

EVALUATING THE EFFICACY OF A CHEMISTRY VIDEO GAME

by

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Dedication

I dedicate this work to my beloved, Brian, my sister Lina, niece Zoe, and brother-in-law Henry.

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Abstract

EVALUATING THE EFFICACY OF A CHEMISTRY VIDEO GAME

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A quasi-experimental design pre-test/post-test intervention study utilizing a within group analysis was conducted with 45 undergraduate college chemistry students that investigated the effect of implementing a game-based learning environment into an undergraduate college chemistry course in order to learn if serious educational games (SEGs) can be used to achieve knowledge gains of complex chemistry concepts and to achieve increase in students' positive attitude toward chemistry. To evaluate if students learn chemistry concepts by participating in a chemistry game-based learning environment, a one-way repeated measures analysis of variance (ANOVA) was conducted across three time points (pre-test, post-test, delayed post-test which were chemistry content exams). Results showed that there was an increase in exam scores over time. The results of the ANOVA indicated a statistically significant time effect. To evaluate if students' attitude towards chemistry increased as a result of participating in a chemistry game-based learning environment a paired samples *t*-test was conducted using a chemistry attitudinal survey by Mahdi (2014) as the pre- and post-test. Results of

the paired-samples *t*-test indicated that there was no significant difference in pre-attitudinal scores and post-attitudinal scores.

Chapter One

Introduction

Research shows that students face great challenge when it comes to learning chemistry concepts (Davenport, Rafferty, Timms, Yaron, & Karabinos, 2012; Onen & Ulusoy, 2012; Stieff, 2005; Woldeamanuel, Atagana, & Engida, 2014). Probable reasons for why this occurs may derive from the fact that in order for one to develop a conceptual understanding of chemistry concepts, they have to be able to draw a connection between quantitative calculations, processes that occur at the molecular or subatomic level, such as the interaction between atoms and molecules, as well as macroscopic phenomena (what one is able to visually observe with the naked eye) (Davenport et al., 2012; Onen & Ulusoy, 2012; Rastegarpour & Marashi, 2012; Stieff, 2005; Woldeamanuel et al., 2014). Unfortunately, due to the difficult nature of learning chemical concepts, students tend to become discouraged from further pursuing studies in the field of chemistry (Sirhan, 2007). This is a very adverse situation as chemistry is one of the most fundamental branches of science that permits learners to understand occurrences that surround their everyday lives (Sirhan, 2007). In order for one to develop a more comprehensive understanding and receive a visual representation of how molecules and atoms behave, computer simulated models are commonly used in chemistry (Davenport et al., 2012; Merchant et al., 2012; Stieff, 2005). However, students face challenges when working

with computer molecular simulations as they often create greater confusion when learning about the subatomic structure and behavior of atoms and molecules (Ke, 2008).

Game-based learning environments can offer a prospective solution to the challenges that are presented when students learn chemistry concepts. According to Annetta (2008) games exhibit the ability to motivate students who would otherwise not be engaged in learning via traditional classroom methods. Consequently, game-based learning models could potentially decrease the amount of students who become turned away from the field of chemistry. It is believed that modern educational video games, such as serious educational games (SEGs), are effective tools which aid in teaching complex material for the following reasons: video games use action instead of explanation, personal motivation and satisfaction are created via video game play, video games also accommodate a variety of skills and learning styles, they reinforce mastery skills, and they enhance decision-making skills (Kebritchi & Hirumi, 2008). Additional advantages of SEGs for professional and educational use also include the following: massive reach, experiential learning, inquiry-based learning, self-efficacy, goal setting, cooperation, continuous feedback, enhanced brain chemistry, and time on task (Guillén-Nieto & Aleson-Carbonell, 2012). According to Annetta, Mangrum, Holmes, Collazo, and Cheng (2009) when video games are used in science classrooms, students improve in their ability to learn science concepts, which leads to increase in performance. Therefore, the incorporation of serious educational games (SEGs) into chemistry curricula could serve as a potential solution to the complexity of learning chemistry concepts. Computer games must be created in a way that combines traditional three-dimensional video game

design with educational concepts in order for students to be engaged in learning chemistry concepts with use of an educational computer game (Morales et al., 2006).

History of Serious Games

Serious games are digital games that utilize educational design and serve a purpose beyond entertainment (Sorensen & Meyer, 2007). The term serious games has existed for more than 40 years (Sorensen & Meyer, 2007). The term “serious games” is believed to have originated from Abt’s book titled “Serious Games” (Abt, 2007), in which the term was used to describe card and board games (Marsh, 2011). The term serious games was later implemented by the Woodrow Wilson International Center for Scholars who used the term to describe video game-based learning and simulations (Marsh, 2011). One of the capabilities of serious games is that they are able to utilize tools such as discussion forums, bulletin boards and concept mapping software into existing institutional systems and cognitive tools, making them commonly used outside of formal education settings (de Freitas, 2006). In addition, serious games can also simulate the following: role-play experiences, social process, immersive simulations that enable one to explore interpersonal development, adaptive thinking, combat tactics, emergency response, diplomacy, governance, health, education, management, logistics, as well as leadership (Raybourn, 2014).

Serious video games have evolved over the years as they have been utilized in a variety of fields, ranging from the military to educational settings. According to Smith (2007) serious games have been adopted into various environments due to the following five factors that are responsible for influencing the degree and implementation of game

technologies: computer hardware costs, game software power, social acceptance, success in other industries, as well as native industry experimentation. Early military games were designed around combat or fighting, such as the board games Chaturanga and wei Hei, which are both approximately 4000 years old (Raybourn, 2014). The design of these games was based on the goal of developing strategies for battles (Raybourn, 2014). For more than 31 years digital games were known to serve as training tools for the military. In the 1970s, the U.S. Army War College was one of the first to use networked multiplayer simulations (Raybourn, 2014). The U.S. Marine Corps were one of the first to utilize game-based learning via a networked multiplayer computer game for training purposes (Raybourn, 2014). This game is known as Marine Doom, in which an interactive virtual environment was designed for four-person fire teams to practice teamwork and decision-making strategies (Raybourn, 2014). All branches of the military for education and training purposes have used video games since the late 1990s (Raybourn, 2014). Serious games have also been used for education and training purposes by international organizations, including NATO (North Atlantic Treaty Organization), DoD (U.S. Department of Defense), DHS (U.S. Department of Homeland Security), and NGOs (non-governmental organizations) (Raybourn, 2014). The use of serious games by the military and government has continued to grow (Raybourn, 2014). Serious games serve as effective learning tools for the military since they are able to provide an engaging, risk free, and cost-effective training environment by simulating hazardous conditions that can be transferred from the virtual to a real-life scenario (Gee, 2003; Marsh, 2011; Prensky, 2004; Stone, 2008). These reasons are also responsible for

why serious games have been used in other fields, such as health, medicine, business, as well as continuing professional development and training (Marsh, 2011).

Serious games have been used in the fields of health and medicine since they are able to offer realistic role-play environments. An example of a serious game in the health field is Fatworld, which was developed by Persuasive Games (Persuasive Games, 2010). Fatworld was designed for the purpose of exploring relationships between obesity, nutrition, and socioeconomics in the United States (Marsh, 2011). Another example of a serious game that is a military game with medical application is Virtual Iraq, which was developed by clinical psychologist, Albert “Skip” Rizzo (Marsh, 2011). The purpose of Virtual Iraq is to serve as a tool for the treatment of returning soldiers who have developed Post Traumatic Stress Disorder (PTSD) (Rizzo et al., 2010). The goal of Virtual Iraq is to try to recreate a story of the soldier’s experience so that he can learn to face the cause that was responsible for his anxiety (Rizzo et al., 2010).

It has been seen in the past several years that there has been a great increase in the amount of young adults and children who play video games (Dunleavy, Dede, & Mitchell, 2008). Since the mid-1980s, when gaming consoles and home computers were first presented, the popularity of video games has continued to be on the rise (Young et al., 2012). The use of video games by children and young adults has increased from 38% in 1999 to 52% in 2004 and 60% in 2009 (Rideout, Foerh, & Roberts, 2010). Griffiths et al. (2011) stated that children and young teenagers are no longer the only target of computer games. The average age of an individual who plays computer games is 28 years old with the majority of computer game players who are between the ages of 18 and 30

years (Griffiths et al., 2011). For this reason, SEGs may be beneficial not only at the K-12 education level, but at the college level as well.

Research Purpose and Research Goals

The purpose of this research study is to evaluate how serious educational games (SEGs) can be implemented in undergraduate college chemistry courses in order to achieve the following goals:

1. Increase students' knowledge of challenging chemistry content
2. Increase students' positive attitudes towards chemistry
3. To learn if serious educational games can be used as a novel approach to introduce the possibilities for creation of other games that can be used to teach other challenging chemistry concepts at the undergraduate college level.
4. To learn if there is a possibility for implementation of a game-based curriculum at the undergraduate college level.
5. The goal in the future is to include serious educational games as part of the undergraduate college curriculum in the chemistry department if data from this study can support increase in positive attitude towards chemistry and knowledge gains of chemistry concepts.

Research Questions

The research questions for this study are:

1. Do students who participate in a chemistry game-based learning environment score higher on assessments of chemistry content?

2. Do student attitudes towards chemistry change as a result of participating in a chemistry game-based learning environment?

Research Site

For this research study I chose a suburban university in the state of Maryland as the research site since I have been on the faculty at this university for approximately seven years. In addition, I was also an undergraduate and graduate student at this university as well, which enabled me to gain experience from both the perspective of a student, as well as a teacher. This experience has led to my understanding over the years of the content matter that students continue to struggle with as observed from my direct experience, as well as the shared experiences of my colleagues.

Definition of Terms

Serious educational games: electronic and/or computer games that target the content knowledge of the K-20 population and make it possible for students and teachers to incorporate real life scenarios with educational content matter (Annetta, 2008).

Knowledge gain: difference between participant's post-test and pre-test scores on chemistry content exam.

Attitude: one's inclination to think, feel, or act in a positive or negative manner toward an object in the environment (Eagly & Chaiken, 1993; Petty, 1995). Consists of three components: the cognitive, the affective, and the behavioral (Eagly & Chaiken, 1993; Petty, 1995).

- The cognitive component refers to a set of beliefs in regard to the attributes of the attitudes' object (Eagly & Chaiken, 1993; Petty, 1995).

The assessment of these attributes occurs via questionnaires (Eagly & Chaiken, 1993; Petty, 1995).

- The affective component refers to feelings about an object (Eagly & Chaiken, 1993; Petty, 1995). Assessment of these feelings occurs via psychological indices such as heart rate (Eagly & Chaiken, 1993; Petty, 1995).
- The behavioral component refers to how one acts toward the object (Eagly & Chaiken, 1993; Petty, 1995). Assessment of the behavioral component occurs via directly observed behaviors (Eagly & Chaiken, 1993; Petty, 1995).

Attitude change: difference between participant's post-test and pre-test scores on chemistry attitudinal survey.

Summative assessment: occurs after learning is completed and provides overall information about the teaching and learning process (Hanna & Dettmer, 2004).

Chapter Two

Literature Review

To describe the role and importance of serious educational games in science education, the literature review examines the requirements, components, and goals for how a well-designed serious educational game (SEG) should be created. Studies are presented from the K-20 academic levels describing successful use of games as tools in education, as well as how each of the games in these studies align with the gaming aspects that are presented by the Federation of American Scientists (2006), Annetta (2010) and Gee (2008) in order to facilitate learning in a SEG. This literature review provides an overview of methods by which SEGs can serve as tools for learning and assessment of a variety of content knowledge in the field of science, as well as other fields that require analytical and critical thinking skills. Specifically, the literature review describes the learning structure of SEGs, as well as how video games may be used as tools for assessment of knowledge of various subject matter and/or mastery of various educational skills which are beneficial to learning. Further, specific examples of research studies are described, as well as various educational games that have been developed and evaluated for success in teaching and assessing various topics in the field of science. Examples of how SEGs have been used at various academic levels, ranging from K-12 to higher education at the undergraduate university level are provided. Certain studies are

presented which show how SEGs have led to statistically significant increases in learning outcome when compared to virtual worlds and simulations. Additionally, examples of studies are provided to demonstrate that there is a link between student attitudes towards science and knowledge gains and how SEGs could potentially lead to increase in students' attitude towards science content, such as chemistry, with the goal of leading to increased knowledge of that particular scientific content.

