected with the games.

Problem solving. In his second category, called problem solving, Gee (2005) describes seven principles:

- 1- **Well-ordered problems:** In an effective learning environment, problems should be presented to learners in a well-ordered way. If learners face harder problems in early stage of their learning they might get frustrated. They need to face the early problems that will lead them to create better solutions for the harder problems. Computer games are very good at providing well-ordered problems. They start with easier levels where

players solve easier problems. Easier problems help players to make better solutions for harder problems in the game.

- 2- Pleasantly frustrating:** Gee (2005) thinks that students learn facts to pass the tests, but they do not develop real problem-solving skills in today's school environment. However, computer games are effective tools for supporting problem-based learning because they are pleasantly frustrating. A good computer game has adjusted challenges that make the players feel challenged, but also that success is possible. A good game also provides an effective feedback that helps the players to see whether they are on the right path for success or not. In this way, players can see their progress and know how well they are doing in the gameplay.
- 3- Cycles of expertise:** Gee (2005) thinks that expertise is a very interesting way of setting up learning. Cycle of expertise requires a repeated cycle of learners' practicing with a challenging problem until they could do it automatically. Learners want to challenge themselves with a new set of skills when they routinize their old skills, so that they should reach the mastered skills to use them in a new challenging problem. Computer games create the cycle of expertise that helps learners to acquire new knowledge and integrate them with the old ones.
- 4- Information 'on demand' and 'just in time':** Gee (2005) believes that people are so poor at verbal information when it is given as big blocks or out of context because they might have no idea how to apply it or what to do with it. Learners receive verbal information best when it is 'just in time' which means when they are ready for it to use and 'on demand' which means when they think they need it. Computer games are effective tools for providing verbal information 'just in time' and 'on demand'. Most

game players do not want to read the game manuals before playing the games. Games create a visual representation of verbal information when players experience the gameplay for a while. After playing the game, game manual gets clear and make more sense for the players. They will be able to get information from the manual just in time and when they need it.

- 5- **Fish tanks:** Learners have to deal with the complexity when they are trying to solve hard and interesting problems. Gee (2005) uses the words “fish tanks” as a simplified ecosystem that illustrates some important variables and their interactions while preventing learners from being overwhelmed by the complexity of the system in the real world. Computer games offer players fish tanks that consist of a few variables to decrease the complexity of the real-world problems and make them easy to understand.
- 6- **Sandboxes:** Gee (2005) states that learners need a time to explore the learning environment before making any progress in learning. He thinks that learners need to spend some time in sandboxes which provide them a realistic environment that has low or no risk, allowing them to explore things with no pressure and fear of failure. Computer games are excellent tools to provide sandboxes where players explore things without fear of failure and other consequences.
- 7- **Skills as strategies:** People need to make practice to acquire new skills. In schools, learners practice new skills with boring, meaningless, and unengaging ways (Gee, 2005). They learn and practice skills best if those skills are integrated into strategies that help them to reach satisfying and relevant goals. In computer games, players

practice skills as strategies towards achieving goals to finish the game levels or win the game.

Understanding. In his last category, called problem solving, Gee (2005) describes two principles:

- 1- **System Thinking:** People learn skills, strategies and ideas not in isolated small parts, but as entire functional systems. Computer games help the players to understand how each element in the game works and how these elements fit into the system of the game. Gee (2005) believes that computer games create an environment for learners to have a deeper understanding that can last a lifetime and prepare them for future learning.
- 2- **Meaning as Action Image:** Gee (2005) states that people can understand words and concepts well when they are associated with images, actions, or goals. Playing computer games allow players to understand words, concepts, and events through concrete imagery and visual experiences. Words and concepts are clearly tied to action images in the game world.

In summary, Gee (2005) describes thirteen principles for how computer games create good learning for learners. These principles are very important to empower learners, increase their problem-solving skills, and provide them a deeper understanding in the learning environments. Computer games mostly employ these principles to create an effective learning environments for today's digital natives. In this study, Gee's (2005) principles of empowered learners, problem solving, and understanding are investigated using co-design, identity, customize, pleasantly frustrating, sandboxes, and meaning as an active image principles. Gee's principles are used to conceptualize students' perceptions of learning climate change science

through educational computer games. These principles are applicable to the educational computer games used in this study.

ARCS Model of Motivation Theory

Motivation is a crucial factor for either success or failure in an academic discipline (Rodgers & Withrow-Thorton, 2005). Lack of motivation decreases the quality of learning and it discourages students from trying to continue learning (Keller, 2010). Because of this reason, teachers should provide effective teaching methods and instructional materials for stimulating students' motivation in the learning environment. In today's classrooms, teachers are faced with identifying different teaching strategies and developing effective learning materials to improve and maintain students' motivation (Luterbach & Reigeluth, 1994). To solve this problem, Keller (2010) proposed a systematic teaching strategy to improve and maintain students' learning motivation, known as the ARCS motivation model. In the ARCS motivation model, Keller proposed four essential factors for motivation. These are:

Attention. Attention refers to whether teaching methods and instructional materials used can capture learners' interest and stimulate their curiosity to learn. Teachers should provide effective instructional materials or teaching strategies to make learning experiences stimulating and interesting for students.

Relevance. Relevance refers to the potential of the courses and the instructional materials. Students need to believe that instructional materials are valuable and personally relevant to them. Teachers need to consider learners' individual needs and goals to affect a positive learning attitude.

Confidence. Confidence refers to learners' beliefs and feelings about whether they will experience success or failure in their learning. If instructional materials are either too difficult or

to easy, learners may lose confidence, and this hinders their motivation and learning. Therefore, teachers should design instructional materials and learning environment considering an appropriate level of difficulty for all learners.

Satisfaction. Satisfaction is basically about learners' feeling of satisfaction with evaluation of their learning experience. Learning should be satisfactory for learners continuing desire to learn. Therefore, teachers need to provide an environment and learning materials for their students to feel good about their learning experience.

In summary, The ARCS motivation model encompasses four major factors that influence the motivation to learn. This model provides a systematic teaching criteria to ensure that learning strategies and instructional materials consider learners' characteristics and meet their needs. In this study, the ARCS motivational model is used to examine to what extent educational computer games as instructional materials convey knowledge and affect students' motivation to learn about climate change science.

Student's perception of learning is inseparable from motivation because they both affect each other. If learners are motivated to learn, then their perceptions of learning will increase because motivation is one of the most crucial factors that affects learning (Gee, 2005). Similarly, if their perceptions of learning are high, then they will be motivated to learn more. In this study, combination of Gee's principles about how games teach (2005) and Keller's ARCS motivation model (2010) are used to conceptualize high school students' perceptions of learning and their motivation to learn climate change science (see Figure 1).

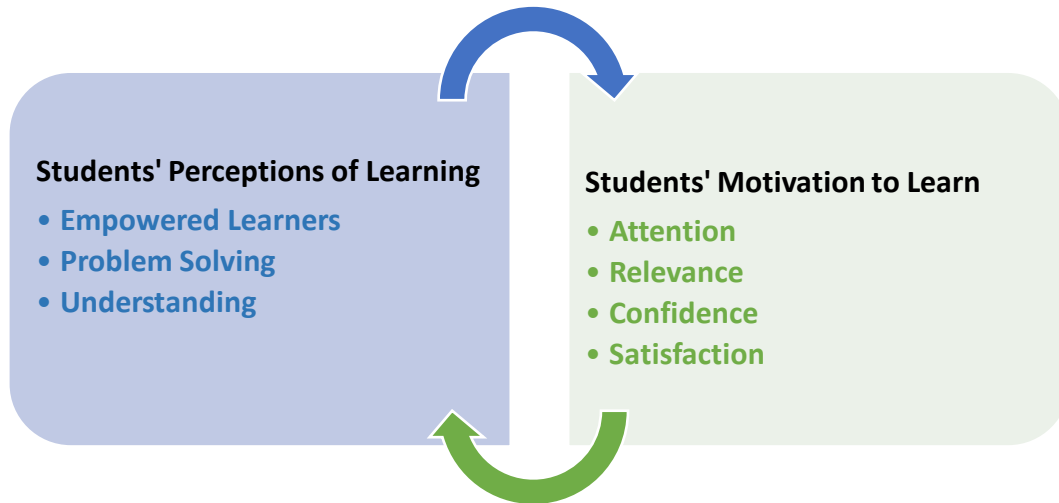


Figure 1. Conceptual Frameworks Combined

Delimitations

The primary focus of the study is to explore high school students' perceptions of learning and their motivation to learn climate change science through educational computer games. The research is limited to high school students within Marine Science courses. The focus of the research is on educational computer games specifically designed to help teaching climate change science. These games were created by a research team at University of South Florida, as an adjunct to teaching climate change concepts linked to the existing district curriculum. Therefore, a delimitation of the study is the restriction of the research to Marine Science high school students, four different educational computer games, and a particular framing curriculum for climate change science.

Definition of Terms

To understand the context of this study, a variety of terms should be defined. For clarification, the following definitions and terms are used in this study.

Global Climate Change: Anthropogenic-induced change in climate patterns attributed to

increase of concentrations of greenhouse gases in the atmosphere (Solomon, Plattner, Knutti, & Friedlingstein, 2009).

Game-Based Learning: It is defined as the innovative learning approach derived from the use of computer games that possess educational value or different kinds of software applications that use games for learning and education purposes such as learning support, teaching enhancement, assessment and evaluation of learners (Connolly, et al., 2009).

Educational Computer Games: Also known as Serious Games, have been developed for people to teach certain concepts while entertaining them at the same time (Squire (2005).

Motivation: Motivation is generally defined as that which explains the direction and magnitude of behavior, or in other words, it explains what goals people choose to pursue and how actively or intensely they pursue them (Keller, 2010).

Simulation Game: Simulations are designed to simulate a real-life situation where the player has to succeed the goals in the game (Herz, 1997).

Quiz-Trivia Game: These games are specifically designed to test players' knowledge about a specific concept (Lucas & Sherry, 2004).

Adventure Game: Adventure games focus on a narrative storyline to explore and solve puzzles throughout the game (Gunn, Craenen, & Hart, 2009).

Summary

In this chapter, the challenges that students faced in climate change science education were discussed. Game-based learning, Gee's thirteen principles for how games teach (Gee, 2005), and ARCS Model of Motivation theory (Keller, 2010) were explained to help establish a theoretical base for the research. In addition, the gap in the literature was explored, namely the

qualitative lens on the effects of educational computer games on students' perceptions of leaning and motivation to learn climate change science.

The next chapter, the review of literature, explores the educational and motivational effects of educational computer games on science learning, as well as existing research concerning the educational and the motivational effectiveness of educational computer games, and their integration into the science curriculum.

CHAPTER II:

LITERATURE REVIEW

The purpose of this qualitative case study is to explore high school students' perceptions of learning climate change science through educational computer games. Further, it is aimed to investigate what roles educational computer games play in motivating students to learn climate change science.

This chapter reviews literature on:

- 1) how educational computer games influence students' perceptions of learning and motivation to learn science,
- 2) what kind of game genres were used in science learning, and
- 3) how researchers measured motivation in the current studies.

Introduction

We are living in an era where science education has a crucial factor for high school students to become successful in the learning environments. However, there is a widespread concern about the complexity of science among the students in all grade levels. In school, many scientific concepts are very abstract, which can make them intrinsically difficult to learn. Also, important scientific theories are often complex, so that having a good appreciation of the scientific idea requires coordination of a good deal of information (Taber, 2014). Because of these reasons, students are facing with enormous challenges that they must confront (Anderman, Sinatra & Gray, 2012). Indeed, the report from National Center for Education Statistics shows

that students in the United States still lag behind students in other countries in science achievement, especially in European and Asian countries (NCES, 2012).

One of the most significant challenges that students faced is lack of motivation in science learning because they think that science instruction is mundane and meaningless to their everyday lives (Kaptan & Timurlek, 2012). Therefore, students are facing a myriad of issues to be fully motivated to understand complex mechanisms of science. In today's classrooms, science learning requires motivational strategies and skills (Anderman et al., 2012) because motivation is an important element for either the success or failure of learning (Rodgers & Withrow-Thorton, 2005). Motivation is inseparable from education because it increases the quality of learning and encourages students to make an effort for learning (Keller, 2010). In an academic context, it is extremely important to provide an environment that includes effective teaching method and instructional materials to be able to stimulate students' motivation. Unfortunately, teachers are faced with finding effective ways to increase students' learning motivation because of the complexity of science curriculum (Luterbach & Reigeluth, 1994). Therefore, students have problems to be fully motivated to understand complex mechanisms of science learning.

Motivation refers to the desire and willingness of the participant to engage in a behavior. Broadly, it refers to what people desire and what they choose to do (Keller, 2010). There are two broad categories of motivation and these are intrinsic and extrinsic motivation. Deci (1975) described intrinsic motivation is a behavior that is driven by "an innate need" to explore new things to gain knowledge. According to Deci (1975), intrinsic motivation is stimulated through challenges to explore for its own sake or internal interest (internal reward), rather than the desire for some external rewards. However, extrinsic motivation refers to a behavior that is driven by external factors, such as praise, money, grades, or punishment. Both intrinsic and extrinsic

motivations are crucial and have several effects on students' learning. First, motivation directs behavior toward specific goals. It helps students to set their goals, direct their behaviors, and make choices to achieve these goals. Second, motivation helps to increase students' efforts directly related to their goals. It increases the energy that students need to pursue a task. Third, motivation affects the cognitive process. It affects what learners pay attention to and how effectively they process it. For instance, studies in mathematics showed that anxiety shrinks the capacity of working memory; therefore, students have difficulty to code and encode the information provided in classroom. In the long run, students could not be able to retrieve information from long term memory. It is the sign of whether students are able to learn the content matter or not (Siegler, Fazio, Bailey, & Zhou, 2013). Last but not least, motivation enhances students' performance. It increases students' time on task which is an important factor affecting their learning and achievement.

Educators play a vital role in providing and encouraging students' motivations in science learning. They need to put a lot of effort to get a classroom full of kids enthusiastic about learning, working hard, and pushing themselves to excel. They try to use different instructional activities to motivate their students and to encourage them to live up to their true potential. One of the most effective instructional activities used in education for increasing students' motivation is game-based learning activities. Game-based learning provides more learner-centered, easier, more enjoyable, more interesting learning environments for learners (Kafai, 2001; Prensky, 2003). Game-based learning, is defined as “the innovative learning approach derived from the use of computer games that possess educational value or different kinds of software applications that use games for learning and education purposes such as learning support, teaching enhancement, assessment and evaluation of learners” (Connolly, Stansfield, & Boyle, 2009, p.

3). Game-based learning has been widely adopted for instructional purposes and gained increasing interest from educators and researchers because it helps learners to achieve desired learning goals with an enjoyable process (Gee, 2003). Entertainment value of the computer games provides motivational appeal for the learners (Malone, 1981). Educational games, known as Serious Games, have been developed for people to teach certain concepts while entertaining them at the same time. According to Squire (2005), educational games present simplified version of complex mechanism for players to acquire desired learning objectives through self-expression and interaction with these tools. Because of this reason, Squire feels that educators and researchers need to have a better understanding of how gaming can influence students' learning experiences and increase their motivation to learn.

Game Genres

Gaming has gained increasing interests from educators and researchers because it affects the way the new generations learn. In fact, not all educational computer games are created equal in order to be a good educational game (Papert, 1998). Games have different genres and these genres have different impacts on the game players. Game genre is defined “as a method of categorization used to better understand a collection of video games” (Khenissi, Essalmi, Jemni, Kinshuk, Graf, & Chen, 2016, p. 3). There is no widely accepted standard taxonomy of game genre in the literature. Herz (1997) created a game taxonomy system used by the today's games industry. In his game taxonomy, he distinguishes the game genres as follows: action games, adventure games, fighting games, puzzle games, role-playing games, simulations, sports games, and strategy games. Thanks to new technologies, category of classification has expanded. For instance, online games and virtual reality games could count as new genres for this categorization. Definition of each game genres is provided in the following section.

Action games: These games are generally reaction based games that require quick judgment and snap decisions. They may include some shooting, but generally they are mostly about getting past the things through the course of the game. Some examples for this type of games are Super Mario, Pac-Man, and Frogger.

Adventure games: These games focus on a narrative storyline to explore and solve puzzles to progress through the course of the game. King's Quest, Myst, and Zork are the most known adventure games in this category.

Fighting games: In these games, the player controls a character to battle another character in the game. Street Fighter, Tekken, and Mortal Combat are the examples of this type game.

Puzzle games: These small games are completed by using logic to achieve the ultimate goals. The most famous example of puzzle game is Tetris.

Role-playing games: These games allow the players to take on the role of a character, and control that character in the game environment. Some examples for this type of games are Dungeons and Dragons, Final Fantasy, and Wizardry.

Simulations: Simulations are designed to simulate a real-life situation where the player has to succeed the goals in the game. SimCity is the most famous simulation game in this game genre.

Sports games: These games are basically combination of action and simulation games where players simulate the practice of sports. NBA, NFL, and NHL games count in this game genre.

Strategy games: These games focus on complicated challenges that need to be solved by the player with skillful thinking and planning. Civilization is the well known strategy game among the game players.

Virtual reality games: In these games, players experience and interact in a three-dimensional artificial environment.

Online games: These games comprise all the game genres mentioned above, but they needed to be played through internet or computer network.

Characteristics of Simulation, Adventure, and Quiz/Trivia Games

Simulation Games

Simulation games provide a simplified model of reality system which includes clearly specified variables and dynamic relationships between these variables (Sauvé, Renaud, Kaufman, and Marquis, 2007). In educational setting, these games can offer a safe and a realistic learning environment for students to practice. Thanks to endless repeat of practice, students play the simulation games until they learn the procedure well. Students also can learn real world problem solving skills in a more enjoyable simulated experience of the real world (Reiber, 1996). According to Ranchhod, Gurau, Loukis, & Trivedi (2014) simulation game has the following characteristics; dynamic, simplified, and realistic.

Dynamic: Simulation games represent a dynamic system which provides real-time feedback for players to manipulate and control. The dynamic and interactive character of simulations represents an effective learning environment for players to explore the simulation of real-life problems and situations.

Simplified: Simulation games are incomplete representation of reality which provides a simplified version of a real-life situation. Therefore, simulations should be simple enough to be manageable and provide a level of abstraction.

Realistic: Simulation games should provide a real-life system and its functioning to represent transferable skills applicable to real-life problems. By playing a simulation game, players can receive quick feedback, which in real-life may span over a several years' period.

Adventure Games

Adventure games present an artificial environment that has a narrative storyline to explore and solve puzzles to progress through the game. The game world is usually like a story, in which the user plays a character (Dillon, 2004). The player moves through the story solving puzzles or problems and interacting with objects in the game world. According to Dillon (2004) key characteristics of adventure games:

Narrative: The narrative story is essential in adventure games. Game play in adventure games is primarily driven by a narrative story through which the player moves as the game progresses.

Control of Main Character: The player generally controls the main character in adventure games. The player as a main character explores the game environment and solve the puzzles through the game play.

Puzzle: Adventure games often include puzzles which are solved through interaction with the game world and its objects. These puzzles provide challenges to advance the story.

Exploration: Adventure games usually require exploration and problem-solving abilities in the game play. The player should carefully explore the immediate surroundings to complete all actions and continue to next move.

Quiz/Trivia Games

Quiz games are one of the simplest types of computer games that test players' knowledge about a specific topic (Reimer & Schrader, 2015). These games are generally designed with multiple choice questions or drag and drop game mechanics to provide competitive environments for game players. Time constraint in these games is one of the most important characteristics that challenges players to win the game.