The purpose of this literature review was to evaluate how serious educational games (SEGs) can be implemented in undergraduate college chemistry courses in order to increase students' knowledge of challenging chemistry content and increases students' positive attitudes towards chemistry. When searching for literature sources, an electronic search was conducted using Science Direct, Psych Info, and Education Research Complete. For this literature review, the search terms that were used are learning structure of video games, assessment of video games, and science video games and learning, serious educational games, chemistry video game, attitude toward chemistry, and attitudinal change. The journal that appeared to yield results most frequently was *Computers & Education*. Therefore, after downloading references that Science Direct, Psych Info, and Education Research Complete yielded, I accessed the *Computers & Education* Journal directly. After accessing the Computers and Education journal, I went through the journal volumes and years that were no more than ten years old. Sources that were close to or more than ten years old (in both *Computers & Education* journal and other sources) in relation to game-based learning and actual examples of educational

games, were not used as it has been suggested that sources that are around ten years old may not serve as viable references in the field of technology and gaming.

Learning Principles of Serious Educational Games

According to Annetta (2008) students spend an average of 6.5 hours per day occupied with use of various media and are surrounded with technology in their everyday lives. Games demonstrate the ability to motivate students who would otherwise not be engaged in learning via traditional classroom methods (Annetta, 2008). The attraction of games for learning continues to grow and can be attributed to a number of various factors. Computer games have been linked to facilitating improvement in the following areas for students: strategic thinking, planning, communication, decision making, cognitive, emotional, social, and psychomotor skills (Demirbilek & Tamer, 2010). According to Federation of American Scientists (2006), if games are designed well then they can serve as beneficial tools for learning and assessment of content knowledge and scientific concepts. Additionally, SEGs provide the ability to practice the topic and/or concept of interest continuously until knowledge is mastered (Federation of American Scientists, 2006). Progress is constantly monitored and feedback is provided immediately in a SEG (Federation of American Scientists). Games make it feasible for the player to immerse in experiences and opportunities that are not possible to simulate in a real life scenario, even via textbook, such as the ability to explore the inside of a cell (Federation of American Scientists). Interesting and well-designed games are able to motivate the players of the game to learn more about the context of the game (such as concepts that are presented in the game) via outside resources (Federation of American Scientists).

Games are able to teach old subjects in novel ways and students are able to learn content knowledge via experiential learning through simulated inquiry experiences (Federation of American Scientists). SEGs provide an interactive and collaborative learning environment (Pivec & Pivec, 2011). Collaborative learning makes it possible for participants of the game to bring novel ideas, exchange information, and simplify problems (Pivec & Pivec, 2011). According to Barab and Dede (2007), knowledge and skills in science should be incorporated as an inquiry process instead of just verbally communicating to students about scientific facts. This can be accomplished via new learning technologies, such as SEGs (Barab & Dede, 2007). Finally, SEGs can serve as tools for assessment (Federation of American Scientists). For example, games make it possible to test decision-making capabilities that would otherwise be difficult to test via a traditional exam, as it would be easier to test various abilities in a game via practical use (Federation of American Scientists). In terms of the mechanics of games, in properly designed SEGs, goals are clear. The player of the game knows the reason for why they are learning something and there are opportunities within the game for one to apply what they have learned (Federation of American Scientists).

Annetta (2010) provides a framework for how learning and engagement take place in a well-designed game-based learning environment. Video games make it possible for the player's identity to be represented via an avatar, which make it feasible for players to either be an individual member of a team or be part of a group of players or learners (Annetta, 2010). SEGs provide an immersive learning environment in which players are engaged in the content (Annetta, 2010). As a result, players of the game

become motivated to succeed in the game (Annetta, 2010). Games provide an interactive learning environment in which players are able to communicate with other players or computerized agents in the game (Annetta, 2010). Games provide a learning environment with increased complexity since many well-designed games contain multiple levels (Annetta, 2010). Connecting levels in a game leads to a setting of increased complexity of the concepts and content that are presented in the game (Annetta, 2010). According to Annetta (2010), students succeed when they are challenged by the content to the extent of their abilities. Well-designed SEGs offer informed teaching as they are able to provide feedback and serve as assessment tools; which also enables games to serve as instructional learning environments (Annetta, 2010). Experiential learning can be seen via the transfer of experiences and knowledge from SEGs to a real-life setting (Annetta, 2010).

Gee (2008) describes the following learning principles for what he considers to be present in good video games for learning:

Co-design. Good well-designed video games should be interactive and provide immediate feedback.

Customize. Good video games are designed such that players are able to customize the game to fit their learning styles.

Identity. Good video games offer players to have an identity by giving them a variety of characters to choose from or be able to design their own, such as an avatar in a game.

Manipulation and distributed knowledge. Players of a good video game have the option to manipulate objects and characters effectively and easily throughout the game environment. Ultimately, these allow the player to achieve their goal in the game.

Well-order problems. Problems in a good game are well ordered, which means that early problems in the game provide sufficient clues for players to be able to later solve difficult problems.

Pleasantly frustrating. Games are able to adjust challenges and offer feedback which challenges the players, yet success is also achievable.

Cycles of expertise. Well-designed games offer a cycle of expertise by enabling players to be able to conquer challenges after practice and then as new challenges arise, new extended practice forms.

Information “on demand” and “just in time.” Verbal information is given “just in time” and “on demand” in a good game, which allows players to obtain information in the game whenever they require it.

Fish tanks. Good games provide players with fish tanks, which are known as simplified versions of the game. These fish tanks can come either in the form of a tutorial or the first few introductory levels in a game that enable new players to easily understand the game as a whole system.

Sandboxes. Good games also provide sandboxes for players, which are also in the form of a tutorial or the first few levels in a game, where the player can practice at a slower and simplified pace and not lose points in the game.

Skill as strategies. In good games, players are able to learn and practice skills which function as strategies in helping to attain goals in a game.

System thinking. Good, well-designed games leave the player with a feel for the rules of the game. The player knows how each element fits into the entire game and understands the rules and principles via game play.

Meanings as actions and images. Good games should be designed in such a way that word meanings and concepts are clear and philosophical points are realized and understood from images and actions.

The learning structures of games and how these learning structures align with SEGs that have been designed for use at various academic levels ranging from the K-12 level to the undergraduate university level will be described below. The success of how well current SEGs align with the learning structures of games described by Federation of American Scientists (2006), Annetta (2010), and Gee (2008), will be analyzed in order to propose how this could lead to the creation of a SEG that can potentially be used to teach chemistry to undergraduate college students. As can be seen from the descriptions previously discussed, there are similarities between the learning structures of SEGs proposed by Federation of American Scientists (2006), Annetta (2010), and Gee (2008). Overall, the learning structures of Federation of American Scientists (2006), Annetta (2010), and Gee (2008) state the concepts for how a well-designed SEG should be created in order to facilitate learning in a game.

Learning Structure of Serious Educational Games

Connolly, Boyle, MacArthur, Hainey, and Boyle (2012) conducted a literature review on computer games and SEGs in order to learn about their positive impacts on users who are age 14 or above, with regard to learning, skill enhancement, and engagement. Results showed that the most frequent outcomes and impacts from computer games and SEGs were knowledge acquisition/content understanding, as well as affective and motivational outcomes (Connolly et al., 2012).

Merchant, Goetz, Cifuentes, Keeney-Kennicutt, and Davis (2014) conducted a meta-analysis in which they investigated the overall effect and impact of various principles of instructional design in the context of virtual reality technology-based instruction, which includes, games, simulations, and virtual worlds. Methods of game-based instruction were evaluated at various academic grade levels, beginning from K-12 to higher level university academic settings. A total of 69 studies were evaluated. The studies that were included in the meta-analysis utilized experimental or quasi-experimental designs. These studies also employed a learning outcome measure in order to assess the effects of the virtual-reality based instructional teaching methods. Results revealed that games displayed higher learning gains than virtual worlds and simulations. However, all three methods of virtual-reality instruction were statistically significant in enhancing learning outcome gains (Merchant et al., 2014). The difference between educational video games, computer molecular simulations, and multi-user virtual environments is as follows: educational video games are electronic and/or computer games that target the content knowledge of the K-20 population and make it possible for students and teachers to incorporate real life scenarios with educational content matter

(Annetta, 2010). In contrast, simulations serve the same purpose of an educational video game, but the simulation does not keep track of scores obtained by the user (Annetta, 2010). According to Dunleavy, Dede, and Mitchell (2008) multi-user virtual environments are three dimensional social environments that simulate real-world experiences, in which students have the ability to interact with one another in the form of avatars. Additionally, students are able to interact with digital characters and various virtual learning tools, such as digital microscopes (Dunleavy et al., 2008). As can be seen from the game-based learning principles of Federation of American Scientists (2006), Annetta (2010), and Gee (2008) described above, there is overlap and similarities between their learning structures. Therefore, examples of studies about SEGs and how they align with each of the learning structures described by the Federation of American Scientists (2006), the framework of Annetta (2010), and the learning principles of Gee (2008) will be presented below. Specifically, studies are presented that align with the following learning structures:

- 1) Clarity of goals
- 2) Repetitive practice of topics/concepts until knowledge is mastered
- 3) Presentation of experiences that are not possible to simulate in a real life scenario
- 4) Immediate feedback
- 5) Motivation to acquire additional content knowledge
- 6) Learning by doing
- 7) Tools for assessment

Clarity of Goals

According to Hwang, Yang, and Wang (2013) the efficiency of educational computer games can be greatly limited or may even be inferior to the conventional technology enhanced learning approach, if there is a lack of the integration of suitable learning strategies into gaming scenarios. This aligns with the learning structure of goals being clear in well-designed educational video games, which would make it possible for students to apply what they have learned.

Sadler, Romine, Stuart, and Merle-Johnson (2013) conducted a quasi-experimental study to evaluate the way how high school students learn biology concepts via a game-based curriculum (the Mission Biotech (MBt) game). In Mission Biotech (MBt) players of the game take the role of a biotechnologist whose goal is to diagnose the pathogenic agent that causes an emergent epidemic. The game is setup as a virtual environment that is modeled after a biotechnology laboratory, which allows for students to simulate experiences as scientists and learn via inquiry of diagnosing molecular diseases. This study utilized a pre- and post-test analysis and multi-level assessment strategy to evaluate student learning and interactions between academic level and learning as a result of the genetics game, for students across various academic levels (general, honors, advanced). This study also provides an example of the importance of creating a well-designed game for teaching, learning, and assessment purposes. For instance, the MBt game is designed to have players think about various genetics concepts that are related to the process of PCR, such as DNA structure. Additionally the game is designed to apply these concepts to realistic and practical scenarios, such as the diagnosis

of a disease causing agent. In terms of meeting educational and curriculum goals and standards, the MBt game was designed to target various state science content standards that are related to genetics and molecular biology (in the state of Florida). Results showed that there were significant and practically significant increases in post-test scores when compared to pre-test scores for students across all three academic levels (general, honors, advanced). It was found that while students in the advanced and honors level classes had higher pre- and post-test scores than students in general level classes, average increase in post-test scores from pre-test scores were similar across all three groups of students across the academic levels (general, honors, advanced) (Sadler, Romine, Stuart, & Merle-Johnson, 2013). The MBt game aligns with the learning structure of goals being clear in well-designed SEGs in that throughout the game the goals of why students have to run PCR are presented clearly by demonstrating the importance of PCR in the ability to diagnose a pathogenic agent.

Repetitive Practice of Topics/Concepts until Mastery of Knowledge is Achieved

The MBt game described above consists of multiple levels with challenging tasks and rewards, which serve as methods of learning and assessment for knowledge of the player of the game. Examples for how these levels serve as tools of assessment are as follows: in the first level players are introduced to the background of a viral disease, the way how a viral disease spreads through a population, as well as molecular techniques that are used to diagnose a virus. The first step is to extract DNA from infected individuals, which allows the game players the ability to learn and apply concepts of DNA analysis. This occurs via a setup with a virtual laboratory that contains the

following virtual tools: a lab notebook, a virtual micropipette for adding reagents to patient sample, a virtual water bath to manipulate the temperature of a sample, and a virtual centrifuge that is used for differentiating parts of the solution. If a player made selections appropriately and accurately at end of analysis steps, such as in regard to reagent volume, centrifuge time then they will have a virtual centrifuge that contains a liquid solution of isolated DNA, which can then be used in later steps in the diagnosis process (Sadler, Romine, Stuart, & Merle-Johnson, 2013). The MBt game aligns with the learning structure of having the ability to practice the concepts learned over and over again until knowledge is mastered because if students are not able to end up with a centrifuge containing a DNA sample as described above, then they will not be able to continue throughout the game and will have to repeat the steps again until they end up with a sample of DNA.

Presentation of Experiences not Feasible via Real Life Scenarios

An example of how games can be used to support learning in situations where one may not have access to a real life scenario at the time, can be seen from the design of a game learning environment called Realgame. Realgame was designed to learn about, practice, and implement business skills. Lainema and Nurmi (2006) describe how Realgame can be used to represent the nature of business organizations. The skills learned and practiced in Realgame can then be transferred and applied to realistic business organizations. For instance, complex and frequent business transactions in this game are possible for players of the game to manage since Realgame contains a clock

speed or speed of the game that can be slowly increased during training. This allows players of the game to learn various skills over time (Lainema & Nurmi, 2006).

Another example of how games can be used to align with the learning structure of being able to support learning in situations where one may not have access to a real life scenario at the time, can be seen in a study conducted by Pivec and Pivec (2011) in which, 75 information design students at the University of Applied Sciences Joanneum in Austria were asked to simulate the role of commercial game designers. The purpose of the study was for the students to create a proposal for an educational games publisher. The students were assigned to work in teams to create a game design company where they choose a specific role such as a game producer, game developer, or programmer (Pivec & Pivec, 2011).

Franco (2012) presented Foldit, a multiplayer online biochemistry game that serves as a teaching tool for the folding, interactions, and structure of proteins for undergraduate university students. This game was created to be used not only in biochemistry, but also in general, organic, and biochemistry (GOB) courses. This particular gaming program consists of tutorial puzzles whose purpose is to introduce students to concepts related to not only the subject matter being taught (biochemistry), but also to concepts of gaming. The game also contains scientific puzzles which serve the purpose of presenting students with the opportunity to contribute to research. Examples of chemistry concepts that are covered by the tutorial puzzles in the Foldit game include structures of proteins and other biological molecules, intra and intermolecular interactions, and molecular folding. The intention of this particular gaming activity was

to be used as a homework project over a period of several weeks while students cover the topic of protein structure in class. The goal of this game is to reinforce the concepts that are covered in class (Franco, 2012). The game Foldit aligns with the learning structure of being able to virtually simulate experiences that are not possible to simulate in real life or via textbook in that it allows students an opportunity to learn about and view proteins and other biological molecules at the molecular level, which is not possible to observe visually with the naked eye in real life scenarios.

The MBt game evaluated by Sadler, Romine, Stuart, and Merle-Johnson (2013) exposes players to various science concepts in the field of molecular biology and genetics, such as PCR. Additionally, the MBt game allows students to conduct PCR in a virtual setting, learn and understand how PCR works, as well as learn about reasons and applications for why and how scientists would use PCR (Sadler et al., 2013). This aligns with the learning structure of being able to virtually simulate experiences that are not possible to simulate in real life or via textbook in that it allows students an opportunity to learn about PCR at the molecular level. While students may be able to run PCR in a real life laboratory scenario, they are not able to visually observe what is happening at the molecular level during the PCR process.

Rastegarpour and Marashi (2012) conducted a study to compare the success of learning chemistry concepts at the high school level by comparing traditional teaching methods with teacher-made card games and computer games. It was found that by using teacher-made card games and computer games, the learning of abstract chemistry concepts was significantly higher than via the traditional teaching classroom method

(Marashi & Rastegarpour, 2012). This aligns with the learning structure of games being able to present topics, such as abstract chemistry concepts, that are not possible to simulate in a realistic scenario since students are not able to observe molecules with the naked eye.

Immediate Feedback

According to Erhel and Jamet (2013) a game environment is able to promote learning and motivation as long as it contains features, such as feedback, that prompt the game players to actively process the educational content that is learned. The MBt game evaluated by Sadler, Romine, Stuart, and Merle-Johnson (2013) aligns with the learning structure of how educational video games are able to provide immediate feedback. This occurs in the MBt game when characters ask students content related questions and provide feedback in response to what the student provided. Teachers are then able to monitor this and use this information as formative data when making instructional decisions (Sadler et al., 2013).

Motivation to Acquire Additional Content Knowledge

According to Cowley, Ravaja, and Heikura (2013) the subjective experience and engagement of video game participants plays a significant role in determining how likely those individuals are to learn content knowledge via participation in gaming. This aligns with the learning structure of games having the ability to motivate students to want to learn more about content presented in the game because as described above, if a game is designed in such a way that it is able to engage students in the content matter presented,

then students will be motivated to gain additional knowledge about content presented in the game.

Hwang, Wu, and Chen (2012) conducted a study in which a competitive online board game was developed for use with web-based problem solving activities. Each of the locations of the board game are supposed to parallel a gaming task, such as a web-based question that searches information or a mini-game. The purpose of the web-based questions is to serve as guidance tools to direct players of the game to search information in order to attempt to answer a series of questions that are related to a specific learning issue, whereas, the mini-games provided supplemental materials throughout the gaming process. This was an experimental study that was conducted with elementary school students in a natural science course. Results showed that this game lead to a significant increase in learning achievements in the web-based problem solving activity, as well as a significant increase in the learning attitudes, interests, flow experience, and degree of technology acceptance of the students (Hwang, Wu, & Chen, 2012). This online board game aligns with the learning structure of motivating players of the game to want to learn more about the context of the game. As stated above by Hwang, Wu, and Chen (2012) there was a significant increase in the learning attitudes of the students suggesting that they were more motivated to learn. Additionally, it is described above that the purpose of the web-based questions in the game, as they were designed, is to guide players of the game to search information related to context presented in order to continue progress throughout the game and be able to answer questions that are presented in the game. Therefore, this game aligns with the learning structure of motivating students to want to

learn more about context presented because if the game captures the students' interests, then the students will be motivated to continue to search for information about the topics presented in the game.

Annetta, Mangrum, Holmes, Collazo, and Cheng (2009) conducted a mixed-methods study with fifth grade students who were 10 – 11 years of age. The study evaluated student knowledge of simple machines, which was part of a unit covered on forces and motion. In addition, this study also looked at whether student engagement and learning increased as a result of using a Multiplayer Educational Gaming Application (MEGA) that was created by the teacher of this class. This study also evaluated whether gender differences played a significant role on use of technology (video game and computer use) and its effect on learning about simple machines. The students were given a pre-test and post-test in order to measure their knowledge of simple machines. Analysis of covariance (ANCOVA) was also conducted, which showed that there was no significant difference between genders. However, a significant difference was found in gain scores. The use of classroom observations and qualitative focus groups showed that there was an increase in student engagement with use of MEGA. Data was collected in four phases for this study. During phase one, a pre-test was given to students (as described above) to test prior knowledge about simple machines. In addition, demographic information and experience of the students with computers and gaming, was collected. During phase two, a post-test (as described above) was given after playing MEGA in order to evaluate whether students gained more knowledge about simple machines after playing MEGA. During the third phase, classroom observations were

conducted in order to determine the effect of MEGA on student engagement of the subject matter. The class sessions were also videotaped and recorded. During the fourth phase, randomly selected focus groups that consisted of ten male and ten female students, were given twelve questions in order to learn about decisions that were made during MEGA activities. The observational analysis showed that there was high student engagement with use of MEGA. It was found that on average females spent more time than males for using the computer for activities, such as checking e-mail and searching the internet. However, males spent more time than females playing video games. This aligns with the learning structure of games having the ability to motivate students to want to learn more about the concepts presented in the game since, as it is stated above, results showed that there was high student engagement with use of MEGA.

Annetta, Cheng, and Holmes (2010) conducted a quasi-experimental, qualitative study with students in a high school biology course in order to determine if students who participate in a Multiplayer Educational Gaming Application (MEGA), demonstrate inventive thinking, high productivity, and effective communication techniques. Results indicated that students became more motivated to interact with their teacher, interaction with classmates increased, and students' motivation in playing MEGA increased (Annetta, Cheng, & Holmes, 2010). This aligns with the learning structure of games having the ability to motivate students to want to learn more about the concepts presented in the game since, as it is stated above, students became more motivated to interact with their teacher and classmates, as well as becoming more motivated to continue playing the

game. This indicates that students would have to learn more about the content presented in the game in order to successfully proceed throughout the game.

Learning by Doing

In the Mission Biotech (MBt) game that was evaluated by Sadler, Romine, Stuart, and Merle-Johnson (2013) players of the game take the role of a biotechnologist whose goal is to diagnose the pathogenic agent that causes an emergent epidemic. The game is setup as a virtual environment that is modeled after a biotechnology laboratory, which allows for students to simulate experiences as scientists and learn via inquiry of diagnosing molecular diseases, which aligns with the learning structure of learning by doing or learning via inquiry.

In a study conducted by San Chee and Tan (2012) the Alkhimia learning program was designed, in which an educational game titled Legends of Alkhimia was developed in order to learn chemistry via inquiry for the 13 and 14 year old age group. Legends of Alkhimia is a multi-user game which simulates a virtual chemistry laboratory learning environment that was embedded into the curriculum of lower secondary school chemistry in an effort to improve teaching chemistry at the secondary school level (San Chee & Tan, 2012).

Tools for Assessment

The main difference between learning in games and learning via traditional educational methods lies in the types of assessment that are used (Sharritt & Suthers, 2011). Traditional educational methods mostly utilize summative assessment, whereas games use formative assessment in a situated environment (Sharritt & Suthers, 2011).