Current Research on Students' Perceptions of Learning Science through Educational Computer Games

Nowadays, computer games are ingrained in our daily lives. People spend most of their time playing computer or video games. We called this new generation "digital natives" in our new world (Prensky, 2001). According to Entertainment Software Association's report in 2016, there are 183 million active gamers in the United States. Also, 63% of U.S. households are home to at least one person who plays video games regularly which is approximately 3 hours or more per week. Despite the fact that U.S people play more computer games than any other group in the world, game-based learning is making a slow progress in our schools (Prensky, 2001). Many people argue that games do not belong in schools. They believe that schools are places to learn to write and read, not playing games. However, many other people argue that computer games are such a great motivator for students that we are crazy not to be using them in schools (Prensky, 2001).

Gee (2003) argues that schools, families, and researchers have a lot to learn about learning from computer games. He thinks that use of games for learning content in schools will become pervasive in the future. He also believes that learning principles that good computer games incorporate can be used in teaching science in classroom environments. Educational

computer games can be one avenue to improve students' learning experiences, promote motivation, engagement, and understanding in science classrooms. Game-based learning has the potential to transform the way in which students learn, motivate, and engage in a way that traditional education does not (Gee, 2003).

According to National Research Council's (2011) report, educational computer games have great potential to improve students' learning in science classrooms. Educational computer games provide an effective learning environment where learners can individualize learning with their own pace, styles, and interests. Thanks to this, the use of educational computer games in science classrooms could potentially improve access to high-quality learning experiences for diverse students. The U.S. Department of Education's (2010) draft National Education Technology Plan states following:

“The challenge for our education system is to leverage the learning sciences and modern technology to create engaging, relevant, and personalized learning experiences for all learners that mirror students' daily lives and the reality of their futures” (p. x).

Over the last decade, researchers have investigated students' perceptions regarding the use of educational computer games in science learning. Marino, Israel, Beecher, and Basham (2013) investigated how the use of video games affects middle and high school grade students' perceptions related to their behaviors and attitudes toward science. The study findings showed that the students had positive behaviors and attitudes regarding the use of educational computer games in science learning. The students expressed the intention to use computer games because they thought educational computer games could make learning about science more fun.

Similarly, Rice, Graves, Stauble, and Mehta (2006) conducted a study to examine how video games influence the participant's perceptions regarding performance on a variety of

Science, Technology, Engineering, and Math (STEM) tasks and tests. Their survey results revealed that video game players are perceived to be superior to non-video game players at STEM tasks and tests. The results also indicated that the participants perceived to be positively associated with science learning.

Riemer and Schrader, (2015) conducted a study to examine students' attitudes, perceptions, and intentions to learn with three different types of educational computer (serious) games in general. The results of the study revealed that students had a positive overall attitude toward learning with educational computer games. In addition, students' perceptions regarding the use of educational computer games in learning were high. The results also showed that students had positive affective perceptions and they perceived that the games have the potential to support their learning performance.

Although educational computer games can be great tools for science learning, there is a limited research in the literature about exploring students' perceptions regarding specifically in science learning. It is still unclear how educational computer games affect students' perceptions of learning science. Therefore, there is a gap in the literature about exploring students' perceptions of learning science through educational computer games. It is very important for researchers to provide a deeper understanding and careful investigation of students' perceptions of learning science through educational computer games.

Current Research on Motivational Effects of Educational Computer Games in Science Learning

In recent years, game-based learning has become a popular area of research and practical tool. Research has primarily focused on achievement, cognitive, and affective dimensions of learning (O'Neil, Wainess, & Baker, 2005). Although there are a lot of research studies have

been done investigating the effects of educational computer games ((Connolly et al., (2012); (Wouters et al., (2013)), these research studies do not directly focus on the motivational effects of educational computer games in science learning. Following literature review fills the gap in the literature by focusing on exploring students' motivation to learn science through educational computer games.

Prior Reviews

Two prior reviews on investigating the effects of educational computer games were found in the literature (Wouters et al., (2013); Connolly et al., (2012)).

Wouters and his colleagues (2013) conducted a meta-analysis study on the effects of game-based learning titled “A Meta-Analysis of the Cognitive and Motivational Effects of Serious Games.” They focused on articles published between 1990 and 2012 and included research studies that employed the experimental group learned the content using a serious game and comparison group engaged in traditional learning method or both groups had to receive the same learning content. Also, they included studies that focused on nondisabled participants and allowed them to estimate effect sizes. In conclusion, they examined 39 research studies and investigated whether serious games are more effective in terms of learning, retention, and more motivating than conventional instruction methods. They used meta-analytic technique to investigate the cognitive and motivational effects of the educational computer games. They found that serious games were more effective in terms of learning and retention, but they were not more motivating than conventional instruction methods.

Connolly and his colleagues (2012) conducted a literature review of journal articles published in between the years 2004 to 2009. The title of the review was “A systematic literature review of empirical evidence on computer games and serious games.” The purpose of the

literature review was to investigate the positive impacts of computer games and serious games on users aged 14 years or above, in terms of learning, skill enhancement, and engagement. They analyzed a total of 129 papers using a data extraction proforma method. They categorized the research studies based upon categorization of the games (purpose of the games, game genre, and platform), categorization of effects of games (such as knowledge acquisition, content understanding, physiological outcomes, affective and motivational outcomes, etc.), and methodology of the studies (such as research design, sample size, etc.). It was found that knowledge acquisition and content understanding were the most frequently occurring outcomes in games for learning and affective and motivational outcomes were in entertainment games. They also found that serious games are being used across many different curricular areas, especially in health, business and social issues, and simulation games are the most used game genres among the studies.

Purpose of the current review

It is the goal of this systematic literature review is to better understand the effects of educational computer games on students' motivation to learn science. Also, it is aimed to investigate what kind of game genres used in science learning and how the researchers measured motivation in their studies.

To better inform the current study, prior research studies have been analyzed systematically, and grouped according to the major themes. There has been a couple of prior reviews that investigate the effects of educational computer games (Wouters et al., (2013); Connolly et al., (2012)). However, motivational aspects of the educational computer games were not the main interest of the researchers in science learning. This literature review is conducted to

fill the gap in the literature considering students' motivation on science learning by using computer game-based learning activities.

This systematic literature review seeks to answer to following questions:

1. To what extent do educational computer games affect students' motivation to learn science?
2. What kind of game genres researchers used in science learning to motivate learners?
3. How did researchers measure motivation in their studies?

To be included in this systematic literature review, each study had to meet all the following inclusion/exclusion criteria:

The inclusion criteria included:

1. Game-based learning
2. Motivational outcomes
3. Science education
4. All grade levels
5. Articles from peer-reviewed journals
6. Empirical studies (qualitative and quantitative)
7. Articles published between the years of 2000-2016

The exclusion criteria included:

1. Descriptive/narrative/prescriptive/conceptual journal articles
2. Dissertations

Electronic search was performed using mainly the Google Scholar, USF Library website, and specific databases such as ERIC, JSTOR, ScienceDirect, Webb of Science, IEEE accessible through the university's library. The search terms included: "game-based learning" or "computer

games” or “digital games” or “educational computer games” or “serious games” or “online games” or “video games” and “science” or “science learning” or “science education” or “science teaching” and “motivation” or “students’ motivation” or “motivational outcomes” or “motivation to learn.”

In total, 13 research studies, investigating the effects of educational computer games on students’ motivation to learn science, were found to meet the criteria and were included in the systematic literature review.

All thirteen research studies have been analyzed systematically, and have been grouped according to the major themes using a comprehensive codebook. The major themes in this systematic literature review were research design, data collection method, grade level, and specific game genres. The findings in relation to major themes were analyzed at a deeper level and organized in a reasonable way to make more sense of the motivational effects of educational computer games in science learning.

Overview of the Studies

In total, thirteen research studies examining motivational effects of educational computer games in science learning were included in this review. Figure 2 below presents the related studies by game genres that researchers employed in their studies. The analysis of the game genres demonstrated that simulation games were used in five studies, role-playing games were used in three studies, strategy games were used in two studies, and one for each action, puzzle and virtual reality game were used in the studies.

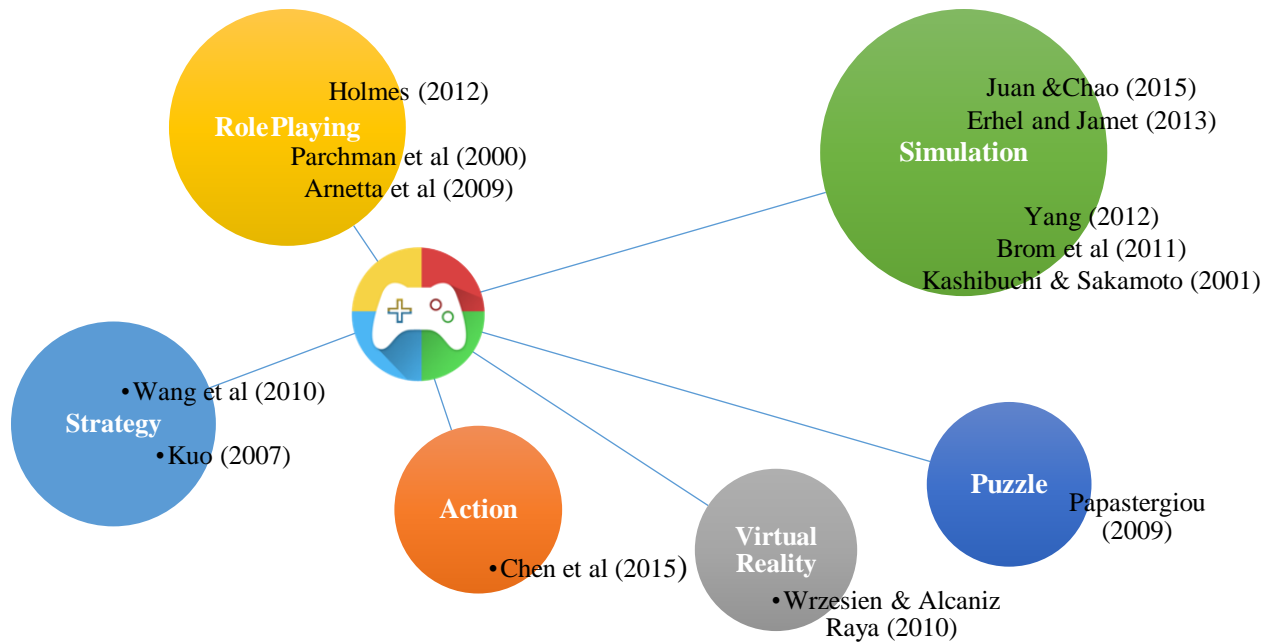


Figure 2. Game Genres used in Studies

Table 2 presents the breakdown of studies by research design and data collection method to measure students' motivational outcomes. The analysis of the study design showed that six studies were employed "quasi-experimental and control comparison" and five studies were employed "randomized experimental and control comparison design," and only one of them was used "one group pre and post test" and "mixed method" research design.

Table 2: Number of Studies by Research Design and Data Collection Method

Data Collection Method to Measure Motivation	Research Design				Total
	Quasi-experimental and control-comparison	Randomized Experimental and control-comparison	One Group Pre and Post	Mixed Method	
Researcher Made Questionnaire	2	3	-	1	6
The Instructional Materials Motivation Survey (IMMS)	1	1	-	-	2
Motivated Strategies for Learning Questionnaire: Motivation Scales (MSLQ-MS)	1	1	-	-	2
Computer Science Learning Motivation Scalogram	1	-	-	-	1
Teacher Survey	-	-	1	-	1
Observation Protocol	1	-	-	-	1
Total	6	5	1	1	13

Detailed analysis of the findings from the listed studies meeting criteria showed in the above generated common themes by game genres. These common themes are simulation games, role-playing games, strategy games, and action/virtual reality/puzzle games.

Simulation Games. Five studies were found fitting into this category. Of these, four studies used quasi-experimental and control-comparison design, and one of them used randomized experimental and control-comparison methods to examine the issue. These studies acknowledge about the students' motivation to learn science mostly through questionnaire formats. When considering motivational effects on science learning, all studies compared a

game-based learning approach to a traditional learning approach. The analysis of the studies revealed that students who played a simulation game gained better learning motivation than those who did not play the game (Juan & Chao (2015); Erhel & Jamet (2013); Yang (2012); Kashibuchi & Sakamoto (2001)). Only one study discovered no statistically significant difference between game group and traditional learning group regarding to students' motivation (Brom et al., 2011). However, the researchers concluded that students' overall appeal towards playing the simulation game was positive.

Table 3. Summary of the Studies for Simulation Games

Author(s)	Research Design/Data Collection Method	Grade Level	Conclusion
Juan & Chao (2015)	Quasi-experimental and control-comparison (IMMS)	High School	Students who played simulation game had stronger learning motivation than those who attended the lectures.
Erhel & Jamet (2013)	Quasi-experimental and control-comparison (Questionnaire)	College	Simulation game provided a learning environment where students had greater learning and motivation.
Yang (2012)	Quasi-experimental and control-comparison (MSLQ-MS)	High School	Students who used a simulation game had better learning motivation than students in the traditional instruction group.
Brom, Preuss, & Klement (2011)	Quasi-experimental and control-comparison (Questionnaire)	High School	There was no statistically significant difference between game group and lecture group in terms of engagement. However, students' overall appeal towards playing simulation game was positive.
Kashibuchi & Sakamoto (2001)	Randomized Experimental and control-comparison (Questionnaire)	High School	Students who played simulation game showed more improvement in the motivation than the students who viewed educational videos.

Role-Playing Games. A total of three studies were found fitting into this category. In all these three studies, researchers employed different research designs, grade levels, and data collection methods to investigate motivational effects of role-playing games. Holmes (2012) conducted a study to assess effects of a role-playing game on middle and high school students' science learning, interests and attitudes about science. The results revealed that the students' post-test science assessment scores and their interests in science increased. However, their attitudes about science decreased. The results from teacher survey indicated that teachers observed an increase in students' interest and motivation to learn science after playing the role-playing game.

Another research study that investigates the effects of the role-playing game on high school students' engagement and learning about genetics was done by Annetta et al. (2009). The results revealed that the students' engagement was greater in the experimental (role-playing game) condition than the control (traditional classroom) condition. Although the students who played the game did not demonstrate a greater understanding of the genetics concepts, their engagement and motivation to learn the topic increased.

Parchman et al. (2000) compared three computer-based instructional strategies (Computer-Based Drill and Practice, Enhanced Computer-Based Instruction, Computer-Based Role-Playing Game) with a computer instruction. The researchers compared the participants' motivation by using Keller's (2010) Instructional Material Motivation Survey and the results showed that the participants in the Enhanced Computer-Instruction group had greater motivation than the participants in the other groups. Also, there was no difference between the role-playing game group and the computer instruction group in terms of motivation.

Table 4. Summary of the Studies for Role-Playing Games

Author(s)	Research Design/Data Collection Method	Grade Level	Conclusion
Holmes (2012)	One-Group Pre and Post (Teacher survey)	Middle School and High School	Teachers observed an increase in students' interest and motivation to learn science after playing the role-playing game.
Annetta, Minogue, Holmes, & Cheng (2009)	Quasi-experimental and control-comparison (Observation Protocol)	High School	Students who played the role-playing game had greater level of engagement than students who attended traditional science classroom activities.
Parchman, Ellis, Christinaz, & Vogel (2000)	Randomized Experimental and control-comparison (IMMS)	College	There was no statistically significant difference between the participants who played the role-playing game and those who used the Computer Instruction method regarding the motivation.

Strategy Games. Two studies were identified in this category. Wang et al. (2010) conducted a study to investigate the effects of a strategy game on motivation and reasoning ability of elementary school students. The researchers divided 124 6th-grade students into a control (n=60), and an experimental group (n=64). Students in the experimental group used strategy games while the control group used a problem based teaching model. The results revealed that there is a statistically significant difference in learning motivation of the experimental group compared with control group. In parallel to these results, Kuo (2007) found that students who played the strategy game successfully motivated in exploring natural science and engaging in learning activities.

Table 5. Summary of the Studies for Strategy Games

Author(s)	Research Design/Data Collection Method	Grade Level	Conclusion
Wang, Tsai, Chou, & Hung (2010)	Quasi-experimental and control-comparison (Computer Science Learning Motivation Scalogram)	Elementary School	The result showed that the strategy game increased students' motivations compared with traditional learning environment.
Kuo (2007)	Mixed Method (Questionnaire)	Elementary School	Students who played the strategy game successfully motivated in exploring natural science and engaging in learning activities.

Action/Virtual Reality/Puzzle Games. Three research studies were found fitting into this category. Chen et al. (2015) conducted a study to explore the effects of solitary and collaborative instructional setting using an action game. Employing randomized experimental control-comparison research design, the researchers compared the students' learning outcomes and motivation. The results showed that the action game encourages exploration of implicit science knowledge and enriches the learning experience and problem solving of the students. However, there was no differences found in learning motivation between control and experimental group.

Another research study was done by Wrzesien & Alcaniz Raya (2010) investigated how a serious virtual reality game affects students' learning effectiveness and their appeal to learn natural science and ecology. The result revealed that students who played the virtual reality game did not perform better in knowledge gain than those who were in the traditional classroom. However, the students preferred to play the virtual game and they were significantly more engaged and motivated in the virtual game learning environment than traditional classroom.

Papastergiou (2009) conducted a study to investigate the effects of puzzle games on high school students' educational effectiveness and their motivation to learn computer memory

concepts. Using a pre and post-test randomized experimental design, the researcher compared the puzzle game learning approach with traditional learning approach. The results indicated that the gaming approach was more effective in increasing students' knowledge of computer memory concepts than the non-gaming approach. In addition, the gaming approach was more motivational for students than the non-gaming approach in terms of increasing the learning of computer memory concepts. According to the researcher's observation, the students in the gaming approach seemed more engaged and interested in task than the students in the traditional learning environment.

Table 6. Summary of the Studies for Action/Virtual Reality/Puzzle Games

Author(s)	Research Design/Data Collection Method	Grade Level	Conclusion
Chen, Wang, & Lin (2015)	Randomized Experimental and control-comparison (MSLQ-MS)	Middle School	There is no differences found in learning motivation between students who played the action game in solitary mode and those who played in collaborative mode.
Wrzesien & Alcaniz Raya (2010)	Randomized Experimental and control-comparison (Questionnaire)	Elementary School	Students who played the virtual reality game had greater appeal (motivation, enjoyment, engagement, usefulness) than student who were in the traditional classroom.
Papastergiou (2009)	Randomized Experimental and control-comparison (Questionnaire)	High School	The puzzle game increased students' motivation compared with the traditional learning environment.

Summary of the findings

The purpose of this literature review was to review the studies examining the effects of educational computer games on students' motivation to learn science. Also, it was aimed to investigate what kind game genres used in science learning and how the researchers measured motivation in their studies. As a result of an intense literature search, a total of thirteen research

studies were included in the study. A detailed analysis into the studies demonstrated that majority of them were quantitative (n=12), and mostly used questionnaires as the data collection method. Only one of the studies was mixed method and it also used a questionnaire to gather data. As for the findings of the studies, a total of four categories were formed from the commonly used game genres in the studies. These were simulation games, role-playing games, strategy games, and action-virtual reality-puzzle games.

Simulation games were the most frequently reported games in science learning (n=5), with role-playing games the second most popular (n=3). The number of strategy games used in the studies was 2 for science learning. Only three studies used any of the other game genre such as action games, virtual reality games and puzzle games.

The synthesis of the findings revealed that game players had stronger science learning motivation than those who did not use educational computer games. Four studies used a simulation game as an intervention supported that these games increased participants' motivation to learn science and make them engaging in the learning activities (Juan & Chao (2015); Erhel & Jamet (2013); Yang (2012); Kashibuchi & Sakamoto (2001)). Only one study has found no significant increase on students' motivation after playing the simulation game (Brom et al., 2011). The majority of the results were overwhelmingly positive for the other genres of the games (Holmes, (2012); Annetta et al., (2009); Wang et al. (2010); Kuo, (2007); Wrzesien & Alcaniz Raya, (2010); Papastergiou, (2009)). Only Parchman et al., (2000) who used a role-playing game and Chen et al. (2015) who used an action game have found no increase on students' motivation to learn science.