The formative assessment in games enables players to receive continuous feedback that is pertinent to their learning activities (Guillén-Nieto & Aleson-Carbonell, 2012; Sharritt & Suthers, 2011). This type of ongoing assessment that takes place in video games leads to the encouragement of learning by providing video game players the opportunity to receive constant evaluation of their strategies (Gee, 2003). The assessment that occurs via video game play occurs as the learner's own self-regulatory process, whereas assessment in traditional learning environments take place via an external evaluator (Sharritt & Suthers, 2011). Shute (2011) describes how computer based games can be used as tools of assessment when players of a game interact with the environment causing the values of the different variables that relate to the game to change. For example, if a character in a game is injured and begins to experience a reduction in their health, it could be assessed in their health meter in the game. Shute (2011) argues that players in a game could have the ability to monitor their thinking skills, creativity, and teamwork skills by having a meter in the game that keeps track of all of these variables' levels. Once these variable levels drop then the player in the game would have to figure out what action to take in the game in order to increase the variable levels again (Shute, 2011).

deFreitas and Oliver (2006) devised a four-dimensional framework which they used to assist tutors with the assessment of game based and simulation based learning in utilization for their teaching practices. The goal of this framework was to attempt to help educators with choosing which game or simulation to use in order to teach a specific learning context, which pedagogic approaches should be used in order to support particular outcomes and activities of interest, as well as determining the validity of using

the game or simulation that the tutors selected for instructional use. The four dimensions of the framework developed by deFreitas and Oliver (2006) are as follows: the focus of the first dimension is the specific context in which playing the game or learning takes place. These include macro-level factors, such as historical, political, and economic factors. Furthermore, micro-level factors are included as well, such as accessibility to resources and tools of interest. There are both benefits and disadvantages to context as it can serve as a supporting factor for learning, or it can lead to substantial obstacles for course delivery. The emphasis of the second dimension is on the attributes of the learner or learner group, such as the age and level of the group or specialized elements of how these individuals learn in terms of their learning background, styles, and preferences. According to deFreitas and Oliver (2006) games and simulations are able to support learning in both formal and informal education settings, while also providing an effective linkage between the formal and informal processes of learning to increase and accelerate learning outcomes. The third dimension concentrates on the internal representational world of a game or simulation. This refers to the approach by which the game is presented, the interactivity, and the levels of immersion and fidelity that are used in games or simulations. The third dimension is of great importance as it focuses on the difference between the engagement of players within the game and the critical reflection process that occurs outside of the game. The fourth dimension is based on the processes of learning that take place during the learning time of the course of formal curricula, as well as during learning that takes place in informal education settings. The fourth dimension inspires reflection of practitioners upon methods, theories, models, and the

frameworks that are used for support of the practice of learning (deFreitas & Oliver, 2006).

Barzilai and Blau (2014) evaluated a game-based learning environment that was a business simulation game. The method of assessment in this study was used to learn about how the game assisted students in solving financial-mathematical word problems, by giving the students a post-game problem-solving assessment (Barzilai & Blau, 2014).

In the study conducted by Sadler, Romine, Stuart, and Merle-Johnson (2013) above, assessments were created both within the game environment, as well as outside the game. This would align with the learning structure how video games are able to serve as methods of assessment. Examples of assessment within the game include characters that would ask students content related questions and provide feedback in response to what the student provided. Teachers were then able to monitor this and use as formative data when making instructional decisions. Examples of assessments outside of the game include a series of four assessments that were designed to coordinate with each of the four levels of the game. The MBt game had four levels that simulated challenges with concepts and expectations of learning the content. A quiz was also developed to assess how well the students understood the ideas and concepts at each level of the game. These quizzes were given outside of the game environment. However, the quizzes closely modeled what students had been exposed to in the game (Sadler, Romine, Stuart, & Merle-Johnson, 2013).

Sandberg, Wielinga, and Christoph (2012) described how learning is assessed in KM Quest, a gaming/simulation environment in which teams of approximately three

group members are assigned a task where they have to manage the knowledge household of a fictional company called Coltec. The goal of the game is to manage the company Coltec in the most effective and efficient manner. For example, one of the senior researchers of the company Coltec may leave to work for a competitor and it would be up to the players of the teams who are playing the game to determine how to effectively propose interventions to allow for the company to maintain its success. As a method of assessment of learning in the KM Quest game, a test was designed that contained 96 multiple-choice questions, which was administered before and after playing the game. This test contained both technical questions about models in KM Quest, as well as questions about content knowledge in relation to the interventions in the KM Quest game (Sandberg, Wielinga, & Christoph, 2012).

Attitudinal Change via Serious Educational Games

Attitude refers to one's inclination to think, feel, or act in a positive or negative manner toward an object in the environment (Eagly & Chaiken, 1993; Petty, 1995). Social psychologists have classified attitudes as consisting of the following three components: the cognitive, the affective, and the behavioral (Eagly & Chaiken, 1993; Petty, 1995). The cognitive component refers to a set of beliefs in regard to the attributes of the attitudes' object (Eagly & Chaiken, 1993; Petty, 1995). The assessment of these attributes occurs via questionnaires (Eagly & Chaiken, 1993; Petty, 1995). The affective component refers to feelings about an object (Eagly & Chaiken, 1993; Petty, 1995). Assessment of these feelings occurs via psychological indices such as heart rate (Eagly & Chaiken, 1993; Petty, 1995). The behavioral component refers to how one acts toward the

object (Eagly & Chaiken, 1993; Petty, 1995). Assessment of the behavioral component occurs via directly observed behaviors (Eagly & Chaiken, 1993; Petty, 1995).

According to Schibeci (1983), attitude toward science consists of an attitude object. Examples of these types of attitude objects include science, science lessons, or laboratory work (Schibeci, 1983). Student attitudes toward science can differ depending on how the context is presented (Lamb, Annetta, Meldrum, & Vallett, 2012). Research shows that positive student attitudes toward science have been shown to improve science achievement (Bennett, Rollnick, Green, & White, 2001; Freedman, 1997; House & Prison, 1998; Levin, Sabar, & Libman, 1991; Oliver & Simpson, 1988; Salta & Tzougraki, 2004; Weinburgh, 1995; Wilson, 1983). Therefore, by improving students' attitudes towards chemistry, the goal is for learning to become improved and for knowledge gains to be attained in college chemistry courses.

Research shows that there is a link between attitudes and motivation. Berg (2005) conducted a mixed-methods study in the form of interviews and questionnaires in order to learn about the factors that are related to attitudinal change toward learning chemistry. The study was conducted in a university level introductory chemistry course. Data was collected from 66 students who attended this course in the form of qualitative student interviews. Results of this study showed that there was an association between positive attitude change and evidence of motivated behavior. On the other hand, a negative attitude change was found to be linked to less motivated behavior.

Students' motivation to learn tends to be greater via video game play since the consequence of failure in video games is low when compared to traditional teaching and

learning methods (Salen, 2008; Sharritt & Suthers, 2011). By participating in video game play, when one finds that their strategies lead to failure they can then attempt to try new or different strategies (Sharritt & Suthers, 2011). However, when one's strategies lead to failure in traditional learning environments then that leads to discouraging consequences, such as receiving low grades, which can further inhibit one's motivation to learn (Sharritt & Suthers, 2011).

Daubenfeld and Zenker (2015) conducted a study with 30 students in an undergraduate physical chemistry course. In this study a game-based learning environment was designed, implemented, and evaluated to learn if student motivation and achievement can be increased. Results showed that there was a significant increase in student motivation when compared to the traditional lecture format, there was an estimated increase in study time by the students, and a decrease in the failure rate on the final exam (Daubenfeld & Zenker, 2015).

Cheng, Annetta, Folta, and Holmes (2011) conducted a study that showed that both knowledge and attitude toward a science topic increased after participation in a game-based learning environment. The goal of this study was to design a fun and engaging way to teach neuroscience concepts, specifically the effect of methamphetamine abuse on the brain and then to evaluate the video game exhibit for how well it taught the participants these concepts, as well as evaluate the attitudes of the participants toward methamphetamine abuse on the brain. This study utilized a quantitative methodology pre- and post-test experimental design. Results showed that overall, regardless of age, gender, ethnicity, race, or sensation-seeking personalities,

knowledge of the participants increased after engaging in the virtual brain exhibit (video game). A sensation-seeking survey was administered to participants in order to discover the possible orientation between sensation-seeking personality and the understanding of methamphetamine abuse on the brain. Additionally, results showed that the scores of the participants on the post-attitude survey, toward the impact of methamphetamine abuse on the brain, were significantly higher for the participants by age group, gender, ethnicity, and sensation seeking (Cheng, Annetta, Folta, & Holmes, 2011).

Ruggiero (2015) conducted a study using quantitative analysis with a quasi-experimental design, in order to learn if a persuasive social impact game is able to increase affective learning and attitude towards the homeless. In particular, this study evaluated the effects of the persuasive mechanics in a video game that was designed to enable the player to have the experience from the perception of an almost-homeless person. This study consisted of a control and two treatment groups. Study participants were between ages 12-18 and were between 7th and 12th grade, consisting of a total of 5139 students. ANCOVA was used as the method of data analysis. Results of this study showed that the affective learning and attitude scores of all three groups decreased from the immediate post-test. However, the game group showed a significant difference from the control group in a positive direction. It was found that students who played the persuasive social impact game maintained a significantly higher score on the Affective Learning Scale (ALS) and the Attitude Towards Homelessness Inventory (ATHI) after three weeks.

Theoretical Framework

Constructivism

According to the constructivist approach to learning, humans are able to develop a better understanding of information that they have constructed on their own and learners are considered as being central to the learning process (O'Donnell, 2012). The classroom is considered the knowledge construction site where the learner is considered the builder of knowledge that they later absorb (O'Donnell, 2012). The constructivist classroom differs from traditional lecture courses in that the teacher serves as a facilitator who plans, organizes, guides, and gives directions to the learners, who are responsible for their own learning (O'Donnell, 2012). The teacher provides support for the learner by offering suggestions, challenging the learner in order to inspire creativity, and assigning projects that enable independent thinking and novel ways for learning information (O'Donnell, 2012). In constructivist classrooms students often work in groups to solve problems and challenges from real world scenarios (O'Donnell, 2012). In a constructivist classroom, the teacher begins by evaluating students' prior knowledge and then facilitates learning based on students' prior knowledge (O'Donnell, 2012). Constructivist learning theories have become more prominent with the increased use of computers both in classrooms and homes as computers are able to serve as learning tools for students by allowing students to experiment and build their own learning at their own rate (O'Donnell, 2012). Therefore, SEGs can serve as a constructivist tool for learning in which the game-based learning environment can serve as a teacher by also evaluating students' knowledge prior to moving on to the next level of the game. Once students achieve mastery of the content, then they are able to proceed throughout the subsequent levels in the game.

The two well-recognized figures who are responsible for the development of constructivist theories are Jean Piaget and Lev Vygotsky. Piaget is known for his four stages of psychological development that the young learner undergoes. The first stage, known as the Sensory-motor Stage, occurs before a child turns 2 (Piaget, 1969). During this stage sensory experiences and motor activities take place (Piaget, 1969). During the second stage, the Preoperational Stage (between age 2 and 7), intelligence is intuitive and is developed through mental representation (Piaget, 1969). Intelligence becomes logical, conserved, and reliant on concrete references during the third stage, the Concrete Operational Stage (between age 7 and 11) (Piaget, 1969). The final stage, which takes place after age 11, is known as the Formal Operational Stage (Piaget, 1969). During this stage, abstract thinking begins and the learner starts to think about probabilities and draws connections by making associations and analogies (Piaget, 1969). Therefore, college students would fall under Piaget's Formal Operational Stage. According to Piaget's constructivist theory, learners should be allowed to construct knowledge that is meaningful for them. Computer based software tools, such as SEGs enhance learning and align with Piaget's constructivist view.

Shelton, Satwicz, and Caswell (2011) evaluated a game called Portal that was developed in 2007 by Valve Entertainment. Portal can be related to the constructivist learning theory of Piaget. The game design of Portal shows a variety of ways in which the player would have to adapt in order to maintain equilibrium. Portal is a shooting game in which the goal is for the player to devise a plan that will allow them to approach the exit. The portal gun creates a challenge for the player of the game to direct objects in the

virtual environment through the three dimensional space by opening doors in the different surfaces of the game (Shelton, Satwicz, & Caswell, 2011).

In order to succeed in the game Portal, the player has to properly make decisions about how to progress through the virtual environment of the game. Each level of the game Portal becomes more challenging than the previous level. The game is designed to stretch the skills of the player and make decisions that allow the player to succeed in each consecutive level that creates more challenge than the previous level. One of the ideas that arise from Piaget is that there should be teaching strategies created by providing environments that cause the student to question and experiment. This can be seen in the game Portal as described above. The environment in the game Portal is open-ended and it allows players the opportunity to have free will when making decisions and entering wherever the player wishes throughout the game. When the player is new to the game they may not have knowledge of the environment within the game and where and how they should proceed in the game. However, as the player becomes more familiar with how to interact in the virtual environment of the Portal game, the movement restrictions of the game are removed and new opportunities to interact with the game become revealed. Therefore, at the beginning the player is becoming familiar with and adapting to the environment of the game. This is similar to how Piaget describes how one goes through assimilation and accommodation to maintain equilibrium in their environment. Piaget described assimilation in which one uses and preserves mental structures to resolve a conflict (Piaget, 1969).

According to Shelton, Satwicz, and Caswell (2011) the game environment contains a set of rules that the player has to uncover and follow in order to proceed from one level to the next and to succeed in the game. The belief of Piaget is that the structure of rules in games is able to simulate important experiences that require children and young adults to learn and understand a set of rules (Shelton, Satwicz, & Caswell, 2011). Piaget described that as an important attribute of development is to maintain an evolving state of equilibrium.

Vygotsky's concept of scaffolding can be applied to college students and game-based learning. According to Vygotsky (1978) sociocognitive development takes place via face-to-face interaction between an individual who is less knowledgeable and one who is more knowledgeable who scaffolds or supports the learning process of the less knowledgeable individual. The more knowledgeable individual serves as a guide for the learner, who is considered the less knowledgeable individual, in order to establish a zone of proximal development (ZPD) where the learner is able to perform at a level that they would not be able to achieve without the assistance of the guide (Vygotsky, 1978). The zone of proximal development is known as the space between the knowledge of the learner and the new information that is presented to the learner (Vygotsky, 1978). In other words, ZPD is the difference between one's present level of development and the next possible level of development that occurs with aid of adults or peers who are more proficient (Vygotsky, 1978). According to Vygotsky (1978), play involved the creation of ZPDs as play is the source of development that creates the zone of proximal development. An application of play for the creation of ZPDs can be applied to game-

based learning environments, such as SEGs similar to how Vygotskian classrooms tend to support a learning environment where students work on problem solving activities (O'Donnell, 2012). According to O'Donnell (2012) the more knowledgeable individual does not always have to be an adult or live person. They can also be expertly designed software that can scaffold the student's thinking process (O'Donnell, 2012). An example of a SEG, which aligns with Vygotsky's principle of scaffolding, is the physics game SURGE that was designed to teach Newtonian mechanics. Clark et al. (2011) conducted a study to evaluate the learning effectiveness of the game SURGE with students between grades 7-9 in the United States and Taiwan. Results of the study showed similar increase in learning and engagement for both countries. The player of the game is the character Surge, who is a smart, brave female alien (Clark et al., 2011). In this game, Surge is called to save the character Fuzzies from the evil Emperor Hooke (Clark et al., 2011). This game aligns with Vygotsky's concept of scaffolding in that there is another character in the game named Lerpz who provides advice for Surge throughout the game and serves as a guide or facilitator for the student playing the game, by helping to scaffold the actions and physics concepts that the player learns while progressing through the game (Clark et al., 2011). Therefore, if one thinks of a game-based learning environment as a digital guide then the game is able to serve as a guide that would enable students to obtain content knowledge and then demonstrate mastery of the content by progressing through the various levels of the game. According to Shelton, Satwicz, and Caswell (2011) in order to succeed in a game, the player has to properly make decisions about how to progress through the virtual environment of the game. Each level of a game

becomes more challenging than the previous level. Games can be designed to stretch the skills of the player and to make decisions that allow the player to succeed in each consecutive level that creates more challenge than the previous level. Additionally, game-based learning environments align with Vygotsky's constructivist learning theory in that they place the learner in an imaginary or real-world context, such as a science game that simulates the environment of a scientist where students have to demonstrate critical thinking skills and problem solving ability in order to succeed in the game. SEGs offer an environment where players are able to solve problems and develop a deep understanding about how complex systems work by themselves (Squire, 2013). In this way, students who play SEGs learn more than just memorize facts as SEGs provide a way for one to see and understand problems and students are able to play the game at their own pace (Squire, 2013).

According to Shelton, Satwicz, and Caswell (2011), in order to succeed in a game, one has to create an imaginary situation such as with the characters of that particular game. This game-based environment and the content it contains can then function as a scaffolding environment in order to facilitate knowledge gain for the learner. Consequently, if one constructs their knowledge, according to constructivist theory, in a game-based learning environment, such as in a SEG, then the SEG environment can enable one to learn via direct experience (experiential learning). The SEG could serve as a platform of experiential learning for college chemistry students as the basis for understanding complex chemical phenomena stems to the subatomic level, which one is unable to observe with the naked eye even when performing live laboratory

experiments. Therefore, the SEG can allow one to learn and observe directly what they are unable to observe outside of a computer-based simulated environment, such as molecules and atoms, while being embedded in a story line of a video game that is applied to chemistry concepts. The student can then learn via direct experience in the SEG and then transfer the knowledge obtained from the SEG and apply to a real-world scenario.

Experiential Learning Theory

Experiential learning theory states that students learn via direct experience and the creation of knowledge occurs by transformation of experience (Kolb & Kolb, 2009). According to the experiential learning model, there are two types of modes for understanding one's experiences (Kolb & Kolb, 2009). These include concrete experience and abstract conceptualization (Kolb & Kolb, 2009). Additionally, there are also two types of modes for the transformation of one's experience, which are as follows: reflective observation and active experimentation (Kolb & Kolb, 2009). The process of experiential learning occurs when knowledge is constructed via the utilization of the four learning modes described above (Kolb & Kolb, 2009). This occurs when a learner experiences a learning cycle of these four modes (experiencing, reflecting, thinking, and acting), which collectively can increase one's learning power (Kolb & Kolb, 2009).

According to Pivec, Dziabenko, and Schinnerl (2003) learning occurs when players interact with a game or play a game as educational content is embedded within the game. In order for students to learn via game play, the game should be engaging in a way for the learner to repeat cycles within the context of a game (Pivec, Dziabenko, &

Schinnerl, 2003). During this repeating cycle (while playing a game), one is able to experience various desirable behaviors that result from the emotional and cognitive reactions from the interaction and feedback from the game (Pivec et al., 2003).

Additionally, there is a debriefing process that occurs, when one is embedded in game play (Pivec et al., 2003). This process occurs between the game cycle and once learning outcomes are attained (Pivec et al., 2003). During debriefing, there is a link between the game/simulation and the real world leading to a relationship that the learner observes between events that take place in the game and realistic scenarios (Pivec et al., 2003). As a result, the experience from the game is connected with learning, which would correspond to the experiential learning theory (Pivec et al., 2003).

Cognitive Dissonance Theory

Attitudinal change can be explained by cognitive dissonance theory. Cognitive dissonance theory was developed by Leon Festinger and is based on the assumptions that humans are sensitive to inconsistencies between their actions and beliefs and realization of the inconsistency will cause dissonance, which will lead one to resolve the dissonance (Festinger, 1957). According to cognitive dissonance theory, one recognizes when they are acting in a way that is inconsistent with either their attitudes, opinions, and/or beliefs (Aronson, 1968; Festinger, 1957; Johnson, Kelly, & LeBlanc, 1995). As a result, one becomes alert when they notice that inconsistency (Festinger, 1957). For instance, if one believes that smoking is harmful, but yet they continue to smoke, they will notice and be affected by this inconsistency. According to cognitive dissonance theory, after one realizes that they have violated one of their principles, they will feel a type of mental

distress (Festinger, 1957). If a learner experiences two cognitions that are dissonant with each other, then they will either alter one of the cognitions or ignore the conflict in order to reduce the dissonance (Festinger & Carlsmith, 1959). According to cognitive dissonance theory, external justification is a vital factor that influences the cognitive dissonance that one experiences (Festinger, 1957; Simon, Greenberg, & Brehm, 1995). Attitude-behavior inconsistencies produce cognitive dissonance and lead to attitude changes only when there is lack of external justifications (Aronson, 1968; Elliot & Devine, 1994; Festinger & Carlsmith, 1959).

According to Wan and Chiou (2010) negative incentives should work in the same way as positive incentives. One method for getting people to perform tasks that they dislike is to threaten them with negative consequences such as punishment (Wan & Chiou, 2010). For example, if students fail to learn chemistry concepts then they face the threat of scoring poorly on exams leading to bad grades in their chemistry courses, which would ultimately lead to low GPA. Consequently, students will face difficulty in landing a job in a STEM field or getting accepted to graduate or professional school. Threats can also be used to prevent individuals from performing actions that they may be tempted to (Wan & Chiou, 2010), such as dropping chemistry courses that are requirements for acceptance into graduate or professional school and/or requirements for their degree. Based on the perspective of external justification in cognitive dissonance theory, greater threats lead to less dissonance, which results in lesser attitude change (Wan & Chiou, 2010).

The degree of the dissonance will depend on the extent of how one feels in regard to their belief, attitude, or principle and the level of inconsistency between their behavior and belief (Festinger, 1957). Cognitive dissonance theory states that the greater the dissonance, the more one will be motivated to resolve that dissonance (Festinger, 1957). Dissonance can then be resolved by either changing one's beliefs, actions, or their perception of an action (Festinger, 1957). For instance, in the smoking example provided above, one option that one could take is to decide that smoking is okay, which would resolve any dissonance. However, if one's belief of smoking being harmful is important to them then this option of changing one's beliefs is not very likely to occur since our basic beliefs and attitudes tend to remain stable (Festinger, 1957). While changing one's beliefs is the simplest method for resolving dissonance, it is not likely to be the most common (Festinger, 1957). The second option for one to change their actions would require one to be sure that they never repeat the action again (Festinger, 1957). For instance, one might say to them that they will never smoke again, which may help to resolve the dissonance. Consequently, one becomes overcome by guilt and anxiety (aversive conditioning), which may lead them to not repeat that action again (Festinger, 1957). However, the challenge to this option could be if one is able to train them to not experience the feelings of guilt and anxiety (Festinger, 1957). Therefore, the most common, yet more complex method of resolving one's dissonance involves changing the way one views, remembers, and/or perceives their action (Festinger, 1957). In other words, one would rationalize their actions (Festinger, 1957). For instance, one might say to them that everyone around them smokes so why not them? This method causes one to

think about their actions from a different perspective or context so that it no longer appears to remain inconsistent with their actions (Festinger, 1957).

Cognitive dissonance theory can be related to college chemistry students as a potential explanation for how students enter chemistry class while holding their beliefs on two opposite spectrums. For example, students often times come into chemistry class with negative attitudes towards chemistry, which may perhaps be a result of negative experiences in chemistry class from the past. On one hand students may come into chemistry class feeling that they hate chemistry and/or that chemistry is difficult. Yet on the other hand, students may believe that chemistry is important for their field of study, for their future career, and it is imperative that they learn and understand chemistry, whether it is in preparation for graduate or professional exams, such as the GRE or MCAT, or for entry into the workforce. Therefore, the tendency to reduce cognitive dissonance can potentially motivate the crucial attitude changes in chemistry students. The goal is to resolve the dissonance and to hopefully shift students' attitude toward chemistry in such a way that they come to view chemistry from a more positive perspective.

Conclusions

Overall results from the various studies that were researched suggest that well designed video games that align with the learning structures as described by Federation of American Scientists (2006), Annetta (2010), and Gee (2008) are able to serve as practical tools of assessment. The goal of the game must be clear so that the player of the game is able to use the game as both a learning tool and an assessment tool to measure

knowledge gained as a result of playing the game (Federation of American Scientists, 2006). Therefore, in addition to designing a practical educational game, careful design and selection of assessment methods both within and outside of the game environment must be considered when assessing for knowledge gains. For instance, assessment outside the game can consist of a quiz that can evaluate content knowledge of what was taught in the game, while assessment inside a game can consist of a character asking the player questions that the player of the game would have to answer correctly prior to being able to move on to the next level of the game and defeating the game.