Another important finding was about the design of the studies. The analysis of the study design demonstrated that six of the studies were quasi-experimental and control-comparison

design. The second most used research design was randomized experimental and control-comparison design (n=5). One of the studies was one group pre and post test design, and the other one was mixed method.

One of the notable findings about the current review was the type of data collection method that researchers employed in their study. Researcher made questionnaire was the most frequently used instrument to measure students' motivation in science learning (n=6). In two studies, the researchers used Keller's (2010) Instructional Material Motivation Survey to measure students' motivation. Two of the other researchers used Motivated Strategies for Learning Questionnaire (Pintrich, Smith, Garcia, & McKeachie, 1991). The rest of the instruments were Computer Science Learning Motivation Scalogram, teacher survey, and observation protocol.

Conclusion and Discussion

The purpose of this literature review was to review the studies examining the effects of educational computer games on students' motivation to learn science and investigate what kind game genres used in science learning and how the researchers measured motivation in their studies. After carefully searching the literature a total number of 13 research articles were considered relevant for inclusion and exclusion criteria. Common themes of the papers were generated to provide detailed analysis of the findings. These common themes were genre of the games specifically, simulation games, role-playing games, strategy games, and action/virtual reality/puzzle games.

High entertainment value is the one of the most important motivational effects of the educational computer games. Despite findings of the Wouters et al. (2013)'s meta-analysis that found educational computer games are not more motivating than the instructional methods used

in the comparison group, the results of this literature review revealed that educational game players had stronger motivation in science learning and they engaged more in science learning activities than non-gaming approach used in the comparison groups.

Similar to Connolly et al. (2012)'s findings, the results of this review showed that simulation games are the most common used game genre in science learning among the studies. Role-playing games and strategy games were also commonly used game genres regarding to increase students' motivation to learn science. Majority of the studies tended to use quantitative research method. Quasi-experimental and randomized experimental design were the most frequently used designs among the studies. There was no qualitative study found in the literature. Finally, questionnaire was the most common used data collection method in the studies.

Summary

Existing literature on the motivational effectiveness of educational computer games shows that educational game players had stronger motivation in science learning and they successfully engaged in science learning activities. Simulation games are the most common used game genre in science learning among the studies. Also, majority of the researchers in these studies tended to use quantitative and mixed research methods. However, there is a gap in the literature that there is no pure qualitative research study focusing on students' perceptions of learning and motivation to learn science through educational computer games. From a methodological perspective, employing qualitative study design can provide a more comprehensive and deeper understanding of students' learning perceptions of learning and motivation to learn science through educational computer games.

The following chapter details the methodology and procedures of the study. The chapter includes research design, participants, instruments, data collection, and data analysis methods.

CHAPTER III: METHODOLOGY

Purpose

The purpose of this qualitative case study is to explore high school students' perceptions of learning climate change science through educational computer games. Further, it is aimed to investigate what roles educational computer games play in motivating high school students to learn climate change science.

For the purpose of the study, the following research questions are presented.

- 1- What are high school students' perceptions of learning climate change science through educational computer games?
- 2- According to high school students, what roles do educational computer games play in motivating them to learn climate change science?

Philosophical Stance of the Study

Case study design requires a careful consideration for researchers to determine the best philosophical orientation to address the aim of the study (Harrison, Birks, Franklin, & Mills, 2017) because a researcher's philosophical position needs to be aligned with the research question, research design, and methods that will be used in the study (Yin, 2003). This study is grounded in an interpretivist theoretical perspective to better address the research questions.

An interpretivist researcher uses “detailed qualitative data to acquire an in-depth understanding of how meaning is created in everyday life in the real-world” (Travis, 1999, p. 1042). An

interpretivist researcher seeks to understand the world from a subjective point of view and develops subjective meaning of experiences through multiple interpretations of a single event (Merriam & Tisdell, 2015). Case studies that take on an interpretivist approach try to explore individuals' lived experiences by analyzing, constructing, capturing, and contextualizing the phenomenon under exploration. This interpretivist case study seeks to explore high school students' perceptions of learning and their motivation to learn climate change science using educational computer games.

Research Design

A qualitative case study design was used to find the best answers for the research questions. To be able to explore high school students' perceptions of learning and their motivation to learn climate change science through educational computer games, a descriptive case study design was employed. While Yin (2003) defines the case study as “a contemporary phenomenon within its real-life context, especially when the boundaries between a phenomenon and context are not clear and the researcher has little control over the phenomenon and context” (p. 13), Merriam and Tisdell (2015) define it “an in-depth description and analysis of a bounded system” (p. 39). Merriam and Tisdell (2015) describe “one of the most defining characteristic of case study research is delimiting the object of study: the case” (p. 38). The case in this research study is high school students' perceptions of learning and their motivation to learn climate change science using educational computer games.

One of the essential elements of case study research is the study of bounded system (Merriam & Tisdell, 2015). In this study, the bounded system is a group of high-school students who take the Marine Science course and use educational computer games to learn climate change science. A set of two research questions were developed to better understand and describe how

educational computer games influence students' perceptions of learning the content and what roles these games play in motivating them to learn climate change science in the learning environment. To meet this purpose, a descriptive case study research design was used.

A descriptive case study design is useful to explore and understand real-life experiences of people in a bounded system. According to Merriam and Tisdell (2015), descriptive case studies yield rich, thick descriptions of the phenomenon. Similarly, Thomas and Myers (2015) explains descriptive case study as the method of exploring the multiple realities of participants to present a thick description of the phenomenon. In the present study, to provide yield and thick description of the phenomenon, I used Gee's principles about how games teach (2005) and Keller's ARCS Motivation Model (2010) to conceptualize students' perceptions of learning and their motivation to learn climate change science through educational computer games.

Research Setting

The study took place at one of the public-school districts located in the Southeastern United States. The school district employs more than 15,000 teachers and teaches over 200,000 students annually. The school district is the one of the largest districts in the country, with twenty-six public high schools located in a variety of settings, including urban, suburban, and rural areas (County School District, 2015).

Study Context

The Climate Change Narrative Game (CHANGE) is a National Science Foundation (NSF) funded project (NSF Grant #DRL-1316782). This project focuses on the development of climate change curriculum for high school elective marine science courses through the work of University of South Florida and the school districts' marine science teachers. The aim of the project is to help high school students learn complex global climate change science by making it

personally relevant and understandable by using an eBook narrative text embedded with educational computer games, local based approach that focuses on the built and natural environment, and hands-on classroom activities.

The project incorporated new climate change science materials into the existing Marine Science curriculum through the use of: (a) scientifically realistic narratives of future Florida residents, (b) local, place-based approach grounded in west-central Florida using scientific data, (c) a focus on the built environment, (d) an intermedia web based eBook text narrative with sections of text narrative alternating with games, and small simulations, (e) hands-on lab activities that teach climate change science and science/engineering practices.

The CHANGE is a five-year research project, which is currently in its final year. The curriculum materials were developed and piloted in four to eight marine science classrooms during the first three years. In pilot studies, both quantitative and qualitative data were gathered from the student and teacher surveys, midterm and final exams, focus groups, classroom observations, and teacher interviews for formative evaluation purposes. The materials were updated based on the results of the formative evaluations. The project is in the last year and all marine science teachers in the twenty-six high schools in the county with marine science courses fully implemented the curriculum in the 2017-2018 school year.

The existing curriculum, with the CHANGE materials, includes nine units delivered over two semesters, with each unit comprising from 2-6 class periods (see Table 7).

Table 7: Marine Science Course Unit Outline

Unit	Subject
Semester 1	
1	Ocean Exploration
	Sea Level Rise
2	Marine Geology
3	Marine Chemistry
4	Estuaries: Sturgeons
	Estuaries: Mangroves
Semester 2	
5	Marine Physics
6	Populations: Producers
7	Populations: Invertebrates
8	Populations: Vertebrates
9	Capstone: Apollo Beach

This research study was conducted when the curriculum was taught in the second semester. During the first semester, I applied for both County and University of South Florida Institutional Review Boards and these processes took very long. I also employed the criterion sampling method to recruit participants using the teachers' usage of the educational computer games from the first semester. This process is explained in later section. Because of these reasons, I conducted the study using the units in the second semester. The units were "Marine Physics," "Populations: Producers," and "Populations: Invertebrates," "Populations:

Vertebrates.” “Capstone: Apollo Beach” unit was excluded because there was no educational computer game designed for this specific unit.

In the CHANGE project, a total number of thirteen different educational computer games were developed for the students, expressly for motivating students to learn the climate change science. Each game was developed by an interdisciplinary team including a Science Education professor, two Instructional Technology professors, a Geology professor who specializes in climate change, research assistants (PhD students) in Science Education, Instructional Technology and Geology, and five alpha teachers who teach the marine science courses in the county high schools.

The game development process typically followed these steps: the game development team looked at the learning objectives of the target unit; the games were created based on the learning objectives and consultation with content experts (science education professor, geologist, and science major PhD students). This allowed the game developers to get an idea about what goals are needed to be accomplished through playing the game. Then content experts provided the core contents and the important aspects of the unit that can be learned through game interaction. These aspects were generally the parts of the unit that students experienced difficulty to learn with traditional approaches.

After getting information about the core contents of the unit, the game development team came together and brainstormed game ideas to hit the most challenging core contents. They also looked at existing games or activities that support similar learning goals to get an idea about what could be done. As a team, they selected the most useful idea and started by creating a storyboard for it. They then created a prototype of the game that included player interaction, winning and losing conditions, and a means for the player to get feedback on progress towards a

win goal through gameplay. The game design team went through an iterative design process that included playing the game, finding any bugs, providing feedback, and making revisions to get it ready for students to play. The first complete draft of the game was shared with the subject matter experts who gave feedback. Revisions were made based on the feedback.

Finally, they addressed the problems of the game and integrated it into the project website for the pilot study. Students and teachers played the game and completed an electronic survey consisting of specific questions related to the game. In the electronic survey, students were asked what are the things they liked or disliked about the game and what, if any, thing could be added to the computer game that would help make the unit more interesting. Formative evaluation from students and teacher enabled the game development team to address specific issues in the games they mentioned. Table 8 below shows the subject of the units, names and type of the games created for each unit.

Table 8: Names and Type of the Games

Unit	Subject	Name of the Games	Types
Semester 1			
1	Ocean Exploration	Climate vs Weather Level 1 and 2	Puzzle
	Sea Level Rise	Water Gauge Warrior	Role Playing
2	Marine Geology	Beachrock Decoder	Role Playing
3	Marine Chemistry	Glacier Melter	Action
4	Estuaries: Sturgeons	Floridian River Food Pyramid	Puzzle
		Tipping Point	Simulation
	Estuaries: Mangroves	Mangrove Maze	Adventure
Semester 2			
5	Marine Physics	Hurricane Curling	Simulation
6	Populations: Producers	Phylum Match and Red Tide	Quiz/Trivia
7	Populations: Invertebrates	Coral Game	Adventure/ Simulation
8	Populations: Vertebrates	Turtle Crossing	Adventure
9	Capstone: Apollo Beach	Role Playing Game	NA: Not a computer game

In this research study, four different educational computer games created for the second semester was used. The games to be used in this study were Hurricane Curling (Simulation), Phylum Match and Red Tide Game (Quiz/Trivia), Coral Game (Adventure/Simulation), and Turtle Crossing (Adventure). The description of each game was provided in the following section.

Hurricane Curling (Simulation Game): The game was specifically designed for the Physics unit. The purpose of this game was to teach students the effects of high pressure area on the paths of hurricane. By playing this game, students learn how hurricanes behave over land and water, how water temperature fuels a low-pressure area turning it into a hurricane, how prevailing winds determine where a hurricane goes, and how high-pressure areas can change the path of a hurricane. Hurricanes in the Atlantic Ocean move from the east to west, usually starting near the West coast of the African continent. Depending on the location of High Pressure Systems, the path of the hurricane can go anywhere from the Caribbean and Central America, all the way to the northeastern seaboard of the United States. Through the game, the players interact with simulation models of the low and high-pressure area on the map. The goal to win the game is to get a category 4 or 5 hurricane to hit Tarpon Springs in Florida. They start the game by placing the low-pressure area somewhere along the coast of Africa and letting it travel across the Atlantic Ocean. The players can manipulate the bubble of High Air Pressure to alter the wind and path of the hurricane, with a view towards hitting Tarpon Springs. Players have five tries to complete win the game. Figure 3 below shows the screenshots of the Hurricane Curling game.

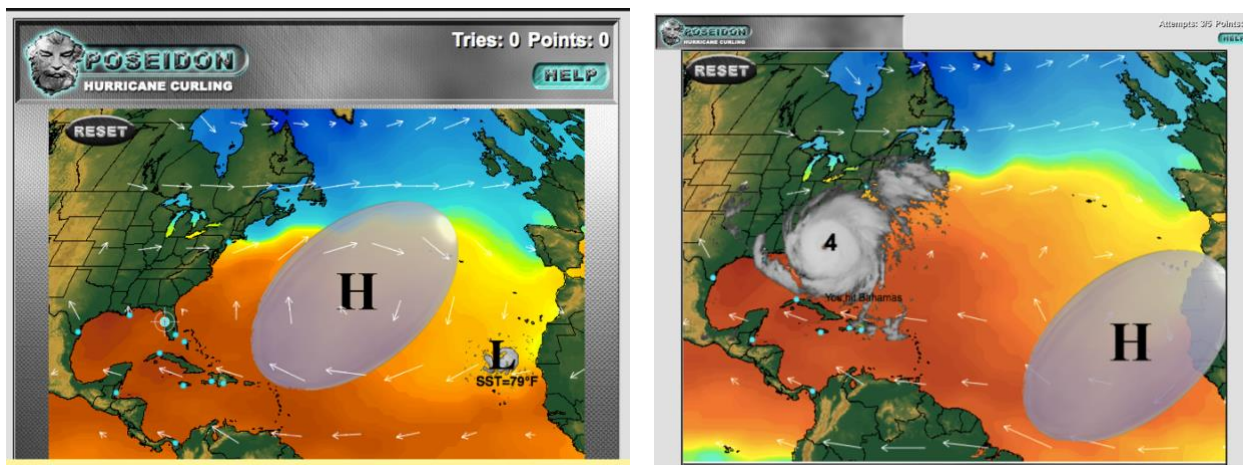


Figure 3. Screenshots of the Hurricane Curling Game

Phylum Match and Red Tide (Quiz/Trivia): These small games were specifically designed with two levels for the Populations-Producers unit. The purpose of the first level called Phylum Match was to teach students the phyla of Algae. By playing this game, students learn different phylums in marine environments. The game was built using a drag and drop game mechanic. Players should respond to five questions correct in a row to win the game and they have 20 seconds to respond to each question. Figure 4 below shows the screenshots of the Phylum Match game.

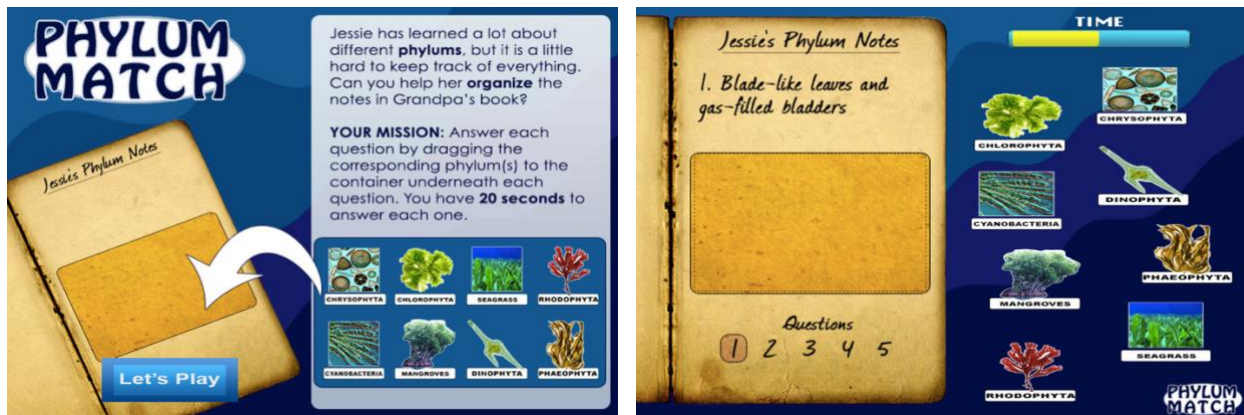


Figure 4. Screenshots of the Phylum Match Game

The second level created for this unit was Red Tide game. The purpose of Red Tide game was to teach students Harmful Algal Blooms, which are often referred to as red tide. By playing this game, students learn information about Harmful Algal Blooms and the factors that contribute to their growth. This game was also built using a drag and drop game mechanic. Players should drag the factors that cause Harmful Algal Blooms and drop over Tampa Bay area to win the game. Figure 5 below shows the screenshots of the Red Tide game.



Figure 5. Screenshots of the Red Tide Game

Coral Game (Adventure/Simulation): Coral game was designed for Population-Invertebrates unit. The purpose of this game was to teach students ideal conditions for coral polyps to live. By playing this game, players control a colony of coral polyps as they travel through the ocean. In the first stage of the game, they must release the spores from their current corals by clicking on each coral to see them appear. The goal is for the players to move as many of the polyps as they can to get to the other level. Once the players gather a pod of polyps they will control them to get another location to start a new colony. They need to maneuver the polyps up and down and find a proper place to settle the polyps. In the third stage, the players need to simulate the ideal conditions for corals to live by manipulating slider bars of sea temperature, water salinity, and acidity of the water. They will win the game if they successfully adjust the slider bars to the best conditions for corals to live. Figure 6 below shows the screenshots of the Coral game.

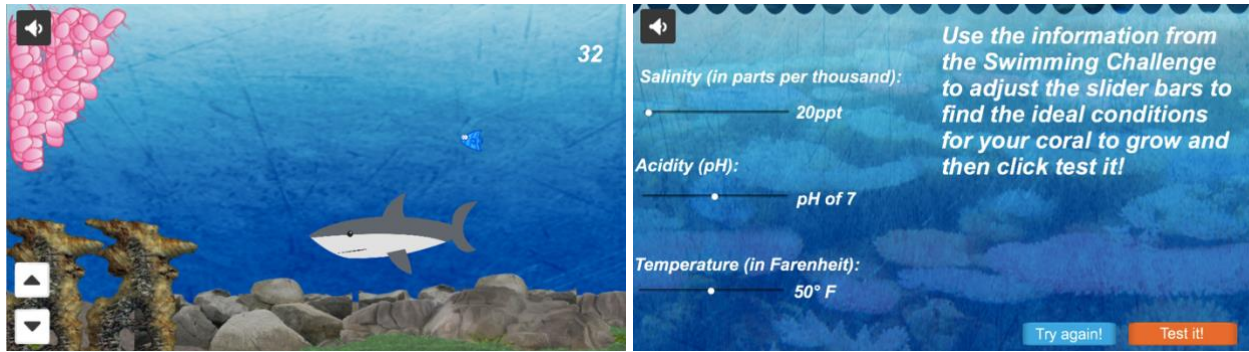


Figure 6. Screenshots of the Coral Game

Turtle Crossing (Adventure Game): The game was specifically designed for Population-Vertebrates unit. The purpose of this game was to teach students the role of the temperature of the sand in determining the sex of baby sea turtles, the phases of life a sea turtle, the predators and natural circumstances in the environment that can prevent the sea turtle from growing into an adult, and how climate change affects the life cycle of the sea turtle. The game had three phases: Nesting, Incubation, and Escape. The goal of the game is to lead a group of ten sea turtles safely into the ocean while making sure the sexes of those turtles are as equally proportional as possible. In the nesting phase, the players take control of a mother sea turtle to lay her eggs on the beach. In this phase, they need to move the turtle and find an appropriate place for the mother turtle to nest her eggs.