The MBt game that was evaluated by Sadler, Romine, Stuart, and Merle-Johnson (2013) is a well-designed game that appears to align with the majority of the learning structures that were presented by the Federation of American Scientists (2006), Annetta (2010), and Gee (2008), whereas the studies for other games that were presented in this literature review, tended to not describe the games in as much detail, which made it difficult to decipher additional learning structures that the games aligned with by just reading the articles, as the description of the games was not as thorough.

Limitations of this field of research (game-based learning) can greatly arise if the SEGs are not designed to align with the learning structures presented by Federation of American Scientists (2006), Annetta (2010), and Gee (2008). While the majority of the game-based learning studies presented in this paper align with the learning structures of Federation of American Scientists (2006), Annetta (2010), and Gee (2008), it was found that overall the SEGs that were presented in these studies were used as tools for assessment in certain science fields, such as biology (Franco, 2012; Sadler, Romine,

Stuart, & Merle-Johnson, 2013), as well as other educational fields, such as math and business analytical thinking skills (Barzilai & Blau, 2014; Lainema & Nurmi, 2006). However, there have not been many chemistry SEGs developed or evaluated, especially at the undergraduate university level. It was also difficult to find studies that evaluated attitudinal change of students towards a particular content area, such as science, after playing the SEG. The studies that were found in this literature review also did not really relate the learning structure of how progress is constantly monitored throughout the game (Federation of American Scientists, 2006), as there was no description of the way how progress of the characters are being monitored in the games. Therefore, it would also be helpful to design an educational science game that would continuously monitor progress, such as having an oxygen meter displayed that shows the current life status of the character in the game or additional progress meters in the game that could show the current critical thinking ability of the character in the game. For instance, the different oxygen meters could be used to show the extent of one's understanding of a particular concept, rather than just losing the game and having to start over if answering a question incorrectly. For instance, if a game is teaching and assessing one's knowledge of chemical reactions then an oxygen meter could be used to show one's understanding of writing a balanced chemical equation instead of just saying "game over" if the player of the game provides the wrong chemical equation. For example, if the chemical equation is wrong because it is not balanced correctly, then the oxygen meter would decrease the life span of the player in the game. When the player begins to balance the chemical equation correctly then the oxygen meter would increase the player's life span in the game. This

would allow students and teachers to know what topics to spend more time covering and skills that students should receive more practice with during class. Perhaps, it may be revealed via a certain science game that students are having difficulty relating and applying certain important scientific concepts. This would give instructors an insight into what types of assignments and projects to design and assign to their class so that the students can receive more practice in order to better develop various skill sets, such as critical thinking or problem solving ability.

In addition, it would be interesting and beneficial to develop more SEGs that align with the learning structure of being able to teach old topics in the field of science in new ways. This can be accomplished if the SEG teaches the topics in fantasy like settings rather than in just realistic type settings such as virtual laboratories, as can be seen from various studies previously discussed (Sadler, Romine, Stuart, & Merle-Johnson, 2013). For instance, a realistic chemistry reaction can be taught via a virtual setting in a game that combines both a real life laboratory scenario with a fantasy type scenario. By incorporating a realistic laboratory scenario in a video game, students still have the ability to learn proper laboratory techniques, such as following proper safety protocols, proper reading and usage of laboratory glassware, chemicals, and instrumentation for measurements and conducting experiments. What better setting than a virtual game setting to learn the explosive hazards of mixing certain chemicals together, such as when disposing chemicals into the wrong waste containers. Students would have the ability to visualize the dangers of what can happen if proper protocol is not followed. However, when combined with a fantasy like scenario that is related to interesting story lines that

may capture students' interests, such as various fantasy creatures taking over a lab and having weapons that are filled with various realistic chemicals, students may be more likely to remember and learn the concepts presented in the game if they are able to also relate the story line that is presented in the game to something that is of interest to them. Not only would this type of game-design be beneficial to students at the K-12 level, but it may also appeal to students at the undergraduate university level as well.

Additional limitations of this field of research can arise if the SEGs are not designed with the important factors that can both lead to and evaluate content knowledge obtained as a result of the game. Therefore, in addition to designing a practical educational game, careful design and selection of assessment methods both within and outside of the game environment must be considered when assessing for knowledge gains.

The majority of the studies that were found that utilized SEGs were mainly conducted at the K-12 level and in other science fields, such as biology. This leaves for more research to be conducted for increasing student learning, exam scores, positive attitude toward chemistry, and motivation to learn with undergraduate college students, specifically chemistry students. For this reason, the creation of a chemistry SEG may serve as an effective tool for teaching and learning complex scientific concepts at the undergraduate college level. From the studies that were evaluated, it was found that SEGs are able to serve as constructive pedagogical tools for individuals of various ages, beginning with young children at the elementary school level ranging to young adults at the undergraduate university level. The studies also show that increase in students'

positive attitudes towards a science subject lead to knowledge gains of that content (Bennett, Rollnick, Green, & White, 2001; Cheng, Annetta, Folta, & Holmes, 2011; Freedman, 1997; House & Prison, 1998; Levin, Sabar, & Libman, 1991; Oliver & Simpson, 1988; Ruggiero, 2015; Salta & Tzougraki, 2004; Weinburgh, 1995; Wilson, 1983), and motivation (Berg, 2005; Daubenfeld & Zenker, 2015; Salen, 2008; Sharritt & Suthers, 2011) of the content being taught by the game. Therefore, by changing attitudes towards chemistry to become more positive, we will most likely see increase in knowledge and motivation for learning college level chemistry concepts.

Chapter Three

Methods

Research Design

This study was a quasi-experimental intervention pre-test/post-test design that compared student knowledge gained and attitudinal change via a within group analysis. This study evaluated student knowledge of the following chemistry concepts in an undergraduate general chemistry course before and after exposure to a serious educational game (SEG) on the following topics:

1. Phase changes
2. Acid-base reactions
3. Haber-Bosch process for ammonia synthesis
4. Using liquid nitrogen for freezing water
5. Electrolysis of water to produce oxygen and hydrogen gases
6. Balancing chemical equations
7. Production of highly flammable H_2 gas from the reaction between a metal and an acid

A pre-test/post-test design was used to evaluate the effect of the chemistry video game on learning the concepts listed above and to evaluate attitudinal change toward chemistry. It is important to understand that this study was conducted with students who

major in either chemistry or another field in the sciences, such as physics or biology. There is also a certain math pre-requisite for the students who participated in this study. Detailed information about the current curriculum and pre-requisite courses are described below. The impact of SEGs may be different for students who are not science majors and/or are following a different curriculum.

Pilot study. A pilot study was conducted with a similar population in the same chemistry lecture courses during the Fall semester. This study was then conducted during the following Spring semester. The pilot study consisted of a quasi-experimental comparative design in which the goal was to determine if students score higher on summative assessments of chemistry content as a result of participating in a chemistry game-based learning environment when compared to students who learn the same content via traditional lecture teaching methods. The final exam served as the summative assessment in both the experimental ($N = 58$) and comparative groups ($N = 54$). The difference between the experimental and comparative group is that the experimental group did not receive any additional instruction of the topics taught in the chemistry video game outside of the game, whereas the comparative group was taught the topics via traditional lecture teaching methods. An independent samples t -test indicated that scores were significantly higher for the experimental group ($M = 58.13$, $SD = 17.51$) than for the comparative group ($M = 51.45$, $SD = 14.99$), $t(110) = 2.16$, $p < .05$ (Tables 3.1 and 3.2). Cohen's d was calculated as a measurement of effect size. Cohen's d was found to be 0.42 (Table 3.1), indicating a moderate effect size.

Table 3.1

Descriptive statistics for chemistry content final exam in pilot study. Means scores are represented as percentages on final exam scores

Source	Group	Mean	Std. deviation	N	Std. error mean	Cohen's d
Final exam	Comparative	51.45	14.99	54	2.04	0.42
	Experimental	58.13	17.51	58	2.30	

Table 3.2

Independent samples t-test for chemistry content final exam in pilot study

Source		Levene's test for equality of variances F	Sig.	t	df	Sig. (2- tailed)	Mean difference	Std. error difference	95% confidence interval	
									Lower	Upper
Final exam	Equal variances assumed	2.28	.13	-2.16 -2.17	110	.033	-6.67	3.09	-12.80	-.55
	Equal variances not assumed				109.25	.0	-6.67	3.07	-12.76	-.58

Participants

Setting. The study took place in the chemistry department of a suburban university in the mid-atlantic region. Approximately 22,000 students are enrolled at this university. The university offers degrees at the bachelor's, master's, and doctoral levels in the liberal arts, sciences, and applied professional fields. This study was conducted with students who were enrolled in the General Chemistry I lecture course which is a course that chemistry, science, and pre-professional studies (such as pre-medical, pre-dental, pre-pharmacy) majors are required to take. Enrollment in the General Chemistry I lecture course ranges from single to triple lecture sections (26 – 90 students).

The students were enrolled in the General Chemistry I lecture course, which is a required three credit course for science majors. Additionally, students who are enrolled in the General Chemistry I lecture course are also required to simultaneously enroll in the one credit General Chemistry I laboratory course. This particular course is for chemistry or other science majors. Students who enroll in this course are chemistry, biology, or physics majors. The majority of students who take this course plan to pursue graduate or professional studies in either the science (masters and/or doctoral level degrees usually in a field related to biology, chemistry, or physics) or medical fields (medical, dental, or pharmacy school). General Chemistry I has a pre-calculus math course which is a pre-requisite or co-requisite (may be taken either prior to enrolling in the chemistry course or taken simultaneously while enrolled in the chemistry course). The students who

participated in this study were administered the chemistry attitudinal survey, the chemistry content exams, and the video game questionnaire (see descriptions below).

The chemistry lectures were taught at a lecture hall in the chemistry department of the science building. Students played the chemistry video game used for this study, in a computer lab that is located in the liberal arts building of the same university.

Subjects. The study sample consisted of 45 students. However, one of the participants did not complete all of the research questionnaires that were administered. Participants were given an informed consent form (Appendix A or E) to read and sign prior to data collection. Demographic information was collected via a 5-item multiple choice questionnaire that was attached to the pre- and post-tests used in this study (see Appendix B or F). Participants in this study were male and female undergraduate chemistry students who were between the ages of 18-21 representing diverse racial backgrounds. Figures 3.1 – 3.5 show the distribution of specific demographic information of the participants in this study such as gender (Figure 3.1), age (Figure 3.2), ethnicity (Figure 3.3), major of study (Figure 3.4), and current educational status (first year, second year, etc... student) (Figure 3.5).

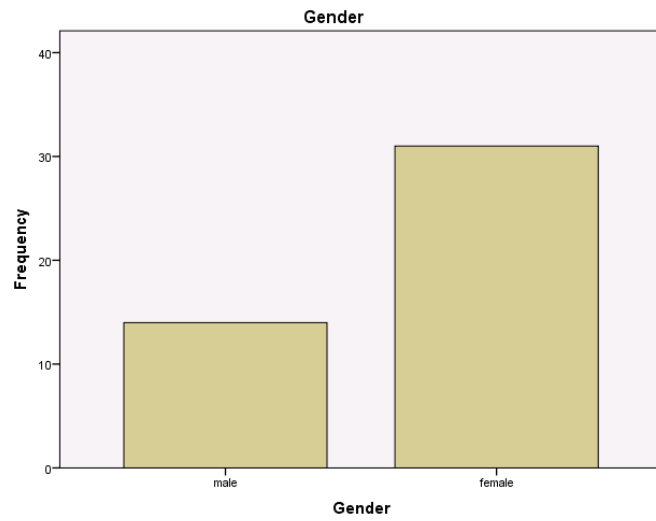


Figure 3.1. Gender distribution of the study participants.

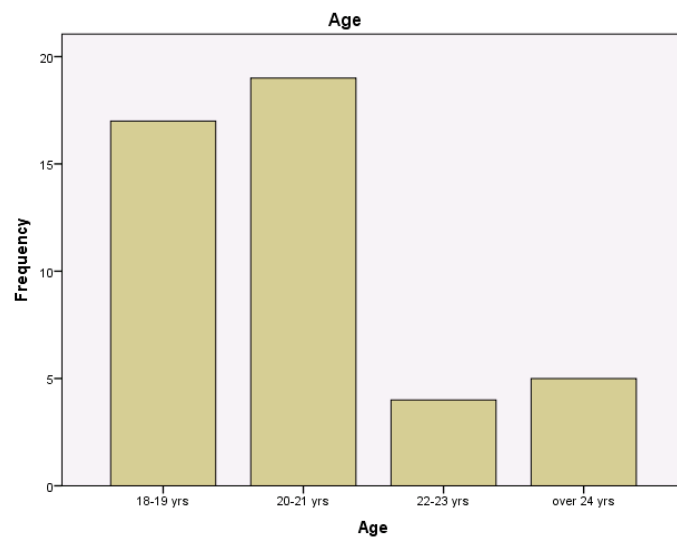


Figure 3.2. Age distribution of the study participants.

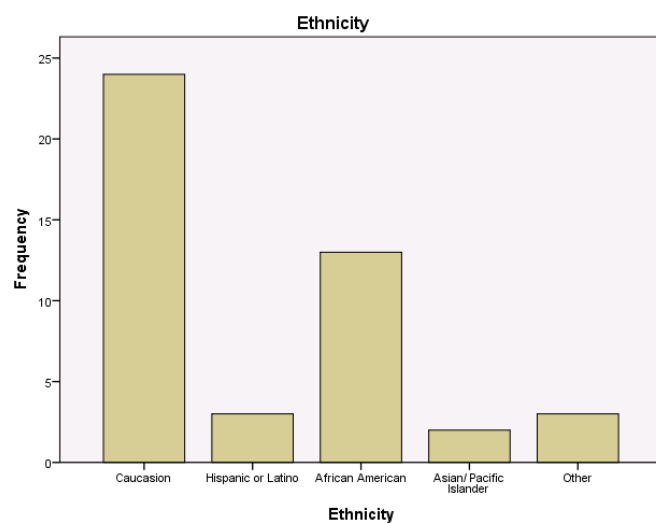


Figure 3.3. Ethnic background distribution of the study participants.

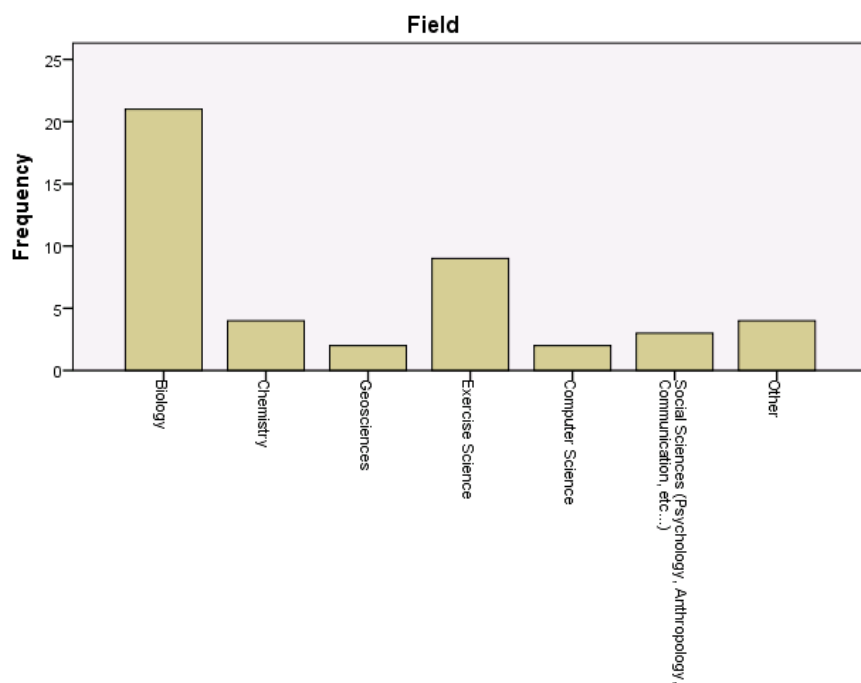


Figure. 3.4. Program of study (academic major) distribution of the study participants.

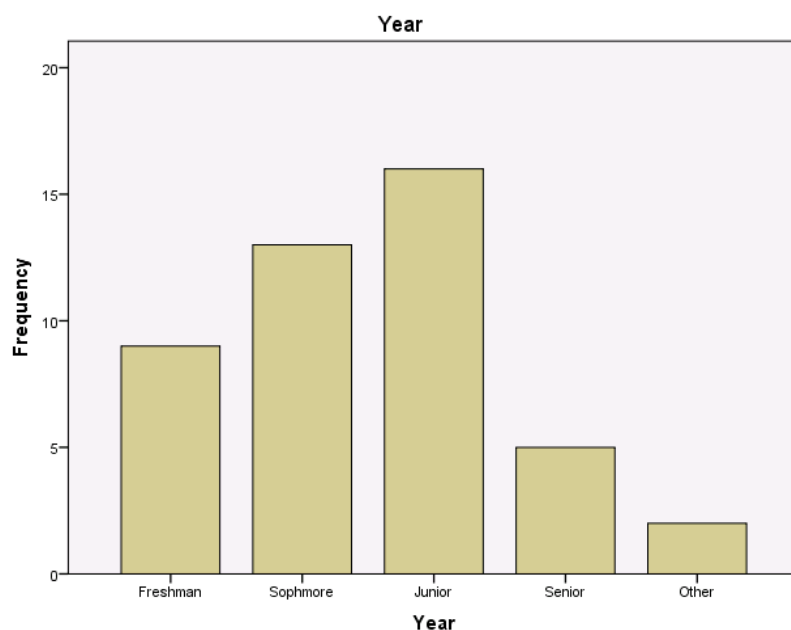


Figure. 3.5. Current academic year of study distribution of the study participants.

Instructors. The researcher who conducted this study taught the chemistry lecture course. The instructor of this course has been teaching this class for approximately seven years. The instructor did not have access to data and did not analyze data until grades were submitted. The research questionnaires used in this study were administered by a colleague of the researcher who conducted this study and then placed into a sealed envelope that the researcher did not have access to until the semester ended

after grades were due. Data was analyzed blindly without looking at participants' names on the consent forms. Prior to data entry the data was sorted by assigning an identification number to each survey packet. Each participant was given a random ID number that was written on top of their questionnaire packets and the consent forms that contained students' names were detached from the questionnaire packets.

Data Collection

Chemistry attitudinal survey. A chemistry attitudinal survey by Mahdi (2014) that consists of a 20-item questionnaire was administered to the students as a pre-attitudinal and post-attitudinal survey (see Appendix C and H). The pre-attitudinal survey was given to students at the beginning of the semester during the first day of class prior to receiving any instruction of course content and the post-attitudinal survey was administered at the end of the semester after students played the chemistry video game in the computer lab. Response items are in the format of a 3-point Likert Type Scale that ranges from 1 "agree" to 3 "disagree." A pilot study was conducted where the chemistry attitudinal survey by Mahdi (2014) was administered to the same population as described above. Cronbach's alpha was calculated for the pilot study and was found to be .98.

Chemistry content pre-test/post-test. The chemistry content test was teacher created 11-item multiple-choice questionnaire that was designed by the instructor of the General Chemistry I course used in this study (see Appendix D and I). Content validity was obtained by consulting with 10 other chemistry professors in the chemistry department of the research site after the chemistry content exam was written. The chemistry content exam was administered as a pre-test during the first day of class prior

to receiving any instruction of course content to evaluate prior knowledge, a post-test to evaluate knowledge gained after the topics were covered in the course via video game play in the computer lab. The final exam was used as a delayed post-test to evaluate if content knowledge was retained. One point was given for each correct answer and zero points were given for each incorrect answer on the chemistry content tests. Exam scores were entered into SPSS as raw scores out of a total of 11 possible points for statistical data analysis. Exam scores were entered as overall number of questions answered correctly rather than data entered at the item level for each exam question, in order to observe more variability in the results. Additionally, this aligned with research question 1 as it does not take into account specific questions at the item level.

Video game questionnaire. The researcher that conducted the study developed a 12-item video game questionnaire (Appendix G). The researcher created Question 1 of the questionnaire to evaluate if there was a correlation between chemistry content post-test score and encountering technical glitches while playing the chemistry video game. Questions 2 – 4 were adopted from the study by Kim and Shute (2015) and questions 5a – 6e were taken from the study conducted by Bourgonjon, Valcke, Soetaert, and Schellens (2010). Cronbach's alpha for the video game questionnaire was found to be .917 (Table 3.3) indicating high reliability of the scale.

Table 3.3

Reliability statistics for video game survey (Appendix G)

Cronbach's	Number of
------------	-----------

alpha	items
.92	12

Intervention

Chemistry video game. The chemistry video game that was used for this study is called Critical Mass. Critical Mass is a first person shooter chemistry video game that was designed by researchers at Purdue University (Morales et al., 2006) to target first year undergraduate college chemistry students who take General Chemistry I and II courses. The player of the game is the main character whose goal is to navigate through a facility that is highly contaminated with CO₂ production where turrets and chemistry challenges attempt to prevent the player from finding the exit of the facility (see Figures 3.6 – 3.8). In order to progress through the game the player has to apply chemistry knowledge that is gained throughout the game, such as learning that liquid nitrogen can be used to freeze water (see Figure 3.7). For instance, the player uses a liquid nitrogen gun to freeze a puddle of water before being able to move across the facility.

Traditional lecture teaching methods, as described below in the procedures section, were used to teach all content during the semester except for the topics listed above that were taught via the Critical Mass video game. The effect of the intervention (Critical Mass video game) on learning chemistry concepts and on students' attitudes towards chemistry was analyzed.

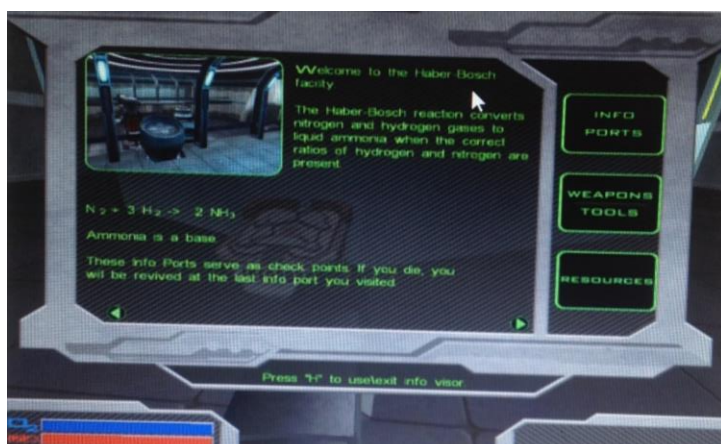


Figure 3.6. A screenshot of the Critical Mass video game welcome and introduction screen.



Figure 3.7. A screenshot of the water tank and electrolysis machine in the Critical Mass video game.



Figure 3.8. A screenshot of one of the video game characters from the Critical Mass video game. This is one of the evil robots that the player of the game must defeat in order to win the game.