In the incubation phase, the players take control of a human who tries to protect the turtle eggs over the course of two months. During that phase, cats and raccoons try to steal eggs from the nest and the players need to fend them off. As time goes the sexes of the turtles appear in egg icons displayed at the top of the screen. The temperature of the sand where eggs were laid is the biggest factor affecting the sexes of the sea turtles. At higher temperatures, the turtle eggs are more likely to become female, at lower temperatures male. However, if the eggs sit in the hot sand for too long they start to overheat and die off. Also, the players need to watch out for high

tides which can also kill the eggs. They need to move the eggs to keep them from getting caught in the tide. If that happens, all the eggs die and the player has to replay the game.

In the escape phase, the player assumes the role of a turtle hatchling. The player need to move the hatched baby turtle towards the ocean avoiding crabs stalking the baby turtles. If a crab touches the baby turtle, it dies and the player has to play the next baby turtle that hatches. The player's final score is determined by how many baby turtles survived, and the relative balance of genders (male and female) of the survivors. The figure 7 shows the screenshots of the Turtle Crossing game.



Figure 7. Screenshots of the Turtle Crossing Game

Population and Sample

Participants included students and their teacher in one of the High School in the Southeastern United States with Marine Science courses. Qualitative research requires the use of purposive sampling methods to select participants for research studies because purposive sampling builds variety and creates opportunities for the researcher to conduct an intensive study (Stake, 2006). In this study, I employed the criterion sampling method to recruit participants. Criterion sampling involves the selection of cases that satisfy an important criterion (Patton,

2002). I used criterion sampling to facilitate the selection of the high school teacher to be included in the study.

A high school teacher was chosen equally based upon the criterion below;

- a) The use of CHANGE materials (specifically educational computer games) in the classroom
- b) Computer Lab access

In the CHANGE project, we had a list serve email account to communicate all teachers who use the CHANGE materials. As a group, we periodically asked the teachers usage of the CHANGE materials in the classroom through list serve emails. Of the teachers' responses to the emails, only three were identified as possible participants (who used the educational computer games and had an access to computer lab in the first semester of the school year in 2017) for the study and were contacted. Of the three that were contacted, only one agreed to take part in the study.

The student participants were selected based on the teacher that was chosen for the study. Students were 10th-12th grade students that represent varying demographics. Marine science course is taken approximately between sixteen to twenty-two students each school year. The marine science course is an elective course, which can be taken by any student with an interest in the marine/life sciences. It can also fulfill state-required science credits as opposed to other science courses, such as Chemistry or Physics. I informed prospective student participants about the purpose, procedures, and confidentiality of participation. After that, I invited them to participate to the study. A total of eight students agreed to take part in the study.

Sampling and data collection were done separately from the original CHANGE project.

In the CHANGE project, complete curriculum materials, eBook, educational computer games,

hands on lab activities, local-based approach, and PowerPoints were used as interventions. The effects of these curriculum materials were investigated through different data collection methods. In this study, I only used educational computer games as an intervention and investigated their effects using a new data collection instrument.

Data Collection Procedures

In this study, I collected that data through the open-ended student and teacher interviews. An overview of the research questions and tools are aligned in (Table 9).

Table 9: Data Collection

Research Questions	Data	Methods
Question 1: What are the high school students' perceptions of learning climate change science through educational computer games?	Student Interview Teacher interview	Semi-structured open-ended interview
Question 2: According to high school students, what roles do educational computer games play in motivating them to learn climate change science?	Student interview Teacher interview	Semi-structured open-ended interview

Data collection procedures took place in one of the high schools in the Southeastern United States in the second semester of 2017-2018 school year. The study was approved by Institutional Review Board (IRB) on May 2, 2018, before collecting data for the study (See Appendix A). Also, the permission was taken from the County before the IRB approval on March 21, 2018 (See Appendix B). After getting both IRB and County approval, I informed

purposefully selected the teacher and the students that verbal and written consents (teacher, student, and parent consents) were required before they participate in interviews. I informed the participants that their participation was completely voluntary and confidential. I also let them know that if they decided not to participate to the study, there would be no adverse consequence.

I conducted one-on-one student interviews (see Appendix C) after students had played each game. They were face to face, semi-structured, and were conducted across 8 sessions for each game, one for each participant. Before the interviews, I requested verbal and written consents from the students and informed them about the interview and then asked them to participate if they choose to do so. They all agreed to participate to the study. I conducted a total of thirty-two student interviews, four with each student, eight for each game. Depending upon students' responses, each interview took around 10 minutes. All conversations during the interviews were recorded with an electronic device.

I also conducted the teacher interview (see Appendix B) after students have played all four games at the end of the semester. Before the interview began, I introduced the purpose of the study and the interview to the teacher. I also requested verbal and written consent before the interview. The teacher interview took around 25 minutes. I conducted all student and teacher interviews at the school in the student lab on an individual basis at times that were mutually agreeable to the students and the teacher and that did not interfere with the school hours. They all wanted to have the interviews during the launch break. So, I offered them free pizza during the interviews. Before coming the school to do interviews, I asked the teacher to nominate four students for each day to play the game and have the interviews. In each day, I let the four nominated students play the game and held the interviews during the launch break. While I was doing the first interview with the first students, others ate their pizzas. I interviewed the other

four students in following day with the same procedures. I tape recorded all the interviews and transcribed these recordings as soon as I finished the first session of the interviews. All research materials including the teacher and the student interviews kept in a flash drive that was stored in a locked file. I will keep the files for at least five years before disposing them all.

Instruments

In terms of understanding how educational computer games influence students' perceptions of learning and their motivation to learn climate change science, I collected the data by using both student and teacher interviews.

Interviews

Interviews are one of the most significant tools to collect data (Creswell, 2013) and they allow the flexibility for participants to give their own meaning to their answers (Galletta, 2013). I conducted semi-structured open-ended interviews with the students (see Appendix C) and the teacher (see Appendix D). Semi-structured interviews allowed me for a general guideline of questions while still leaving room for the possibility of follow-up questions to better understand the participants' positions on the effects of using educational computer games for learning climate change science (Galletta, 2013). I designed the interview questions to address the study's research questions using Gee's (2005) principles about how games teach and Keller's (2010) ARCS Motivation Model. I derived the interview questions related to students' motivation to learn from Keller's the Instructional Materials Motivation Survey (IMMS). Keller's IMMS survey consists of 36 questions covering attention, relevance, confidence, and satisfaction concepts. I picked up two or three questions which specifically tied with each concept from the IMMS survey and added why and how questions to the end to get more detailed explanation of why and how the games affect the students' motivation to learn. I interviewed purposefully

selected the teacher and her eight students using a face-to-face, one-on-one interview method. Before the interview, I introduced the goal of the interview and the purpose of the study to the participants. I requested verbal and written consents (teacher, student, and parent consents) before the interviews. Each interview with the students took around 10 minutes, depending upon their responses. I conducted a total of 32 student interviews (8 students x 4 games) through the second semester (see Appendix C). I also conducted the teacher interview after students have played all four games at the end of the semester (see Appendix D). The teacher interview took around 25 minutes. The interviews helped me to better understand students' perceptions of learning and their motivation to learn climate change science using the educational computer games.

Data Analysis

According to Merriam and Tisdell (2015), data analysis in case study is the process of making sense of the data and involves consolidating and interpreting what people have said. Similarly, Stake (1995) defines the data analysis in a case study as constructing meaning of beginning and final reactions to the collected data. In this research study, open ended, semi-structured interview transcripts of students and the teacher were the main data sources.

Duff (2012) states that in qualitative studies data analysis takes place from the starting of data collection and into the transcription processes. Therefore, every step of the data collection and transcription is significant in analyzing the data. In this study, the data analysis process took place from the beginning of the data collection because every single interview helped me to understand the case better and address the research questions. According to Merriam and Tisdell (2015), one of the first stages of data analysis in case studies should be bringing all the data together and all the data should be retrievable. Therefore, at the beginning of the analysis

process, I brought the transcript of the students and the teacher interviews together, and I coded them together.

Qualitative data analysis can be done through using both deductive and inductive processes. In the deductive approach, themes and codes come from the conceptual framework, previous literature, or the list of the research question; whereas in the inductive approach, themes come from interpretation of the raw data itself (Miles, Huberman and Saldana, 2014). In this study, I used both inductive and deductive analyses to analyze the data. The primary analysis was deductive, based on an existing framework of themes established by Gee's principles about how games teach (2005) and Keller's ARCS Motivation Model (2010). However, I also employed inductive analysis to remain open to the emergence of additional themes and categories in the data. I used inductive analysis to provide clear and better explanations of each theme of the study.

I used Gee's (2005) principles to investigate the students' perceptions of learning climate change science through educational computer games. Gee (2005) presented these principles under three main categories: empowered learners, problem solving, and understanding. Under these three main three categories, I analyzed both the teacher's and the students' responses using co-design, identity, customize, pleasantly frustrating, sandboxes, and meaning as an action image principles because only these principles were applicable to the educational computer games I used in the study. Similarly, I used Keller's (2010) ARCS theory of motivation model to explore what roles the educational computer games play in motivating the students to learn climate change science. The themes were derived from Keller's (2010) ARCS theory of motivation model and they were attention, relevance, confidence, and satisfaction. I analyzed both the teacher's and the students' interviews data based upon these four main themes. In addition, I

used inductive approach to find out how and why the educational computer games affect students' motivation to learn climate change. I developed the interview questions to tie both frameworks, and intended to focus on certain data that leads better understanding of students' perceptions of learning and their motivation to learn climate change science through educational computer games.

I analyzed all the data gathered from the interviews using the computer-assisted data analysis software, HyperRESEARCH. Upon finishing the interviews, I transcribed the audio-recordings manually using Microsoft Word. I sorted, reviewed, and read several times the data of the interview transcripts to determine the students' perceptions of learning and their motivation to learn science using educational computer games. Then, I identified and created the themes based upon the theoretical frameworks of the study ("Empowered Learners, Problem Solving, Understanding" and "Attention, Relevance, Confidence, Satisfaction"). I presented the findings under these created themes. I also created tables of the themes to visually describe where the students' responses were similar and where they differed. I added narrative descriptions of these similarities and differences to be able to make it easier for the readers to understand the visual representation of the tables.

In addition to the students' data analysis, I analyzed the teacher's responses using the same themes to see how they align with or diverge from the students' responses. I talked about the teacher's findings after presenting the students' findings in each theme of the study. In order to increase trustworthiness and credibility of the findings, I also asked a peer to check the data analysis. First, I explained him the themes generated from the theoretical frameworks. Second, I asked him to do the analysis separately using the existing themes I presented. Finally, we came together and compared our findings from the data.

Trustworthiness, Credibility, & Transferability

Instead of focusing on validity and reliability of the data, qualitative researchers focus on trustworthiness of the data. Trustworthiness consists of following components; credibility, transferability, dependability, and conformability (Merriam & Tisdell, 2015).

Triangulation and member checking are well-known and commonly used methods to address credibility of the study. Triangulation means using different sources of data to validate the authenticity of each source (Merriam & Tisdell, 2015). There are four types of triangulation methods in qualitative studies; (1) the use of multiple methods, (2) multiple sources of data, (3) multiple investigators, and (4) multiple theories (Merriam & Tisdell, 2015). In this study, I used multiple source of data (a series of student interviews and teacher interview) method to increase the credibility of the study.

Peer-reviewing is another important way to increase credibility (Merriam & Tisdell, 2015). Peer-reviewing was done during the data collection and data analysis process to evaluate how accurately the researcher collected and analyzed the data. I shared the themes and data analysis with a post-doctoral fellow at University of South Florida. I explained the themes and analysis to him and we analyzed the data separately using the same themes. Then, we came together to compare our findings. In addition, I asked the participants to review transcriptions of their recordings to ensure that I captured their responses accurately.

Transferability basically means the generalization of the study findings to other situations and contexts (Merriam & Tisdell, 2015). There are several ways for transferring the findings in qualitative studies. The most common way is using rich and thick description to enhance the transferability of the study (Merriam & Tisdell, 2015). This research study was designed specifically as a descriptive case study to describe the lived experiences of the students in a

bounded context. I used a thick and high detailed description of the study findings to increase the transferability. However, findings of this study might not always be transferred to other situations. Purposive sampling is another way to address the issue of transferability in research studies. In this study, I selected the participants with the purposeful sampling strategies.

The Role of the Researcher

Since the researcher is considered an instrument of data collection (Denzin & Lincoln, 2003), it is critical to clarify researcher's role in the qualitative research studies. Therefore, my role in this study was an observer, as I was the primary instrument of data collection and analysis. In addition, I was a developer of many of the curriculum materials (especially the educational computer games) and instruments used in the study. My expertise in designing and working with the educational computer games helped me to make more sense of what the students had to say, and it helped me to provide a deeper understanding of what the students' thought about the games used in the study.

In qualitative studies, as Patton (2002) stated “the human factor is the great strength and the fundamental weakness of qualitative inquiry and analysis—a scientific two-edged sword” (p. 433), the human factor is an issue in data interpretation. Because of my involvement with the team that developed the educational computer games and participation in the CHANGE project, my desire to see these programs as efficacious could be read as impacting the outcome of the study. As a team, we created the educational computer games *for the purpose* of increasing students' motivation and perception of learning climate change science. My experience in designing the games might influence my thoughts and ideas about how the games positively affect the students' perception and motivation to learn climate change science. In order to address this potential bias, I followed the procedures during the data collection and data analysis

to ensure the trustworthiness and credibility of the findings. I invited a peer reviewer who was not involved in the CHANGE project or application development to conduct the data analysis separately. We coded the data independently and then came together to discuss and come to consensus on the findings. This increased my confidence that my interpretations were not unduly influenced by my investment in the development of the games.

Ethical Issues

Before starting the study, I obtained approvals from both the County and University of South Florida Institutional Review Boards. I provided appropriate guidelines to the participants in the study to ensure that they are fully aware of the study's scope and their involvement as participants. Also, I informed them about how their privacy will be handled and the way their information will be kept confidential. I used pseudo-names (city names) instead of the real names in all transcripts and other written documents to protect students' and teacher identity. All participants participated in this study were voluntary and I informed them that if anyone was wishing to exit may do so at any time without prejudice. I conducted all interviews on an individual basis at times and places that were mutually agreeable to the participants and that did not interfere with the class hours. I also invited participants to review transcriptions of their recordings to ensure that their responses were accurately captured.

CHAPTER IV: FINDINGS

The purpose of this qualitative case study was to explore high school students' perceptions of learning climate change science through educational computer games, and their motivation to learn using these games in climate change science learning.

I proposed the following research questions;

1. What are the high school students' perceptions of learning climate change science through educational computer games?
2. According to high school students, what roles do educational computer games play in motivating them to learn climate change science?

This chapter reveals the finding of the study, beginning with a description of the participants and gives detailed analysis of students' perceptions of learning climate change science using the educational computer games, and concluding with detailed analysis of the roles of these games in motivating them to learn climate change science.

Demographic Data of the Interview Sample

Eight high school students (6 males, 2 females) and their teacher (female) volunteered to be interviewed on their experiences in using the educational computer games on climate change science learning. The students were at various grade levels, four were eleventh grade, three were twelfth grade, and one was tenth grade. All students have met their science benchmark which means at least 3 out of 5 on the Marine Science end of course review. A total of eight students

were included in this study (see Table 10). The teacher (Denver) has been teaching the Marine Science course for six years. She was using the educational computer games to teach climate change science for two years in her classroom. All participants played the four educational computer games used in the study.

Berlin was a junior student and had average interest in both learning science and playing video games. Dallas was also a junior student. He had a low interest in learning science, however, he had a high interest in playing video games. He defined himself as a hardcore gamer. Jackson was a sophomore student and he had a high interest in both learning science and playing video games. Jakarta was a senior student and did not have much interest in playing video games. She had average interest in both learning science and playing video games. Milano was a junior student and he had a high interest in learning and average interest in playing video games. Tokyo was a senior student. He had average interest in learning science and high interest in playing video games. Vegas was also a senior student and he had low interest in learning science. However, he had a high interest in playing video games. Vegas defined himself as a hardcore gamer. Lastly, Zagreb was a junior student and she had average interest in both learning science and playing video games.

Table 10. Summary of the Background Information about the Participating Students

Name	Gender	Grade	Interest in Learning Science	Interest in Playing Video Games
Berlin	Male	Junior	Average	Average
Dallas	Male	Junior	Low	High
Jackson	Male	Sophomore	High	High
Jakarta	Female	Senior	Average	Average
Milano	Male	Junior	High	Average
Tokyo	Male	Senior	Average	High
Vegas	Male	Senior	Low	High
Zagreb	Female	Junior	Average	Average

Students' Perceptions of Learning Climate Change Science Using the Educational Computer Games

I used Gee's (2005) principles to explore students' perceptions of learning climate change science through educational computer games. Gee (2005) presented these principles under three main categories: empowered learners, problem solving, and understanding. Under these three main three categories, I analyzed students' responses using co-design, identity, customize, pleasantly frustrating, sandboxes, and meaning as an action image principles (see Table 11). I used these principles because only these principles were applicable to the educational computer games I used in the study.

Table 11. Gee's Principles used in the Study

Empowered Learners	Problem Solving	Understanding
<ul style="list-style-type: none"> • Co-design • Customize • Identity 	<ul style="list-style-type: none"> • Pleasantly Frustrating • Sandboxes 	<ul style="list-style-type: none"> • Meaning as Action Image

Empowered Learners

In this category, I analyzed the students' responses using "co-design," "customize," and "identity" principles.

Co-Design. Educational computer games help learners to become active participants in the learning process, rather than passive consumers. Games are interactive so that the learners' actions matter in the game world and this allows them to become active participants in their own learning (Gee, 2005).

The analysis of the data revealed that the games helped the students to become active learners in the learning environment because they found them interactive to play (see Table 12).

Table 12. Summary of the “Co-design” in the Games

Name	Hurricane Curling	Phylum Match & Red Tide	Coral Game	Sea Turtle Crossing
Berlin	X			
Dallas	X			
Jackson			X	X
Jakarta				X
Milano	X	X		X
Tokyo	X	X	X	X
Vegas	X		X	
Zagreb		X		X

Table 12 above shows the students who specifically mentioned that they grasped the content better thanks to the interactivity of the games. Five students (Berlin, Dallas, Milano, Tokyo, and Vegas) stated that the Hurricane Curling game was interactive. For instance, Milano thought that the interactivity of the Hurricane Curling game helped him understand the hurricane by himself thanks to the interactivity and said:

It was very interactive. I think being able to move the objects around by yourself, but not like having it like set in a specific work like it's just depends on where you put it and see how it works. It helped me to learn better.

Similarly, Vegas stated:

Interacting with the hurricane, and like moving it around, it was a kind of fun. You know it's just to see like you know the size of hurricane is increasing or decreasing. It just gives you a better understanding how the hurricane works.

Three students (Milano, Tokyo, and Zagreb) mentioned that the Phylum Match & Red Tide games were interactive, and they thought that their actions matter in these games. For example, Zagreb stated that the games provided feedback which helped her to interact with the game elements and see what she did wrong or correct in the games. She stated:

I feel like having to drag each one like for the first the phylum part dragging them like it helped me like be interactive with it and like see which ones were correct. And then the red tide one, I feel like that it was interactive because if it was wrong I don't remember if it told you if it was wrong or not, but you would just have to keep trying till you got the right one.

Similar to the Phylum Match & Red Tide games, three students (Jackson, Tokyo, and Vegas) believed that the Coral game was very interactive and they learned the best when the content is presented in an interactive way. Jackson was one of these students and he thought that interacting with the game objects helped him to actively get involved in his own learning and he learned the best in this way.

Five students (Jackson, Jakarta, Milano, Tokyo, and Zagreb) found the Sea Turtle Crossing game very interactive. Tokyo was one of these students who liked the interactivity of the game and interestingly he mentioned that this feature helps learners to understand the content easier and they would not be “normal” if they do not understand it in that way. He said:

Like protecting the eggs and moving the eggs, seeing which eggs are like turning male or female and their overheating at the high tide. It was very interactive. I liked it a lot.

Something like I said before like it stimulates certain outcomes only if you like certain actions taking place in the game and it makes easier to understand the content. If you don't get it, you need like I don't know... The only reason you wouldn't be able to get if you are not normal, it's like that.

Customize. Educational computer games allow learners to use their own favored learning styles, rather than prescribed learning processes. The games are very powerful tools to provide different learning styles which can work for different people (Gee, 2005).

The analysis of the data revealed that the games helped the students to perceive the contents with different learning styles (see Table 13).

Table 13. Summary of the “Customize” in the Games

Name	Hurricane Curling	Phylum Match & Red Tide	Coral Game	Sea Turtle Crossing
Berlin	Visual	Experiential		Visual
Dallas	Visual	Experiential		Visual
Jackson	Visual/Kinesthetic	Experiential	Experiential	Visual/Kinesthetic
Jakarta			Experiential	Visual/Kinesthetic
Milano	Visual			
Tokyo	Visual/Kinesthetic	Experiential	Experiential	
Vegas	Visual/Kinesthetic		Experiential	Visual
Zagreb	Visual	Experiential	Experiential	Visual

Table 13 above shows the students who specifically mentioned that the games allowed them to perceive the content with different learning styles including visual learning, kinesthetic learning (learning by doing), and experiential learning (trial and error).

The students who played the Hurricane Curling and the Sea Turtle Crossing game thought that these games provided them different styles of learning to fit their own learning preferences. They mentioned these games helped them to discover the contents with either visually or kinesthetically or both ways. For instance, Tokyo was one of the students who believed that the Hurricane Curling game helped him to understand the facts about the hurricanes both visually and kinesthetically. He thought that the game allowed him to see differently and not forcing him to understand the content in a certain way and he stated:

It just gave me a better understanding of the material because I'm in other classes that like forced me to like learn in certain ways so like I guess people who have like trouble learning it in a certain way, the game provides like “learn differently” for example, visually and like kinesthetically, it would be really helpful for them.

Similarly, Vegas mentioned:

The game provided different learning styles especially for ones who don't know how hurricanes work, I think this would be the best way to do it. Because it was interactive and visually shows how it works.

Similar to the Hurricane Curling game, six students (Berlin, Dallas, Jackson, Jakarta, Vegas, and Zagreb) thought that the Sea Turtle Crossing game allowed them to understand the content via their favored learning styles. Berlin, Dallas, Vegas, and Zagreb mentioned that the game visually showed them the life process of the sea turtles. They thought they visually comprehend better and they prefer to learn this way when it is compared to learning from listening to a lecture or reading a textbook. In addition to visual learning, Jackson and Jakarta mentioned that the game helped them grasp the content not passively reading or listening it, but rather actively doing it. Jackson said:

Like for me I hate reading because it gives you a point where you almost gonna go to sleep. Then playing games make me more like happy, active and focused, like moving your body, and learning by doing instead of like just passively reading. It is more interesting and keeps me motivated to learn more.

Similarly, Jakarta said:

I think it is like the game I feel like it is better than like reading a book or something because I think like it grasps like students' attention and like it is more. You actually learn by doing it instead of like a bookwork or PowerPoints. I think it is like more entertaining yeah it is more entertaining than the other methods.

In addition to visual and kinesthetic learning, experiential learning was another learning style that the students thought the Phylum Match & Red Tide and the Coral games provided

them to get into the content differently. The students thought these games allowed them to get familiar with the contents by trial and error. Jackson was one of these students who discovered the facts about phylums by trial and error in the Phylum Match game and he said:

Ummm, I thought I learned pretty much like kind of like process of elimination like with a trial and error. Because with the pyhlums game I did get it wrong a couple times so like after a while I realized that it gave you time and if you don't get it right in a certain amount of time then you gotta start matching all over again. So, once I like got it wrong I would just click another one to see like which one I thought it was.

Similarly, Tokyo stated:

It doesn't let you go on unless you know the material and ummm... the games are interactive so like you know like with a trial and error. That's the thing that most people learn. I did learn like through trial and error that like certain phylums go into certain places.

Identity. Educational computer games allow learners to take on new roles that trigger a deep investment and feel authentic to learn new skills. Learners can achieve these goals by taking a role-playing (identity) of the characters in the games (Gee, 2005).

Among the four games I used in this study, only the Sea Turtle Crossing game had a feature of role-playing (identity) in the game mechanic. In this game, the students take the role-playing of the mother sea turtle who was finding a place to nest her eggs, a guy who was trying to protect the eggs from the cats and raccoons, and baby sea turtles who were trying to get into water. The analysis of the data showed that the Sea Turtle Crossing game offered the students the opportunities to take on identities of the characters in the game and helped them to perceive the content better through these new identities (see Table 14).

Table 14. Summary of the “Identity” in the Games

Name	Hurricane Curling	Phylum Match & Red Tide	Coral Game	Sea Turtle Crossing
Berlin				X
Dallas				X
Jackson				X
Jakarta				
Milano				X
Tokyo				
Vegas				
Zagreb				X

Five students (Berlin, Dallas, Jackson, Milano, and Zagreb) mentioned that they understood the life process of the sea turtles by taking on identities of the characters in the game. They enjoyed taking the role of the characters and found it very interesting to learn that way. Berlin was one of these students and he thought that “I gotta be a sea turtle basically and think that way, so it gave me a better perspective about the sea turtle’s life process.” Dallas was another student who found switching roles in the game interesting and he said:

Well I like that you kind of went from the sea turtle nesting to the person protecting the eggs and then back to the baby sea turtles trying to get to the sea, so you turn a switch roles and that was interesting.

Similarly, Milano mentioned that the game was authentic to learn by allowing him to take the roles of the characters in the game and he stated:

It was authentic, first you take the role-playing of the mother sea turtle who was finding a place to nest her eggs, and then hippie guy who trying to protect the eggs from animals, and baby turtles trying to get into water. It was really cool.

In conclusion, the analysis of the students’ responses showed that the games “empowered learners” by helping them to become active participants, allowing them to use their own favored

learning styles, and letting them take on new roles that trigger a deep investment to learn new skills in the learning environment. In addition to the students' responses, the teacher's (Denver) responses supported these findings as well. Denver mentioned "the games were perfect match with what we were doing in the class" and she was very happy to use them in the curriculum.

With regards to the "co-design" principle of the games, she thought the games were interactive and they helped the students to get actively involved in the learning process. She described her students as active learners so that they can understand better when they actually do it rather than only reading or hearing the content. She said:

With playing the games, you know it was like an extra ummm... what do I want to say... it was like an extra layer to what they were learning because like I said before my students are very active learners. They have to do it in order for them to really understand the content.

With regards to the "customize" principle, she thought the games helped the students to understand more with different learning styles including visual, kinesthetic, etc. She mentioned that she had some students who loved to learn visually and some other students who liked learning by doing so that the games allowed them to have an opportunity to grasp the content with their own favored learning styles.

As for the "identity" principle, she mentioned that the Sea Turtle Crossing game was very useful because the game allowed the students to take on the roles of the sea turtles and try to understand the content through their lenses. Denver thought the Sea Turtle Crossing game was "her favorite out of all games" because it helped her students to make a meaningful connection with the content by taking the roles of the mother sea turtle who was looking for a place to hatch

her eggs, the guy who was trying to protect the eggs, and the baby sea turtles who were trying to get into the water.

Problem Solving

In this category, I analyzed the students’ responses using “pleasantly frustrating” and “sandboxes” principles.

Pleasantly Frustrating. Educational computer games should have adjusted challenges that make the games challenging, but doable. The games also need to provide an effective feedback that helps the players to see their effort is paying off (Gee, 2005).

The analysis of the data revealed that the games provided adjusted challenges that helped the students to feel challenged, but also that success is possible and the feedback that helped them to see whether they are on the right path for success or not (see Table 15).

Table 15. Summary of the “Pleasantly frustrating” in the Games

Name	Hurricane Curling	Phylum Match & Red Tide	Coral Game	Sea Turtle Crossing
Berlin	X		X	X
Dallas	X		X	X
Jackson	X	X		X
Jakarta	X	X	X	
Milano		X		X
Tokyo	X	X		X
Vegas	X		X	X
Zagreb		X	X	

One of the main reasons that made students feel “pleasantly frustrated” was the challenging feature of the games. The students mentioned several times that the games were challenging, but doable and they loved to be challenged in the learning environment. Dallas was one of the students who believed the Hurricane Curling game was challenging, but doable and he mentioned “I mean at first it was kind of challenging, but you kind of get the hang of it pretty

easily, so it took a few tries to get the goal.” The students also mentioned that they liked to be challenged because that challenge made them engaged with the content and learn better. Tokyo was one of these students and he said after playing the Phylum Match and Red Tide games:

Ummmmm, in a sense, it challenged me. So, in that case, saying it was challenging. Yes, it was and I like challenging stuff cuz you know it helps you to engage more, like you know get better, and stuff better.

Similarly, Dallas found the Sea Turtle Crossing game more challenging than the other three games, but he thought that it was still the most enjoyable one among the games. He said:

Well, it was a little bit it was just a little bit more than the other games like there was more to do and there were more variables, but that also kind of made it look a little bit more challenging than the others, but it was still the most enjoyable.

Another main reason that made students feel “pleasantly frustrated” was the feedback in the games. The students loved to see their progress and how their effort was paying off while playing the games. The students especially liked the visual feedback in the Hurricane Curling game. Vegas was one of the students who thought that the visual feedback helped him to understand how to strategically create a category five hurricane to hit the target in the game. He stated:

I love the simplicity and I love the difficulty at the same time. It was cool and the visual feedback definitely helped me understand how hurricanes are formed, what caused them to increase and what caused them to decrease. It was the most interactive way I could find out that hurricane survives more in the water while the land kind of kills it off. It was pretty easy, what I had to do was I just grabbed the high-pressure move it around to see

which areas its strongest and which ones its weakest and once I do that I had to find a way strategically move it into the target.

The students also liked the visual feedback in the Sea Turtle Crossing game. The game was designed to provide the visual feedback (gender of the eggs, calendar, etc.) to the players to see how they are making progress towards the goal of the game. Thanks to visual feedback, the students were able to see whether they are moving in the right direction towards success or not. For instance, Milano mentioned that the visual feedback in the games helped him to understand more how he was making progress in the game and he said:

Ummmm, probably the one the eggs really turning the different genders on the calendar on the side and eggs on the top, it helped a lot because if I didn't see them I probably wouldn't understand why and how they changed. So, the visual feedback helped me to see how well I was doing and understand the content more.

Sandboxes. Some educational computer games have sandboxes which provide learners a realistic environment that has mitigated risks, allowing them to play and learn without feeling too much pressure or fear of failure (Gee, 2005).

The analysis of the data showed that the students were able to experiment and discover the content in a real-world environment without having any fear of failure in the Hurricane Curling and the Sea Turtle Crossing games (see Table 16).

Table 16. Summary of the “Sandboxes” in the Games

Name	Hurricane Curling	Phylum Match & Red Tide	Coral Game	Sea Turtle Crossing
Berlin				
Dallas				
Jackson	X			
Jakarta				
Milano	X			X
Tokyo				
Vegas				
Zagreb				X

Table 16 above shows the students who specifically mentioned that the games allowed them to find out the content by providing them (sandboxes) a realistic environment that has little or no risk.

Two students (Jackson and Milano) talked about how the Hurricane Curling game provided them a simulation of a real-life situation and how this feature helped them to understand the content. For example, even though Jackson found weird the goal of the game which was creating a category 5 hurricane to hit Florida, he found it very interesting to grasp the content in that way and he said:

It is kinda simulate the real-life situation which was kinda cool. It was close to real-life scenario because first it was weird because like the hurricane's target was actually Florida and it kinda reminded me the Hurricane IRMA a little bit. Yeah, it was kinda like it starts as a small and then it increases all the way to category 5 before it hits the target. It was very interesting to learn that way.

Zagreb was one of the students who liked to learn with sandboxes in the Sea Turtle Crossing game. She mentioned it was interesting to learn real-life situation with risk-free opportunities to practice and learn and she said:

I thought it was always interesting like you know like whenever you go to the beach and like see the sea turtles nests and so I thought like it's always interesting to like find out what happens, but like you're always told like don't go near the nest and stuff like that so you don't really getting to see it, but the game was cool because it shows you what happens in the real world and like actually you are able to like go near it without having to touch them and like doing nothing to them.

Milano was the only student who liked the real-life simulation in both the Hurricane Curling and the Sea Turtle Crossing games. He found it very useful to have a real-world situation to experiment what they have learned in the classroom so that the games helped him to realize how the hurricanes are formed and how the sea turtles survive in the real world.

To sum up, the analysis of the students' responses revealed that the games increased the students' "problem solving" skills because the games were challenging, but doable, they provided effective feedback that helps them to see their effort was paying off and learn the content in a real-world environment without having any fear of failure. In addition to the students' responses, the teacher's responses aligned with these findings as well.

As for "pleasantly frustrating" principle, Denver thought the games had adjusted challenges to make the students feel challenged, but success is possible. She described her students as competitive so that they always wanted to be challenged and win the games. Similar to what the students said, Denver also believed that the Sea Turtle Crossing game was more challenging than the other games. However, she thought "the game challenged the students, but then it helped them to understand the material at the same time."

As for "sandboxes" principle, Denver thought that the Hurricane Curling game provided a safe realistic environment for the students to experiment how to create a category 5 hurricane

and how it travels through the Atlantic Ocean without having a fear of failure. She stated that the students were able to understand the topic better with the realistic simulation model of hurricanes in the game.

Understanding

In this category, I analyzed the students' responses using "meaning as an action image" principle.

Meaning as an Action Image. Learners understand words, events, and processes better through concrete imagery and visual experiences. Educational computer games are great tools to provide learners visualization of the words, concepts, events, and processes (Gee, 2005).

The analysis of the data showed that the students were able to perceive the content better thanks to visual experiences that they had in the games (see Table 17).

Table 17. Summary of the "Meaning as an Action Image" in the Games

Name	Hurricane Curling	Phylum Match & Red Tide	Coral Game	Sea Turtle Crossing
Berlin	X			X
Dallas	X			X
Jackson	X	X	X	X
Jakarta	X	X		X
Milano	X	X	X	X
Tokyo	X		X	X
Vegas	X			X
Zagreb	X	X	X	X

Table 17 above shows the students who specifically mentioned that the visualization of the games helped them to understand the words, events, and processes better.

All students who played the Hurricane Curling and the Sea Turtle Crossing games mentioned that these games provided them visual representation of how hurricanes are formed and the life cycle of the sea turtles, allowing them to understand complex phenomenon through

visual experiences. They mentioned these games visually showed them “events” which was about how the hurricanes work and “process” which was about the life cycle of the sea turtles. For instance, Dallas stated that the Hurricane Curling game was a good tool for students because the game clearly showed him how the hurricanes form, and he said:

Well... I thought it was good tool to use for students because it was really accurate and kinda easily and clearly showed me what happens when hurricanes form. I liked that it showed just exactly how big or how small the hurricanes will get in high pressure and low-pressure area.

Similar to the Hurricane Curling game, all students thought that the Sea Turtle Crossing game helped them to visually see the life process of the sea turtles. Berlin was one of those students who believed that the game helped him by showing every steps of the life process of the sea turtles starting from hatching to getting into water. He stated:

Visualization helped me a lot like seeing kinda what happens to the turtles when they hatch their eggs and how so many of them go away and by showing what happens to baby turtles when they hatched in and how so many of them die instead of making it in to water. The game showed me everything that could happen to them.

Besides providing opportunities for the students to perceive events and processes better through visualization, the games also helped them to perceive the words and the concepts with the visual interaction. For instance, in the Phylum Match & Red Tide games, four students (Jackson, Jakarta, Milano, and Zagreb) thought that the games helped them to understand the names of the different phylums and the factors that cause red tide through visual representation. Jackson was one of these students who mentioned that the games helped them to perceive the content visually by saying:

It kind of like with the red tide one, it shows you like the factors that cause red tide and it shows you pretty much the definition of each phylum and you just had to match them in the Phylum Match game. I thought it helped me a lot by showing what each phylum does and it shows you like if this happens like what you can expect with red tide.

Similarly, in the Coral game, four students (Jackson, Milano, Tokyo, and Zagreb) mentioned that they were able understand the ideal conditions for corals to live through the visual interaction in the game. Tokyo was one of these students and he mentioned that the game helped him to grasp the content by visually interacting with the game elements. He said:

The game helped me to learn the optimal conditions for coral to live, pH, water temperature, salinity mmm, and the fishes that they somewhat interfere with by allowing me to visually interact with the game objects.

In summary, the analysis of the students' responses showed that the games increased the students' "understanding" with explaining the words, events, and processes through concrete imagery and visual experiences. The teacher's responses were quite similar with the students' responses. She thought that visualization feature of the games was highly valuable for the students to understand the complex phenomenon in science. She especially talked a lot about the visual feature of the Hurricane Curling and the Sea Turtle Crossing games and that feature helped her students to understand the contents better. She mentioned that the Hurricane Curling game helped the students (especially the visual learners) to understand how hurricanes work by "visually showing what happens with the hurricane and what causes it to go from a category 1 to 5." Similar to the Hurricane Curling game, she thought the Sea Turtle Crossing game was "very useful to show the students the life cycle of the sea turtles and how the temperature affects their

gender.” She described herself as a visual learner and thought that “this is the best way I can learn anything because when I actually see it, it cements in my brain.”

Motivational Roles of the Educational Computer Games

I used Keller’s (2010) ARCS theory of motivation model to explore what roles the educational computer games play in motivating the students to learn climate change science. Therefore, the themes were derived from Keller’s (2010) ARCS theory of motivation model. These themes are attention, relevance, confidence, and satisfaction. I analyzed the students’ interviews based upon these four categories.

Attention

Attention is extremely important to make students’ learning experience stimulating and interesting (Keller, 2010). Analysis of the data revealed that all four games gained the students’ attention because of various reasons. These reasons were engaging, interesting, and focusing.

One of the main reasons the students thought the games increased their attention was they found the games “engaging” (see Table 18).

Table 18. Summary of the “Engaging” in the Games

Student Name	Hurricane Curling	Phylum Match & Red Tide	Coral Game	Sea Turtle Crossing
Berlin	X	X	X	X
Dallas	X	X	X	X
Jackson	X	X	X	X
Jakarta	X	X		X
Milano	X	X	X	X
Tokyo	X	X	X	X
Vegas	X	X	X	
Zagreb	X		X	X

Almost all students thought the games helped them to keep their attention because the games “forced” them to engage with the content. For instance, Jackson explained how the Hurricane Curling game was engaging and kept his attention high saying:

The game was very engaging because if you don’t know like what you are doing you had to control basically the whole simulation, if you don’t know what you are doing and then basically nothing happens. You have to engage with it to win the game.

Jackson also shared that he sometimes got distracted by his classmates in regular classroom environment. However, the Hurricane Curling game helped him to keep his attention and made him engage with the content. He said:

I was not distracted at all. I mean maybe people like talking to me then I get distracted that happens in normal learning, but the game like I just played it by myself and I was involved in it. It kept my attention.

The students also thought that the games were engaging because the contents were presented in a form of a video game. Dallas and Vegas thought that it did not matter what the content was about, they would prefer to learn with the games because the games helped them to visualize the content and made them easier to get into the content. For instance, Dallas explained why he thought the Coral game was engaging:

Umm like I said earlier, I'm a visual learner, so instead of like a textbook for me which I can't really get into, like if you have a game I play video games as is like it's just easier for me to get into whatever subject it is just because it's in the form of video game.

Interactivity of the games was another reason why students found them engaging. The students loved how the games were interactive and encouraged them to keep trying until they

reached the goal of the games. They found the games interactive because they were able to move the objects around and actively interact with the game elements. For instance, Milano stated

The movement in the Red Tide game was engaging because I would have to try and grab each element that causes the Red Tide and place it in the right area on the map. It like helped me to engage and pay attention more.

Role-playing feature of the games was another reason that students found them engaging. For instance, in the Sea Turtle Crossing game the students loved to get the roles of a mother sea turtle who was trying to find a place to nest her eggs, a guy who was trying to keep the cats and raccoons away from the nested eggs, and baby sea turtles who were trying to get the ocean. Berlin engaged with the content by taking the roles of the characters in the game by saying “you got to be a turtle basically and think like that way.”

In addition to engaging, another reason why the students thought the games increased their attention was they found them “interesting” (see Table 19).

Table 19. Summary of the “Interesting” in the Games

Name	Hurricane Curling	Phylum Match & Red Tide	Coral Game	Sea Turtle Crossing
Berlin				X
Dallas	X	X	X	X
Jackson	X			X
Jakarta	X			X
Milano	X	X	X	X
Tokyo	X	X	X	X
Vegas	X	X	X	X
Zagreb	X			X

Students especially found the Hurricane Curling and the Sea Turtle Crossing games very interesting. Seven students (Dallas, Jackson, Jakarta, Milano, Tokyo, Vegas, and Zagreb) found the Hurricane Curling game very interesting. For instance, although Jackson was not into the

topic “hurricane,” the game helped to make it interesting for him to learn by saying “Ummm. I am not that big into the hurricanes so not really, but I thought like it took like a boring topic and made like it made it interesting to learn.” Similarly, Jakarta thought that the Hurricane Curling game was interesting because “there were different techniques that you needed to use in order to even hit the target.” In addition, all students found the Sea Turtle Crossing game interesting because they thought that the game “stimulated their interest to learn more about the life cycle of sea turtles.”

Some students (Milano and Tokyo) also found the games interesting because they had a special interest in learning science. For instance, Milano mentioned several times that he wanted to “become a scientist” in the future and he found all the games interesting to learn more about the science. He stated after playing the Coral game:

I feel like most people wouldn't care about how the corals are growing and what conditions they need, but I care because I want to be a Marine Biologist and I feel like that information I learned from the game would have helped with that.

Although Milano and Tokyo had a special interest in learning science, Dallas and Vegas did not. However, they had a special interest in playing video games. These two students found all the games interesting because they had an interest in playing any types of video games including educational computer games. They thought playing games helped them to understand more any subjects even though they did not have any special interest into them. For instance, Vegas stated after playing the Red Tide and Phylum Match games:

Well, I'm not particularly a fan of the science or marine biology as an example, but I am interested in games in general. So, even someone who doesn't like the subject itself, I can actually get into the subject and understand it a bit more.

Although several students found the Hurricane Curling and the Sea Turtle Crossing games very interesting some students did not find the Phylum Match & Red Tide and the Coral games very interesting. Berlin, Jackson, Jakarta, and Zagreb had no special interest in learning about the Red Tide & Phylums and the Coral games. Hence, these games did not help to stimulate their interest to learn the content.

Another main reason that the students thought the games increased their attention was they found the games “focusing” (see Table 20).

Table 20. Summary of the “Focusing” in the Games

Name	Hurricane Curling	Phylum Match & Red Tide	Coral Game	Sea Turtle Crossing
Berlin	X	X	X	X
Dallas	X		X	
Jackson	X	X	X	X
Jakarta	X	X	X	
Milano		X		
Tokyo			X	X
Vegas				
Zagreb	X	X	X	X

The students mentioned several times that the games helped them to keep focus on the lesson by presenting the content which was what they were learning about and by making it easier and more challenging to learn. They believed that the games kept them focus on “what they were doing and what they were learning all the time.” Tokyo was one of the students who believed the Hurricane Curling game kept him focus on learning about hurricanes and he mentioned:

I read them in a textbook and learn about it a little bit because I live in Florida and kinda need to know about hurricanes. The game was all about the hurricanes and whatever we

were trying to talk about during the lesson and it helped me to focus more learning about hurricanes and helped me to keep my attention.

The students also found these games helpful to focus on the lesson because they thought “it was easier to learn the content by playing a game.” Dallas mentioned after playing the Coral game:

Umm, well, it was just easier for me to see what was going on by playing the game. It was just easier for me to focus and understand everything. Umm, I just made everything look a little bit more understandable.

In addition to making the content easier to learn, Zagreb thought that these games provided a challenge for her to focus on the lesson more. She mentioned that “the games (Red Tide and Phylum games) were like a challenge and they made me more focused on what needs to be done and what we are learning.”

In conclusion, the analysis of the students’ responses revealed that the games increased the students’ “attention” by making the learning more engaging and interesting and by helping them to focus on the content more in the learning environment. In addition to the students’ responses, the teacher’s responses supported these findings as well. Denver mentioned the games were “engaging” and they helped the students to engage with the content more because “they helped the students to understand more with different methods like visually, actively getting involved in the content of the games.” She also found the games “interesting” to stimulate the students’ interest in learning the content. She stated that “the games always make the learning more interesting for the students cuz I feel like it's fun for them then they are gonna tend to learn it and remember it better.” In addition to engaging and interesting, Denver thought the games helped the students to focus on the lesson more. She mentioned that the games were all about

what they discussed in the class so that they helped them to focus more and understand more the content.

Relevance

Relevance is a key factor for learners to be motivated to learn. Therefore, they need to believe that instructional materials are worth-knowing and personally relevant to them (Keller, 2010). Analysis of the data revealed that students found the games personally relevant to them because the games provided a real-world connection and worth knowing information.

“Real-world connection” feature of the games was the one of the main reasons that students found them relevant (see Table 21).

Table 21. Summary of the “Real world connection” in the Games

Name	Hurricane Curling	Phylum Match & Red Tide	Coral Game	Sea Turtle Crossing
Berlin	X			X
Dallas	X			X
Jackson	X	X		X
Jakarta	X			X
Milano	X	X	X	X
Tokyo	X	X	X	X
Vegas	X			X
Zagreb	X			X

All students stated that “real-world connection” in the Hurricane Curling and the Sea Turtle Crossing games helped them to make a personal connection with the content. They especially talked a lot about the hurricane Irma we had on September 2017 after playing the Hurricane Curling game. They all found the Hurricane Curling game was related to their own life and took advantage of playing it which provided a real-life situation to them. For instance, Dallas stated how important was to know about hurricanes and how the game simulated how the hurricanes work by saying:

Well I think it's important for people to know about hurricanes. You know we just had Irma and that was really devastating so I think people should take time to like learn about it. It's pretty same, it's a simulation that shows how the hurricane forms and that was definitely something I could relate to.

Similarly, Tokyo mentioned:

Well considering that I live in Florida that like this does like apply to like my every day like yearly life because like every year we probably have a hurricane or two. You know we had Irma and Maria. It is really important for people to know the hurricanes.

All eight students also found the Sea Turtle Crossing game personally relevant to them. Almost all students heard about the sea turtles in the class or in the news and they were worried about them. They thought the game helped them to make a personal connection by providing a real-world scenario of the life cycle of the sea turtles. Milano was one of the students who believed that the game had a real-world connection and he said:

It is a real thing that turtles come on the beach and people are going to try and look at them and probably mess with the eggs. The game showed us how the turtles have to try and get into the water and I liked figuring out how the genders change based on the temperature.

In addition to providing a real-world connection, the games also provided “worth knowing information” to the students (see Table 22). The students found the content of these games relevant because they thought the games helped them to obtain useful information.

Table 22. Summary of the “Worth-knowing information” in the Games

Name	Hurricane Curling	Phylum Match & Red Tide	Coral Game	Sea Turtle Crossing
Berlin	X			X
Dallas	X			
Jackson	X		X	X
Jakarta	X	X	X	X
Milano	X			X
Tokyo	X			X
Vegas	X			
Zagreb	X	X	X	X

All eight students believed that the content of the Hurricane Curling game was worth knowing so that it was worth learning as well. While Jackson, Jakarta, and Vegas thought the content of the Hurricane Curling game was worth knowing because “it was a part of the lesson,” rest of the students thought that it was worth knowing because “people should know the things about the hurricane.” Milano was one of the students who believed that the content of the game was worth knowing by saying “Like in life I feel like you should know like why these things happen in nature, like how the hurricane is formed and created and those types of stuff.” Similarly, Zagreb stated “Since we live in Florida we have hurricanes and we kinda need to know information about hurricanes.”

All students except for Dallas and Vegas also believed that the content of the Sea Turtle Crossing game was worth knowing. These students thought “it was important to learn about the life cycle of the sea turtles because they threatened or endangered due to human actions.” Tokyo was of the students who thought the sea turtles were endangered because of human actions:

I like to see like a sea turtle and like in their natural habitat, it's gonna be very rare because these things are going like endangered and like all this tourism it's not bad you know economically for us, but like it is like you know it is natural in economics like all

these like these beach chairs are everywhere, these umbrellas and people and then these things hatched and there's like there's like leftover cans and like sharp glass so you see like a turtle died because it stepped on a piece of shark glass you know like that shouldn't happen like it should not made of the scene. This should be like maybe grown 20 years lay the eggs and maybe not be in danger, but like just because of a piece of glass.

Also, like the pollution in the oceans, it is sickening. I don't like it.

Milano was another student who also worried about the sea turtles' life because of the human actions and he mentioned:

I feel like people should know like what turtles have to go through to try and survive basically. Because most people when they see the turtles nesting or something like that they all want to come around and look and it probably messes up their life.

Although almost all students believed that the Hurricane Curling and the Sea Turtle Crossing games provided real-world connection and worth knowing information to them they did not have the same feelings for the Phylum Match & Red Tide and the Coral games. The students generally had a hard time to personalize the content of these games (see Table 23).

Table 23. Summary of the “Hard to personalize” in the Games

Name	Hurricane Curling	Phylum Match & Red Tide	Coral Game	Sea Turtle Crossing
Berlin		X	X	
Dallas		X	X	
Jackson			X	
Jakarta		X	X	
Milano				
Tokyo				
Vegas		X	X	
Zagreb		X	X	

Although the contents of these games were related to the place where the students live, they did not personalize the contents to the things they have seen, thought, or done in their real-life. For instance, Berlin had a hard time to personally relate to the content of the Phylum Match & Red Tide games. She said “the content might be worth learning depending on what you want to be, if it is necessary yeah, but not for everyone.” Dallas, Jakarta, Vegas, and Zagreb also thought that it was hard to personalize the content of these games because “they have never seen the phylum or red tide before.”

Similar to the Phylum Match & Red Tide games, the students were not able to make personal connection with the Coral game. All students (except for Milano and Tokyo) mentioned either “I do not go to the beach very often” or “I have never seen a coral before” so it was hard for them to make personal connections with the content.

To sum up, the analysis of the students’ responses demonstrated that the students found the games relevant because the games provided real-world connection and worth knowing information to them. However, the students had a hard time to personalize the content of the Phylum Match & Red Tide and Coral games. The teacher’s responses were similar with the students’ responses. Denver mentioned that the real-world connection of the games helped the students to make a personal connection with the content. For instance, she believed the Hurricane Curling game made the content personally relevant to the students because the game was built on using the local-based approach. In addition, she thought the games provided worth-knowing information to them. She stated, “Since we are living in Florida, it is really important to learn the content related to climate change science and the games were great tools to provide the worth-knowing information.”

Confidence

Confidence refers to learners' expectations for success in their learning. Therefore, they need to feel confident about their learning (Keller, 2010). Analysis of the data demonstrated that all students felt confident about their learning and they thought the games helped them to discover useful information (see Table 24).

Table 24. Summary of the “Confidence” in the Games

Student Name	Hurricane Curling	Phylum Match & Red Tide	Coral Game	Sea Turtle Crossing
Berlin	X	X	X	X
Dallas	X	X	X	X
Jackson	X	X	X	X
Jakarta	X	X	X	X
Milano	X	X	X	X
Tokyo	X	X	X	X
Vegas	X	X	X	X
Zagreb	X	X	X	X

All students were able to complete the four games successfully and achieved the intended learning outcomes at the end. They also believed that “they had a control over their own learning experience” which improved their confidence level in the learning environment.

The students also considered these games as either “easy to understand,” or “well-balanced,” or “difficult to understand” (see Table 25).

Table 25. Summary of the “Difficulty Level” of the Games

Name	Hurricane Curling	Phylum Match & Red Tide	Coral Game	Sea Turtle Crossing
Berlin	Well-balanced	Difficult	Easy	Well-balanced
Dallas	Well-balanced	Difficult	Easy	Well-balanced
Jackson	Easy	Well-balanced	Easy	Well-balanced
Jakarta	Well-balanced	Difficult	Easy	Well-balanced
Milano	Well-balanced	Difficult	Easy	Well-balanced
Tokyo	Well-balanced	Difficult	Easy	Well-balanced
Vegas	Well-balanced	Difficult	Easy	Well-balanced
Zagreb	Well-balanced	Difficult	Well-balanced	Well-balanced

Almost all students (except for Jackson) thought the difficulty level of the Hurricane Curling game as “well-balanced.” They all felt very confident about what they understood from the game because they found the game “challenging, but doable.” For instance, Dallas stated how the Hurricane Curling game was well-balanced to understand the conditions for a hurricane to form and how it travels by saying:

It's not too hard, but it's not too easy at the same time. It's good for learning about what conditions have to be there in order for hurricane to not only form, but at the same time how it travels. So, I think it's at a good level, where it is at.

Similarly, all students found difficulty level of the Sea Turtle Crossing game “well balanced.” They thought the game a bit more challenging than the Hurricane Curling game, but they were pleased with the level of challenge they had at the end. While Vegas described that challenge as “a nice tasteful challenge,” Tokyo felt “the game has to be challenging to make him get engaged in the learning.”

Although the students liked the difficulty level of the Hurricane Curling and the Sea Turtle Crossing games and defined them as “well-balanced,” they did not like the level of difficulty in the Phylum Match & Red Tide and the Coral games. While they considered the

Phylum Match & Red Tide games “difficult,” they thought that the Coral game was “easy.” They described the Phylum Match & Red Tide games as “difficult” because the games required them to have a prior knowledge about the phylums and red tide in order to be completed. The students had struggled to retrieve that prior knowledge that they had in the classroom. Even though they felt confident about their learning at the end of the Phylum Match & Red Tide games, they had a hard time to complete these games. For example, Berlin did not remember the names of phylums while playing the Pyhlum Match game, but the game helped him to figure them out by “trial and error.” He stated “At first, I didn’t remember much of it so, it was kind of hard, but then I figured that out after a couple of tries.”

In contrast, they found the Coral game “easy” to complete. In the Coral game, the students were getting information about the ideal conditions for corals to live with the pop-up screens as they move along the game. They had to remember the information provided in pop-ups and use them at the end of the game. Therefore, almost all students (except Zagreb) found the difficulty level of the Coral game much easier than the other games. For instance, Jackson found the game easy and explained the difficulty level of the game by saying:

I thought was pretty simple because it kind of it showed you like everything you needed especially in the second part when it stops the screen showed you kind of like what conditions you need to select for corals to live at the end of the game.

In summary, the analysis of the students’ responses revealed that all students felt “confident” about their learning using the games. They also considered these games as either easy to understand, or well-balanced, or difficult to understand. In addition to the students’ responses, the teacher’s responses aligned with these findings as well. Denver thought “the games make the learning accessible to all types of the students” because they all love playing

video games and they feel confident when they understand using these games. In terms of difficulty level of the games, similar to the students, she found the Hurricane Curling and the Sea Turtle Crossing game as challenging, but doable, the Phylum Match & Red Tide games as difficult and the Coral game as easy. She also thought the Phylum Match & Red Tide games were “a little bit confusing” because there was a lack of direction in the gameplay.

Satisfaction

Satisfaction is about learners’ feeling of satisfaction with evaluation of their learning experience. Learners should be satisfied with their learning experiences in the learning environment (Keller, 2010). Analysis of the data revealed that the games gave the students a satisfying feeling of accomplishment and made the learning more enjoyable because the games were “fun” and the students were able to reach the goal of the games by gaining desired learning outcomes (“goal completion”).

“Fun” feature of the games was one of the main reasons that made the students feel satisfied in their learning. Almost all students mentioned that they had fun while playing all four games (see Table 26).

Table 26. Summary of the “Fun” in the Games

Name	Hurricane Curling	Phylum Match & Red Tide	Coral Game	Sea Turtle Crossing
Berlin	X		X	X
Dallas	X	X	X	X
Jackson	X	X	X	X
Jakarta	X	X	X	X
Milano	X	X		X
Tokyo	X		X	X
Vegas	X	X	X	X
Zagreb		X	X	X

The students believed that the games provided them a more enjoyable learning environment than the traditional learning environment. Almost all students mentioned that “they were able to understand the topic better while playing the game and having fun with it at the same time.” Some students (Jackson, Jakarta, and Milano) mentioned that they had fun while playing the Hurricane Curling game even though they did not successfully finish it in their first try. Jakarta was one of these students and she thought the game was fun even though she did not win it in her first try. She said:

I thought it was very educational and fun at the same time. It teaches you about the lesson that you learn. It was kinda difficult like trying a get the hurricane to hit the Tampa, but I did not give up and I still tried it until I got it. Even though I still did not get it, it was still fun, I enjoyed it and I feel like a lot of more students would love to play it.

“Goal completion” was another main reason that made the students satisfied in their learning. Almost all students felt extremely satisfied when they beat and reached the goal of the games (see Table 27).

Table 27. Summary of the “Goal Completion” in the Games

Name	Hurricane Curling	Phylum Match & Red Tide	Coral Game	Sea Turtle Crossing
Berlin	X	X	X	X
Dallas	X	X	X	X
Jackson	X	X	X	X
Jakarta		X	X	X
Milano	X	X		X
Tokyo	X			X
Vegas	X	X	X	
Zagreb	X	X	X	X

The students especially struggled in the Phylum Match & Red Tide games and they found them very challenging and difficult to complete. However, they felt very happy and satisfied

when they successfully finished these games. Challenging feature of these games made them satisfied and showed them their efforts were paying off at the end. For instance, Berlin and Jackson had a hard time to win the games, but they felt very satisfied with their results. Jackson said “It made me feel like I was satisfied with my last results that I got. I have finally passed it and felt very happy.” Berlin stated “It took me a few tries to get it and then I finally got it and felt very happy.”

Rewarding feature of the Hurricane Curling and the Sea Turtle Crossing games was another satisfaction factor for the students related to “goal completion.” In these games, the students were rewarded with the game points (Hurricane Curling) and little stars (Sea Turtle Crossing). The students tried very hard to get the maximum points (5 points) and full stars (5 stars) in these games. Tokyo was one of the students who tried hard to get full stars in the Sea Turtle Crossing game and he stated:

It was hard for me, but I won the game in the second try. Even though I got three stars out of like five and the first one I got one I was like woowow Goodness, this time I have done much better (laughs). I was very satisfied.

Zagreb was another student who focused on improving her result in the Sea Turtle Crossing game and she said:

Yeah I felt very satisfied because you had to like improve your score and like focus on like how to get that score when you had focus on the challenge of like getting an even amount like boys and girls sea turtles and finally get the full stars.

To conclude, the analysis of the students’ responses showed that the games made the students feel “satisfied” about their learning because the games were fun and the students successfully reached the goal of the games by gaining desired learning outcomes. The teacher’s

responses supported these findings as well. Denver said “the games were fun to play and the students want to learn, but they also want to have fun, so the games can do both of these at the same time and they are all for it.” As for the goal completion in the games, Denver liked the reward system in the Sea Turtle Crossing game and she found it very useful to make the students enjoyed and feel competitive to reach the highest score of the game.

Summary of the Findings

In summary, eight high school students and their teacher participated, with playing four different educational computer games in this study. Six students were male and two of the students and their teacher were female. The students were at various grade levels, four were eleventh grade, three were twelfth grade, and one was tenth grade and they all met their science benchmark on the Marine Science end of course review. The students also had varied interest in both learning science and playing video games.

Findings from the students’ responses demonstrated that the educational computer games helped the students to perceive better in learning climate change science. The games also helped the students to be more motivated to learn climate change science. The teacher’s responses also supported these findings.

I used Gee’s (2005) principles about good computer games to explore students’ perceptions of learning climate change science through educational computer games. Gee (2005) presented these principles under three main categories; empowered learners, problem solving, and understanding. Under these main three categories, I analyzed students’ responses using the principles of co-design, identity, customize, pleasantly frustrating, sandboxes, and meaning as an action image.

As for the co-design principle, the students thought the games helped them to become active learners in the learning environment because they found them interactive to understand with. Interactive feature of the games helped the students to be actively involved in their own learning so that they perceived better in learning climate change science. The students also believed the games provided an effective feedback which helped them to interact with the content and see their progress in the games.

As for the customize principle, the students mentioned the games helped them to understand the contents by providing different learning styles. The students thought that the games allowed them to understand the content with different learning styles such as visual learning, kinesthetic learning (learning by doing), and experiential learning (trial and error) which can fit their own learning preferences.

As for the identity principle, only the Sea Turtle Crossing game offered the them the opportunity to take on identities of the characters in the game and helped them to grasp the content through these new identities. They found it interesting and fun to take a role of the character in the game and find out the content in that way.

As for the pleasantly frustrating principle, the students thought the games were challenging, but doable and they provided effective feedback that helped the them to see their effort was paying off. They several times mentioned that they loved to be challenged in the learning environment so that the games challenged them to get engaged more with the content.

As for the sandboxes principle, the students shared that they were able to experiment and deiscover the content in a real-world environment without having any fear of failure. the Hurricane Curling and the Sea Turtle Crossing games allowed them to comprehend the content by providing them a realistic environment that had little or no risk. They found it very interesting

to understand a real-world situation with risk-free opportunities to practice and learn in these games.

As for the meaning as an action image principle, the students mentioned the games visually helped them to perceive the words, events, and processes better. They thought the visualization feature of the games was very useful for them to understand the complex phenomenon in science. They shared that they were able to grasp the content thanks to visual experiences that they had in the games.

In addition to the students' perceptions of learning climate change science, I used Keller's (2010) ARCS theory of motivation model to explore what roles the educational computer games play in motivating the students to learn climate change science. Keller's (2010) ARCS theory of motivation model had four categories, attention, relevance, confidence, and satisfaction and I analyzed the students' responses under these four themes.

For attention, the students believed the games increased their attention by making the learning more engaging and interesting and by helping them to focus on the content in the learning environment. They thought the games helped them to keep their attention because the games forced them to engage with the content. They also found the games interesting to understand more about the science and kept them focused on what they were doing and what they were learning in the classroom.

As for the relevance, the students shared that the games provided them a real-world connection and worth-knowing information in the learning environment. They mentioned the real-world connection of the games helped them to make personal connection with the content. They also thought the games presented them with useful information to understand. In addition,

the students had a hard time to personalize the content of the Phylum Match & Red Tide and Coral games.

As for the confidence, the students thought the games helped them to feel confident about their learning. They also believed the games allowed them to have control over their own learning experience. The students considered these games as either easy to understand, or well-balanced, or difficult to understand.

As for the satisfaction, the students mentioned the games gave them a satisfying feeling of accomplishment and made the learning more enjoyable. They thought the games were fun and helped them to enjoy in the learning environment. In addition, they shared that they were able to reach the goal of the games by gaining desired learning outcomes at the end of the games.

Conclusion

This chapter presented the findings of the students' responses. The responses to the research questions were provided through the students' perceptions of learning climate change science using the educational computer games and what roles these games play in motivating them to learn climate change science. Finally, it provided a summary of the findings.

Chapter five presents discussion and the researcher interpretation of these findings, and concludes with implications for practice and suggestions for further study.

CHAPTER V:

DISCUSSION

In this final chapter of my dissertation, I discuss the findings presented in Chapter 4 in relation to the study's research questions and prior research. Additionally, I discuss research and pedagogical implications of my study. I finish the chapter presenting study limitations and recommendations for further research.

Discussion of Research Question 1

What are the high school students' perceptions of learning climate change science through educational computer games?

The first research question was about the students' perceptions of learning climate change science using the educational computer games. In order to respond to this question, I talked about how the educational computer games affect the students' perceptions of learning climate change science using Gee's (2005) principles about how games teach. I also talked about the teacher's responses to see how they align with or diverge from the students' responses.

Educational computer games have huge potentials to create an environment for learners to have a deeper understanding that can last a lifetime and prepare them for future learning (Gee, 2005). In line with prior research studies (Marino et al., (2013); Rice et al., (2006); Riemer & Schrader, (2015)), the findings of the current study also showed that the educational computer games increased the students' perceptions of learning science, specifically climate change

science. This study, however, also shed light on the specific characteristics of the educational computer games that affect the students' perceptions to learn climate change science. The findings revealed that the games have different characteristics to improve the students' perceptions to learn climate change science. I explored these features using Gee's principles related to how games teach. Gee (2005) presented these principles under three main categories; empowered learners, problem solving, and understanding. Under these three main categories, I investigated the students' perceptions of learning using co-design, identity, customize, pleasantly frustrating, sandboxes, and meaning as an action image principles.

Within the "empowered learners" category, Gee (2005) describes four principles, co-design, customize, identity, and manipulation and distributed knowledge. However, only the first three principles (co-design, customize, and identity) were applicable to the educational computer games used in the study. As for the co-design principle of the games, the analysis of the data showed that the students found the games to be interactive and that the games helped them to become active learners in the learning environment. The interactive feature of the games helped the students to get actively involved in the learning process (Prensky, 2001). Similar to what Gee (2005) said, the students mentioned several times that they want to be active agents rather than just passive recipients in the learning environment, so the interactivity of the games allowed them to reach that goal. The games created an interactive environment where the students actively engaged with the game elements so they were able to see that their actions and decisions mattered through the gameplay. Therefore, the interactive feature of the games affected the students' perceptions of learning climate change science positively.

As for the customize principle, the analysis of the data revealed that the games helped the students to understand the contents by supporting different learning styles. The students

mentioned the games allowed them to grasp the content by engaging different learning styles including, visual learning, kinesthetic learning (learning by doing), and experiential learning (trial and error). The students thought the games provided them different styles of learning to fit their favored learning preferences. Some students mentioned that they understand the content better visually while others mentioned that they can understand best through learning by doing or through by trial and error. They all preferred to learn using the games when compared to learning from a lecture or reading a textbook.

Regarding the identity principle, only the Sea Turtle Crossing game had a feature of the identity in the game mechanic. The analysis of the data revealed that the game offered the students the opportunities to take on identities of the characters in the game and helped them to understand the content through these new identities. Since the students were able to identify with the game characters, such as the mother sea turtle, the guy who protects the eggs, and the baby sea turtles, they were able to understand the content more efficiently. The students genuinely enjoyed taking on the identities of the characters and, as a result, were more eager to learn.

In addition to the analysis of the students' data, the analysis of the teacher's data produced similar findings. The teacher found that the games empowered learners by helping them to actively participate in learning, allowing them to use their own learning styles, and letting them take on new roles that trigger a deep investment to learn new skills in the learning environment. She mentioned the games helped her students to actively participate in class discussion because they helped the students to understand more of the content using different learning methods. The games created a different method of learning environment where students had a better perceptions of learning climate change science.

Within the “problem solving” category, Gee (2005) describes seven principles: well-ordered problems, pleasantly frustrating, cycles of expertise, information ‘on demand’ and ‘just in time’, fish tanks, skills as strategies, and sandboxes. However, only the pleasantly frustrating and the sandboxes principles were applicable to the educational computer games used in the study. Regarding the pleasantly frustrating principle, the analysis of the data revealed that the games provided adjusted challenges which helped the students feel challenged, but also helped them realize success is achievable. On a number of occasions, students mentioned that they enjoyed being challenged because it enabled them to become more engaged with the content, which in turn helped with the learning process. In addition to providing adjusted challenges, the games provided effective feedback that helped the students determine whether they are on the right path for success or not. Students looked forward to receiving effective feedback as it allowed them to monitor their progress and see first-hand how their efforts were paying off.

Pertaining to the sandboxes principle, analysis revealed that the games provided a safe and realistic environment for students to experiment and discover content without fear of failure. Students in this study found that the games, specifically the Hurricane Curling and the Sea Turtle Crossing, helped them to explore what they learned in the class, their own pace. This is similar to what Gee (2005) stated about how games allow learners to explore things with their own speed and own time. They also found these games interesting because they provided them a real-life situation with risk-free opportunities to practice and understand the content better.

The teacher’s findings aligned with the results produced from students’ findings. The teacher believed the games increased the students’ problem solving skills because the games were challenging, but doable. Additionally, the games provided effective feedback which helped them to track their efforts and confidently understand the content in a real-world environment

without having any fear of failure. She mentioned that the games provided the students with a good challenge and enabled them to feel more confident with the course content. In addition, it was important that the games provided a safe and realistic environment for students to experiment and practice what they learned in the classroom.

Within the “understanding” category, Gee (2005) describes the principles of system thinking and meaning as an action image. In this category, meaning as an action image principle was applicable to the educational computer games in the study. The analysis of the data showed that the games increased the students’ understanding through explanation of words, events, and processes through concrete imagery and visual experiences. Visualizing scientific phenomenon is valuable for student learning of science (Ainsworth, 2008). The students thought the games were well suited for visualization. The students often mentioned that they understand better when content is presented in a form of games because they helped them to visualize words, events, and processes. They thought the games made the complex mechanism of climate change science easier to understand.

The teacher’s responses were quite similar with the students’ responses. The teacher thought the games increased the students’ understanding with explaining the words, events, and processes through concrete imagery and visual experiences. She thought that the visualization feature of the games was highly valuable for the students to understand the complex phenomenon in science. She defined her students and herself as visual learners and mentioned that she always wanted to provide visualization of the abstract content to make it easier to understand. Therefore, she thought the games helped the students to grasp the content easier through visual experiences.

In summary, the analysis of the data revealed that the educational computer games increased the students' perceptions of learning climate change science. The findings also showed that the games have different characteristics to improve the students' perceptions to learn climate change science. Interactivity, providing different learning styles, role playing, challenging, creating a realistic environment, and providing visual experiences to understand were the specific characteristics of the educational computer games used in this study. These features had a positive impact on the students' perceptions of learning climate change science.

Discussion of Research Question 2

According to high school students, what roles do educational computer games play in motivating them to learn climate change science?

The second research question was about the roles of educational computer games in motivating the students to learn climate change science. To respond to this question, I reviewed about the motivational roles of the educational computer games in learning climate change science using Keller's (2010) ARCS motivation model. I also talked about the teacher's responses to see how they align or diverge with the students' responses.

Educational computer games have great potential to increase students' motivation and can be excellent tools for supporting learning and motivating younger generations (Garris et al., 2002). Similar to previous research studies (Annetta et al., (2009); Erhel & Jamet (2013); Holmes, (2012); Juan & Chao, (2015); Kashibuchi & Sakamoto, (2001); Kuo, (2007); Papastergiou, (2009); Wang et al., (2010); Wrzesien & Alcaniz Raya, (2010); Yang, (2012)), the findings of the current study also showed that the educational computer games increased students' motivation to learn science, specifically climate change science. This study, however, also shed light on the roles of the educational computer games in motivating them to learn

climate change science. The findings showed that the games play various roles to motivate the students to learn climate change science. I explored these motivational roles using Keller's (2010) ARCS theory of motivation model. This model had four essential factors of learning motivation: attention, relevance, confidence, and satisfaction. I presented motivational roles of the games under these four factors.

“Attention” is one of the essential factors of learning motivation because it makes students' learning experience stimulating and interesting (Keller, 2010). The findings in this study demonstrated that the games increased the students' attention because they made the learning more engaging, interesting, and focused. One of the main reasons behind students' increased attention had to do with the level of engagement involved between the game and student. The games helped them to engage with the content thanks to the features of interactivity, visualization, and role-playing. The game mechanic, the repeated cycle of interaction in the games (Schell, 2008), forced the students to actively interact with the game elements and helped them to engage with the content (Prensky, 2001). Visualization was another feature of the games, which made the students fully drawn to the content. Visualizing the scientific phenomenon through gaming helped the students to engage and made it easier to get them into the content (Ainsworth, 2008). Finally, role-playing feature of the game (Sea Turtle Crossing game) helped with peaking the students' interest in the content. They felt engaged by taking on the roles of the characters in the game and seeing the world through their lenses.

Another important reason why the students thought that games increased their attention was because they found the games to be interesting. The students thought the games made the content interesting to learn. Even though some students did not have any special interest in learning science, the games (Hurricane Curling and Sea Turtle Crossing games) helped to

stimulate their curiosity to learn the content. The students believed the games took the boring topics and made them interesting to learn. Although several students found the Hurricane Curling and the Sea Turtle Crossing games very interesting, some students did not find the Phylum Match & Red Tide and the Coral games interesting. Some of these students could not figure out how to play the games because they did not want to read the directions. They did not read directions because they prefer to figure out the things with trial and error. Therefore, they might not find these games as interesting as others.

The focusing feature of the games was another main reason which increased the students' attention. They believed that the games not only kept them focused on what they were learning in the classroom, but they also made learning easier and more enjoyable. The games were designed so that students could achieve the desired learning outcomes in the class in order to focus more on learning the content. The games also helped the students to focus more on the content because they thought the games made it more understandable than other ways of learning such as reading a textbook, listening to a lecture, etc. They also thought that the games provided a challenge for them to focus on the lesson more. The students enjoyed the challenge that the games presented, which in turn resulted in their increased focus in the classroom.

In addition to the analysis of the students' responses, the teacher's responses supported these findings as well. The teacher thought the games increased the students' attention by making learning more engaging and interesting and by helping them to focus on the content. Not only did she find the games to be very engaging, they were also very useful teaching tools because her students love to play computer games. She believed the games were interesting enough to trigger the students' curiosity to learn more about climate change science. This engagement and curiosity made the students focus on and learn more about the content she was

trying to teach in the class. She thought the games were great materials to catch the students' attention to learn science.

“Relevance” is another essential factor of motivation because learners need to understand the significance of the learning and believe the information is relevant and valuable to them (Keller, 2010). The finding in this study showed that the games provided the students with a real-world connection and worth-knowing information that is related to learning climate change science. They thought the real-world connection of the games helped them to make the content personally relevant to them. The students talked a lot about Hurricane Irma after playing the Hurricane Curling game. They mentioned the game helped them to make a personal connection with Hurricane Irma and learn the facts about how hurricanes work. They loved to see a game which allowed them to connect the facts with a real-world setting and helped them to see what was happening in regards to climate change in their local area.

In addition to providing a real-world connection to the students, the games also presented them with useful information to learn climate change science. They thought the content of the games were important to learn for a number of reasons. First, they thought the content of the games was relative to what they were learning in the classroom so they needed to learn the information in order to pass the tests. Second, they found the content to be applicable in the real world. The students especially thought the content of the Hurricane Curling and the Sea Turtle Crossing games were important to learn because these games helped them to understand what was going on in their local area. Finally, the content of the games helped them to be aware of how human actions affect climate change and to realize what to do to mitigate these actions.

Even though the students believed that the Hurricane Curling and the Sea Turtle Crossing games provided a real-world connection and useful information, they did not have the same

opinions regarding the Phylum Match & Red Tide and the Coral games. The students had a hard time personalizing the content of these games. Since they were not familiar with phylums, red tide, and corals, they found it difficult to personalize the content of these games.

The teacher's responses were similar to the students' responses. She found the games relevant because they provided a real-world connection and useful information to the students. She thought the games were built using a local based approach which helped the students make personal connections to the content. However, like her students said, she also thought that they had a hard time to personalize the content of the Phylum Match & Red Tide and Coral games. Although these games had a local based connection, both the students and teacher found them hard to personalize. However, they all believed that the content of these games was interesting and important to know.

“Confidence” is another significant factor of motivation because learners need to feel confident about their learning in the learning environment (Keller, 2010). The students in this study stated that the games helped them feel more confident about what they were learning and allowed them to have more control over their own learning experiences. They thought the games built positive expectations for success and enhanced their beliefs in their competence. Furthermore, the students considered the games as either easy to understand, well balanced, or difficult to understand. In line with Gee's “pleasantly frustrating” principle (2005), Keller (2010) also mentioned the difficulty level of the learning materials should be challenging, but doable. The students' learning experience will be meaningful if there is enough challenge to require an effort succeed, but this challenge should not create any anxieties or failure (Gee, 2005; Keller, 2010).

The students found the difficulty level of the Hurricane Curling and Turtle Crossing games to be well-balanced, challenging, but doable. These games improved the students' confidence level by helping them to get engaged with the content and to see their efforts were paying off with effective feedback. Although the students liked the difficulty level of the Hurricane Curling and the Sea Turtle Crossing games, they did not like the level of difficulty in the Phylum Match & Red Tide and the Coral games. While they considered the Phylum Match & Red Tide games difficult, they thought the Coral game was easy. The students found the Phylum Match & Red Tide games difficult because they were in quiz-format and they had a hard time retrieving the information from their long-term memory. They also had some problems with the directions and did not like the feedback mechanism of the games. As previously mentioned, they did not want to read the directions in the games and this led them to get confused about how to complete the games. Although they found the games difficult to complete, they felt confident about their learning. On the contrary, the students thought the Coral game was easy to complete. They thought the game was not very challenging that requires an effort to be completed. They easily reached the goal of the game by responding correctly of the optimum conditions for corals to live.

In addition to the students' responses, the teacher's responses aligned with these findings as well. The teacher thought the students felt confident about their learning after playing the games. She thought the games were visual and interactive, so the students got an opportunity to do it while they were being taught the information. She believed the games helped them to enhance their beliefs in their competence and she observed these beliefs in classroom discussions. In terms of difficulty level of the games, she also had similar opinions as her students. She found the Hurricane Curling and the Sea Turtle Crossing games well-balanced.

However, she found the Phylum Match and Red Tide games hard to complete. She mentioned these games needed to have clear directions, so the students would not get confused while playing them.

“Satisfaction” is another significant factor for motivation because learners should have a satisfying feeling about their accomplishment (Keller, 2010). The findings in this study demonstrated that the games contributed to them having a satisfying feeling of accomplishment and made the learning more enjoyable. In line with Prensky’s “fun” factor of the games that makes learners motivated to learn (Prensky, 2001), the students in this study thought the games were fun and provided them enjoyment and pleasure to learn climate change science. They thought the traditional methods of teaching (learning from a lecture or reading from a textbook) were boring, but the games helped them to learn climate change science and let them have fun at the same time.

In addition to the fun feature of the games, goal completion was another reason that made the students feel satisfied in their learning. As Prensky (2001) mentioned, we are a goal-oriented species and completing the goals in the games makes us feel satisfied and motivated to learn more. The students in this study thought the games helped them to reach desired learning outcomes by trying to reach the goal of the games. Therefore, they felt satisfied with their learning about climate change science. Additionally, rewarding feature of the Hurricane Curling and the Sea Turtle Crossing games helped the students feel satisfied about their learning. The students tried to get the maximum points to complete the games and they felt very satisfied with their learning experiences.

In addition to the analysis of the students’ responses, the teacher’s responses were similar with these findings. She thought the games helped the students feel satisfied about their learning

because they were fun to play. The teacher also believed that the games were a positive factor because they added enjoyment to the students' learning experience. In addition, she mentioned the reward system of the games helped the students to see the results of their efforts, which provided them an extrinsic motivation to learn the content.

In summary, the analysis of the data revealed that the educational computer games increased the students' motivation to learn climate change science. The findings also showed that the games play various roles in motivating the students to learn climate change science. These roles were creating an engaging, interesting, focused learning environment; providing real-world connections and worth knowing information; and presenting the content in a challenging, but a fun way.

Conclusion

Climate change is a complex topic to teach. Teaching climate change requires overwhelming amount of information from different subject topics (Ekborg & Areskoug, 2006), and these topics are often taught in a disjointed way. In addition, larger effects of climate change will be seen in the future so that students have a hard time to make personal connection with the events related to climate change. Due to the complexity of climate change science and other factors negatively affect students' perception of learning and motivation to learn climate change science (McCright & Dunlap, 2011). This also makes the teachers job of motivating the learning of climate change a challenge (Luterbach & Reigeluth, 1994).

To address these types of challenges, I provided in-depth investigation of the high school students' perceptions of learning and motivation to learn climate change science using the educational computer games. The findings revealed that the educational computer games had a positive impact on increasing the students' perceptions of learning and motivation to learn

climate change science. The findings of this study showed that the educational computer games provided a learning environment where students perceived learning better by visualizing the scientific phenomenon, making personal connections, actively interacting, engaging, and having fun with the content, and getting highly motivated to learn climate change science.

While looking at the data more broadly, I found some similar and relatively consistent patterns occurred in the students' responses related to perceptions of learning and motivation to learn climate change science using the games. These similarities and consistencies could be explained in various ways. First of all, it is something to bear in my mind that none of the educational computer games used in this study had the production values of commercial games. These games cannot compete with the commercial games in terms of both production and entertainment values. However, these games may still have production and entertainment values in terms of increasing the students' perceptions of learning and motivation to learn. In addition, the production values of the educational computer games varied across the four different educational computer games used in the study. Therefore, it was possible to see some similar patterns in the students' responses related to perceptions of learning and motivation to learn climate change science using the games (see Table 28).

Table 28. Summary of Similar Patterns between the Games

Codes	Hurricane Curling	Phylum Match & Red Tide	Coral Game	Sea Turtle Crossing
Meaning as an Action Image	8	4	4	8
Sandboxes	2	0	0	2
Interesting	7	4	4	8
Real-world connection	8	3	2	8
Worth-knowing information	8	2	3	6
Hard to personalize	0	5	6	0

Having experienced varying perspectives on designing educational computer games as a game designer and a researcher, it can be said that the Hurricane Curling and the Sea Turtle Crossing games had a higher production values than the Phylum Match & Red Tide games and the Coral Game. The production values of these game could be one of the reasons that may cause similar patterns shown in the Table 28. As for the meaning as an action image principle, all the students mentioned the Hurricane Curling and the Sea Turtle Crossing games visually helped them to perceive the content better. However, only half of the students thought the visualization feature of the Phylum Match & Red Tide games and the Coral Game was very useful for them to grasp the content better. The Hurricane Curling and the Sea Turtle Crossing games contributed different types of understanding beyond the factual knowledge. Interactive visual representations of these two games helped to students to perceive the content better than the other two games because the students performed more repeated cycles of interaction and got more feedback (known as “game mechanic”) while playing the Hurricane Curling and the Sea Turtle Crossing games. Ultimately, neither Phylum Match & Red Tide games nor Coral Game had that type of game mechanic in this context. As for the sandboxes principle, the students thought the

Hurricane Curling and the Sea Turtle Crossing games provided them (sandboxes) a realistic environment that has little or no risk. The students enjoyed playing these games by experimenting the content in a real-world environment without having any fear of failure. However, other two games did not have that feature in the game play.

Besides the production values of the games, content of the games may also cause similar patterns shown in the Table 28. Since the contents of the games were different from each other, the students may or may not like the contents of a specific game used in the study. For instance, while all students thought “real-world connection” in the Hurricane Curling and the Sea Turtle Crossing games helped them to make a personal connection with the content, only a few students thought the Phylum Match & Red Tide and Coral Game helped them to make personal connection with the content. The students found the Hurricane Curling and the Sea Turtle games related to their own life and took advantage of playing it which provided a real-life situation to them. In addition to this, although almost all students believed that the Hurricane Curling and the Sea Turtle Crossing games provided “real-world connection” and “worth knowing information” to them they did not have the same feelings for the Phylum Match & Red Tide and the Coral games. Although the contents of these games were related to the place where the students live, they did not personalize the contents to the things they have seen, thought, or done in their real-life. Consequently, the students generally had a hard time to personalize the content of these games.

Although the educational computer games used in this study had different production values and different contents which may cause similar patterns in the students’ responses related to perceptions of learning and motivation to learn climate change science, they may also cause relatively consistent patterns in the findings (see Table 29). It did not matter how well the games

were designed or what the content of the games was about, almost all students found the games “pleasantly frustrating” where the games had adjusted challenges that helped the students to feel challenged, but also that success is possible. The students stated several times that all four games they played were challenging, but doable. They loved being challenged in the learning environment.

Table 29. Summary of Relatively Consistent Pattern across the Games

Codes	Hurricane Curling	Phylum Match & Red Tide	Coral Game	Sea Turtle Crossing
Pleasantly frustrating	8	7	7	7
Engaging	8	7	7	7
Focusing	5	5	6	4
Confidence	8	8	8	8
Fun	7	6	7	8
Goal Completion	6	7	6	7

In addition to challenging feature of the games which made the students pleasantly frustrated, the games were also “engaging” and they helped the students to engage with the content more. The students thought the games were engaging because the contents were presented in a form of a video game and they would prefer to learn with the games. Furthermore, the students shared the games helped them to “focus” on the lesson more because the games were all about what they discussed in the class so that they helped them to focus more on the lesson. They also thought the games helped them to feel confident about their learning because they had a control over their own learning experience which improved their “confidence” level in the learning environment. Finally, almost all students mentioned the games gave them a satisfying feeling of accomplishment and made the learning more enjoyable. They thought all four games were “fun” and helped them to enjoy in the learning environment. Moreover, they

shared that they were able to “reach the goal” of the games by gaining desired learning outcomes at the end of the games.

Limitations

While this study contributes to the literature by investigating the effects of educational computer games on the high school students’ perceptions of learning and motivation to learn climate change science, it has some limitations. One of the limitations was related to transferability of the findings. This research study was designed specifically as a descriptive case study to describe the lived experiences of the high school students in a bounded context. In addition, the students, in this study, had varying levels of interest in learning science and playing video games. The genre and the production value of the educational computer games also varied. Therefore, it was possible to see differences in the students’ responses related to perceptions of learning and motivation to learn climate change science using the games. Hence, it is crucial for readers of this research to bear in mind that results of this study cannot always be transferred to other situations.

In this research study, I used four different educational computer games, and conducted one-on-one student interviews after students have played each game. Even though the Phylum Match & Red Tide games were created as two levels for the Populations-Producers unit, the contents of these game were quite different. While the purpose of Phylum Match game was to help the students to understand the phyla of Algae, the purpose of Red Tide game was to help them to learn Harmful Algal Blooms. Since the students played these games together, I was not able to conduct two separate interviews with the students for these games. Therefore, I was not able to differentiate the students’ perceptions and motivation to learn for these two levels of the

games. I reported the students' responses as a single game with two different levels for these games. Thus, this was another limitation for the study.

Self-reporting was another limitation of the study. Since this study employed interviews with the high school students, interview data depended on the participants' ability to reflect their opinions and experiences through the uses of their language. Despite conducting the interviews in their classrooms, some students were too shy to comfortably express themselves. This self-reporting issue impacts the credibility and trustworthiness of the study.

Research Implications

In this study, Gee's (2005) principles about how games teach were used to explore the students' perceptions of learning climate change science. In addition, Keller's ARCS Motivation Model (2010) was used to investigate the motivational roles of the educational computer games in teaching the students climate change science. Using these frameworks provided a structured procedure for data collection and analysis to narrow down the students' lived experiences in learning climate change science using the educational computer games. Having a structured guideline, it was easier to describe how the educational computer games affect the students' perceptions of learning and what roles these games play in motivating them to learn climate change science.

In this study, it became evident that the educational computer games increased the students' perceptions of learning climate change science. The findings presented that the games have different characteristics to improve the students' perceptions to learn climate change science. The educational computer games had different features such as interactivity, providing different learning styles, role playing, challenging, creating a realistic environment, and

providing visual experiences to learn. These features helped to increase the students' perceptions of learning.

Another research implication was related to motivational roles of the educational computer games in learning climate change science. It became clear through the study that the educational computer games increased the students' motivation to learn. Even though Keller's ARCS Motivation Model (2010) was well defined enough to explain the students' motivation to learn with the educational computer games, the findings of this study contributed to this model by adding what roles the educational computer games play in motivating them to learn climate change science. These roles were creating an engaging, interesting, focused learning environment; providing real-world connections and worth knowing information; and presenting the content in a challenging, but doable and fun way.

Pedagogical Implications

This study may have varying implications for individuals in different fields. One of the main implications specifically impacts educators in teaching climate change science in learning environment. The study showed that the educational computer games helped to increase the students' perceptions of learning and their motivation to learn climate change science. Educators should keep in mind that the games have great potentials to provide a learning environment where students perceived learning better by visualizing the scientific phenomenon, making personal connections, actively engaging with the content, and getting highly motivated to learn climate change science. Educators may use the educational computer games to motivate the students to understand the complex mechanism of climate change science. The games increase students' motivation and help students to become self-directed and self-motivated learners.

Another implication specifically impacts game designers in designing games for educational purposes. Gee's (2005) principles about how games teach is very useful to create an effective educational computer game. Game designers should keep these principles in mind to design their games that trigger learning and make the learners highly motivated to learn.

Although Gee's principles relate mostly to the computer games as part of a larger learning environment, some of them are still applicable to the creation of short educational computer games in education. As clearly shown in this study, Gee's co-design, customize, identity, pleasantly frustrating, sandboxes, meaning as an action image principles were applicable for the educational computer games. The games that applied these principles helped the students to effectively perceive the complex scientific phenomenon related to climate change science.

Educational game designers should at least use these principles to create games that help students understand and enjoy learning.

Recommendations for Future Research

In this qualitative case study research, I explored the high school students' perceptions of learning and their motivation to learn climate change science using Gee's (2005) principles about how games teach, and Keller's ARCS Motivation Model (2010). Further research that uses other theories to conceptualize the students' perceptions and motivation to learn could help broaden our knowledge of phenomenon. Findings collected through the lenses of different theories can expand our understanding of the lived experiences of the high school students in the learning environments.

In this study, I conducted a series of interviews with the students and their teacher to explore the effects of educational computer games on the students' perceptions of learning and motivation to learn climate change science. Since high school students made up the participants

of this study, some individuals were too shy to express themselves during the interviews. This self-reporting issue affects the credibility and trustworthiness of the study. For future research, it is necessary for researchers to have multiple sources of data such as interviews, observations, reflective journals, etc. Researchers should try to have multiple sources of data to make the research findings more credible and trustworthy.

In addition, I used only four educational computer games to explore the students' perceptions of learning and motivation to learn learning climate change science. For future research, more types of educational computer games could be useful to investigate the students' experiences learning with the games. In addition, I conducted this in a single institution. Therefore, replication of this study at other institutions and using different educational computer games may increase transferability of the findings.

Finally, in this qualitative case study research, I only focused on exploring the high school students' perceptions of learning and their motivation to learn climate change science using the games. Further research that focuses on how these types of games affect students' learning of climate change science could help broaden our knowledge of phenomenon.

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APPENDICES

Appendix A: County IRB

PUBLIC SCHOOLS

March 21, 2018

Mr. Metin Besalti
13102 National Drive, Apt. C
Tampa, FL 33617

Dear Mr. Besalti:

County Public School district has agreed to participate in your research proposal, *Games for CHANGE: High School Students' Learning Experiences and Motivation to Learn Climate Change Science through Educational Computer Games*. A copy of this letter **MUST** be available to all participants to assure them your research has been approved by the district. **Your approval number is RR1718-57. You must refer to this number in all correspondence.** Approval is given for your research under the following conditions:

- 1) Participation is to be on a voluntary basis. That is, participation is **NOT MANDATORY** and you must advise **ALL PARTICIPANTS** that they are not obligated to participate in your study.
- 2) If the principal agrees the school will participate, it is up to you to find out what rules the school has for allowing people on campus and you must abide by the school's check-in policy. You will **NOT BE ALLOWED** on any school campus without first following the school's rules for entering campus grounds.
- 3) You must **request approval from this department before other schools are added to your sample.**
- 4) Parent consent and student assent **must** be obtained for all students involved in your research. You must indicate in your letter to the parent all the types of data you will be collecting (i.e., race, gender, testing scores, etc.) treatment proposed, and assessment measures. You **must** have this consent before you begin your research.
- 5) Confidentiality must be assured for all. That is, **ALL DATA MUST BE AGGREGATED SUCH THAT THE PARTICIPANTS CANNOT BE IDENTIFIED.** Participants include the district, principals, administrators, teachers, support personnel, students and parents.
- 6) Any student data **MUST** be **DESTROYED** when the project has been completed.
- 7) Research approval does not constitute the use of the district's equipment, software, email, or district mail service. In addition, requests that result in extra work by the district such as data analysis, programming or assisting with electronic surveys, may have a cost borne by the researcher.
- 8) This approval **WILL EXPIRE ON 6/30/2018**. You will have to contact us at that time if you feel your research approval should be extended.
- 9) A copy of your research findings must be submitted to this department and for our files.

March 9, 2018
Page 2

FINGERPRINTING:

Your proposal indicates that you will come into contact with students. You must be FINGERPRINTED as a VENDOR. You will NOT BE ALLOWED to do your research until the process has been completed for you and your staff. Your institution should be listed as a vendor in myvendorlink.com. The instructions for fingerprinting as a vendor is attached to this letter. **YOU MUST present to the principal THE FOLLOWING: THIS APPROVAL LETTER, AND YOUR YELLOW BADGE INDICATING YOU HAVE BEEN FINGERPRINTED.**

Good luck with your endeavor. If you have any questions, please advise.

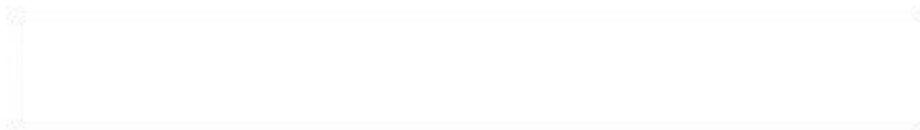
Sincerely,



Strategic Data and Evaluation
Office of Strategy Management

JM/vv

cc: Lillian Wichinsky, Ph.D., Director, Office of Community Engagement & Partnerships (USF)



Appendix B: USF IRB



RESEARCH INTEGRITY AND COMPLIANCE
Institutional Review Boards, FWA No. 00001669
12901 Bruce B. Downs Blvd., MDC035 • Tampa, FL 33612-4799
(813) 974-5638 • FAX (813) 974-7091

5/3/2018

Metin Besalti
Educational and Psychological Studies
13102 National Dr Apt C
Tampa, FL 33617

RE: **Expedited Approval for Initial Review**

IRB#: Pro00029879

Title: Games for CHANGE: High School Students' Learning Experiences and Motivation to Learn Climate Change Science through Educational Computer Games. NSF DRL-13 16782

Study Approval Period: 5/2/2018 to 5/2/2019

Dear Mr. Besalti:

On 5/2/2018, the Institutional Review Board (IRB) reviewed and **APPROVED** the above application and all documents contained within, including those outlined below.

Approved Item(s):

Protocol Document(s):

[Summary of the Study_revised.docx](#)

Consent/Assent Document(s)*:

[SBAdult_Minimal_Risk_2.2018_revised.docx.pdf](#)

[SBAssent_Form_with_optional_child_signature_line_6.2017_revised.docx.pdf](#)

[SBParental_Permission_2.2018_revised.docx.pdf](#)

***Please use only the official IRB stamped informed consent/assent document(s) found under the "Attachments" tab.** Please note, these consent/assent documents are valid until the consent document is amended and approved.

It was the determination of the IRB that your study qualified for expedited review which includes activities that (1) present no more than minimal risk to human subjects, and (2) involve

only procedures listed in one or more of the categories outlined below. The IRB may review research through the expedited review procedure authorized by 45CFR46.110 and 21 CFR 56.110. The research proposed in this study is categorized under the following expedited review category:

(6) Collection of data from voice, video, digital, or image recordings made for research purposes.

(7) Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.

Children as Participants (45 CFR 46, Subpart D)

Research Involving Children as Subjects: 45 CFR §46.404

This research involving children as participants was approved under 45 CFR 46.404: Research not involving greater than minimal risk to children is presented.

Requirements for Assent and/or Permission by Parents or Guardians: 45 CFR 46.408

Permission of one parent is sufficient.

Assent is required of all children.

As the principal investigator of this study, it is your responsibility to conduct this study in accordance with IRB policies and procedures and as approved by the IRB. Any changes to the approved research must be submitted to the IRB for review and approval via an amendment. Additionally, all unanticipated problems must be reported to the USF IRB within five (5) calendar days.

We appreciate your dedication to the ethical conduct of human subject research at the University of South Florida and your continued commitment to human research protections. If you have any questions regarding this matter, please call 813-974-5638.

Sincerely,



John Schinka, Ph.D., Chairperson
USF Institutional Review Board

Appendix C: Student Interview

1. What do you think about the game you played?
2. What are the things you either liked or disliked about the game?
3. Did the game help you to learn the topic? How?
4. Could you please tell me about your experiences on learning with the game?
5. Thinking about your experiences so far, which elements in the game helped you to learn the topic most?
6. Do you think playing the game helped you to become a better learner? Why or why not?
7. Do you think that the game you played increased your problem-solving skills? Why or why not?
8. Did the game help you to focus on the lesson? How?
9. Did the game help you to engage with the content? How?
10. Do you feel that the game helped you keep your attention? How?
11. How the content of this game is related to your interest?
12. Do you believe that the content of the game is worth knowing? How?
13. Can you relate the content of this game to things you have seen, done, or thought about in your own life? How?
14. What do you think about the difficulty level of the game?
15. As you played this game, did you feel confident that you could learn the content? How?
16. Did playing this game give you a satisfying feeling of accomplishment? Why or why not?
17. Did you enjoy playing the game? Why or why not?

Appendix D: Teacher Interview

1. What do you think about the games you used in the class?
2. What are the things you either liked or disliked about the games?
3. Do you believe that the games helped your students to learn the topic? How?
4. Could you please tell me about your experiences on using the games in the class?
5. Do you think playing the games helped your students to become a better learner? Why or why not?
6. Do you think that the games your students played increased their problem-solving skills? Why or why not?
7. Did the games help them to focus on the lesson? How?
8. Did the games help them to engage with the content? How?
9. Do you feel that the games helped them to keep their attention? How?
10. How the content of the games is related to things you are teaching?
11. Do you believe that the contents of the games are worth knowing? How?
12. Can you relate the content of the games to things you have seen, done, or thought about in your own life? How?
13. What do you think about the difficulty level of the games?
14. As your students played the games, did you feel confident that they could learn the content? How?
15. Did playing the games give them a satisfying feeling of accomplishment? Why or why not?
16. Did they enjoy playing the games? Why or why not?