Table 3.4

Research matrix

Research Questions	Data Collection Methods	Data Analysis
RQ1. Do students who participate in a chemistry game-based learning environment score higher on assessments of chemistry content?	Chemistry content pre-test: first day of class	One-way repeated measures ANOVA
	Chemistry content post-test: right after playing the Critical Mass video game	
	Chemistry content delayed post-test (Final Exam) (three weeks after the post-test)	
	Video game questionnaire administered with post-test right after playing the Critical Mass video game	
RQ2. Do student attitudes towards chemistry change as a result of participating in a chemistry game-based learning environment?	Pre-attitudinal survey: first day of class	Paired Samples <i>t</i> -test (Dependent Samples <i>t</i> -test)
	Post-attitudinal survey: at the end of the semester right after playing the Critical Mass video game	

Procedures

At the beginning of the semester during the first day of class, prior to receiving any instruction of chemistry content, students were administered a packet that consisted of an informed consent form that outlines the procedures of this study (see Appendix A), demographic survey (see Appendix B), the chemistry pre-attitudinal survey (see

Appendix C), and chemistry content pre-test (see Appendix D) in order to evaluate student knowledge of chemistry concepts (see list of topics above under description of research design) before exposure to learning the concepts in the class and student attitude towards chemistry before being influenced by this particular General Chemistry course.

The General Chemistry I lecture section met for a total of 150 minutes each week during the Spring semester. Teaching methods consisted of a combination of PowerPoint and overhead/chalk/smart board to deliver content to students. Students used a General Chemistry textbook and online textbook companion website for practice problems and online homework and quizzes. Traditional lecture teaching methods were utilized for all topics during the semester except for the topics listed above, under the description of the research design, for which the content was taught via video game play in a computer lab. Students were given one hour in the computer lab to play the Critical Mass video game instead of learning the chemistry topics listed above via traditional lecture teaching methods. Right after playing the Critical Mass video game in the computer lab, students were administered a packet that consisted of an informed consent form that outlines the procedures of this study (see Appendix E), demographic survey (see Appendix F), video game survey (see Appendix G), the chemistry post-attitudinal survey (see Appendix H), and the chemistry content post-test (see Appendix I) in order to evaluate knowledge gains of chemistry content on the topics listed above and students' attitudinal change towards chemistry.

At the end of the semester (three weeks after the post-test), the chemistry content exam (see Appendix D or I) was administered to the students as part of the final exam,

which served as the delayed post-test, in order to evaluate if student knowledge of chemistry concepts was retained.

Fidelity of treatment. The same professor wrote the pre-, post-, and delayed post-tests. The questions on the pre-, post, and delayed post-tests were exactly the same questions. To eliminate discrepancy in grading, all of the tests were in multiple-choice format. In addition, the students were required to also enroll in a one credit General Chemistry I laboratory while simultaneously being enrolled in the lecture course. While different professors may teach the laboratory courses, the Chemistry department follows a standardized laboratory curriculum for all General Chemistry laboratory sections. Therefore, to control for internal validity, students who were in the lecture sections followed the same laboratory curriculum that consisted of the same schedule, laboratory experiments, laboratory assignments, and grading rubrics that were used for those assignments.

Data Analyses

Statistical analysis. At the conclusion of data collection, after the semester ended and grades were submitted, response item data from the chemistry attitudinal survey, the chemistry content tests, the demographic survey, and the video game survey were entered into the statistical software SPSS version 23 for data interpretation and analysis. Students' responses on the chemistry content survey were scored one point for each correct answer and zero points for each incorrect answer out of a total of 11 possible points. Chemistry content exam data was entered into SPSS version 23 as raw scores (number of questions correct) in order to determine whether there was a significant

difference in test scores of the pre, post, and delayed post-test. This enabled the first research question to be answered. A one-way repeated measures analysis of variance (ANOVA) was used to evaluate if there was a significant increase in students' exam scores in order to evaluate if students learned chemistry content (pre- and post-test) and to evaluate if content knowledge was retained (delayed post-test) as a result of playing the chemistry video game.

Exploratory Factor Analysis (EFA) with Principal Axis Factoring and Promax rotation was conducted on the video game survey to determine the number of underlying factors (subscales) in the questionnaire. Pearson's Correlation was then conducted to determine if there was a correlation between students having to restart the chemistry video game (encountering technical glitches) and chemistry content exam post-test scores as well as the two factors of the survey (video game experience/background and video game preference) and post-test score.

Principal Component Analysis (PCA) with Varimax (orthogonal) rotation was conducted on the chemistry attitudinal survey to determine the number of underlying factors (subscales) in the questionnaire. A paired samples *t*-test (Dependent *t*-test) was then used to learn if there was a significant increase in students' attitudinal scores as a result of implementing the chemistry video game into the course. Student responses on the chemistry attitudinal survey were coded as 1 (agree), 2 (not sure), 3 (disagree). The chemistry attitudinal survey consists of a 3 point Likert-type scale as described above. For the purposes of this study, attitude change is operationally defined as the difference between participant's post-test and pre-test scores on the chemistry attitudinal survey.

Chapter Four

Results

The results of the study are presented below for each research question.

Research Question 1. Do Students Who Participate in a Chemistry Game-Based Learning Environment Score Higher on Assessments of Chemistry Content?

Chemistry content pre-test/post-test. A one-way repeated measures analysis of variance (ANOVA) was conducted to evaluate the null hypothesis that there is no change in students' chemistry content exam scores when measured before participation in a chemistry game-based learning environment (first day of class before beginning instruction), right after playing the chemistry video game (in the computer lab), and during the final exam (three weeks after playing the chemistry video game). Mauchly's Test of Sphericity indicated that the assumption of sphericity had not been violated, $\chi^2 = 2.593$, $p > .05$ (Table 4.2). The results of the ANOVA indicated a statistically significant time effect, $F(2, 86) = 8.36$, $p < .001$, $\eta^2 = .163$ (Table 4.3). Thus, there is significant evidence to reject the null hypothesis. Follow up comparisons using Bonferroni as post hoc test indicated that the pairwise difference between pre-test and delayed post-test was significant, $p < .001$ (Table 4.4). While the differences between pre-test and post-test and post-test and delayed post-test were not statistically significant, $p > .05$ (Table 4.4), there was still an increase in exam scores over time (pre-test, $M = 5.68$, $SD = 1.79$; post-test, M

= 6.52, SD = 1.89; delayed post-test, M = 7.11, SD = 1.74) (Table 4.1, Figure 4.1), suggesting that participation in the chemistry game-based learning environment increased students content knowledge of chemistry as no additional classroom instruction outside of the chemistry video game was provided to teach the topics presented in the game.

Table 4.1

Descriptive statistics for chemistry content exams. Means scores are represented as raw scores out of a total of 11 points

Source	Mean	Std. deviation	N	Std. error	95% confidence interval	
					Lower bound	Upper bound
Pre-test	5.68	1.79	44	.27	5.14	6.23
Post-test	6.52	1.89	44	.28	5.95	7.10
Delayed Post-test	7.11	1.74	44	.26	6.58	7.64

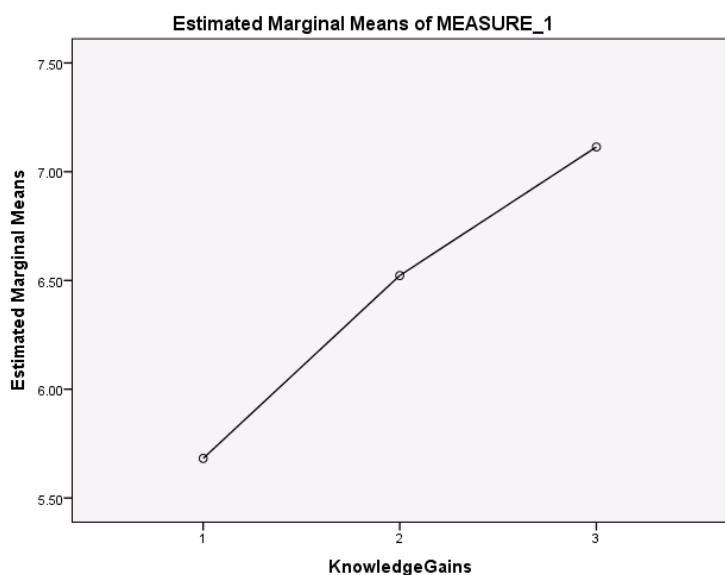


Figure 4.1. Comparison of mean raw scores (y-axis) for pre-test, post-test, and delayed post-test for knowledge of chemistry content. Knowledge gains on the x-axis refers to chemistry content exams across three time points (pre-test, post-test, delayed post-test).

Table 4.2

Mauchly's test of sphericity

Within subjects effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Epsilon Huynh-Feldt	Lower-bound
Chemistry content exams	.94	2.59	2	.27	.94	.99	.50

Table 4.3

Tests of within-subjects effects

Source		Type III sum of squares	df	Mean square	F	Sig.	Partial Eta squared	Noncent. parameter	Observed power
Chemistry content exams	Sphericity assumed	45.56	2	22.78	8.36	<.001	.16	16.71	.96
	Greenhouse- Geisser	45.56	1.89	24.14	8.36	.001	.16	15.77	.95
	Huynh-Feldt	45.56	1.97	23.12	8.36	.006	.16	16.47	.96
	Lower-bound	45.56	1.00	45.56				8.36	.81
(Error)Chemistry content exams	Sphericity assumed	234.44	86	2.73					
	Greenhouse- Geisser	234.44	81.14	2.89					
	Huynh-Feldt	234.44	84.75	2.77					
	Lower-bound	234.44	43.00	5.45					

Table 4.4

Pairwise comparisons for pre-test, post-test, and delayed post-test using Bonferroni post-hoc test

Measure		Mean difference	Std. error	Sig.	Lower bound	95% confidence interval for difference	Upper bound
Pre-test	Post-test	-.84	.39	.11	-1.8		.12
	Delayed post-test	-1.43	.31	<.001	-2.21		-.66
					-.12		1.80
Post-test	Pre-test	.84	.39	.11	-1.48		.29
	Delayed post-test	-.59	.36	.31	.66		2.21
					-.29		1.48
Delayed post-test	Pre-test	1.43	.31	<.001			
	Post-test	.59	.36	.31			

Video game questionnaire. Exploratory Factor Analysis (EFA) with Principal Axis Factoring and Promax rotation for correlated factors (.563) (Table 4.5) on 12 survey items from a video game questionnaire (Appendix G) was conducted on data that was gathered from 45 respondents. According to Bartlett's Test of Sphericity, the correlation matrix is significant, $\chi^2(66, N = 45) = 624.088, p < .001$ (Table 4.6), and the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy ($KMO = .884 > .60$) (Table 4.6), which warrants factor analysis. Additionally, the measure of sampling adequacy (MSA) values, that are provided in the main diagonal of the anti-image correlation matrix (AIC) (Table 4.7), range from .788 to .949, which is also greater than the cut-off value of .60, and the off-diagonal values are relatively small, also making it adequate to proceed with factor analysis.

The Scree Plot (Figure 4.2 and Table 4.8) suggests two factors to retain as their Eigenvalue is greater than 1. The examination of the Structure Matrix under the Promax rotation (Table 4.9), reveals that the first factor, Factor 1, has higher loadings (correlations) with eight items (questions 2 – 4, 6a – 6e). The second factor, Factor 2, has higher loadings (correlations) with four items (questions 1, 5a – 5c). 64.70% of the total variance in the set of 12 variables is accounted for by the first factor and 13.04% of the total variance in the set of 12 variables is accounted for by the second factor (Table 4.8). Based on the research studies (Bourgonjon, Valcke, Soetaert, & Schellens, 2010; Kim & Shute, 2015) from which items of the video game questionnaire were adopted it was suggested that Factor 1 can be labeled video game background/experience and Factor 2

can be labeled video game preference. Question 1 had a negative factor loading (Table 4.9) while all other questions had positive factor loadings. This suggests that students who have more experience with and preference towards video games most likely had to restart the chemistry video game less times than students who do not prefer video games and have less experience playing video games. This may be attributed to the fact that if one plays video games more often then they may be more likely to successfully navigate their way through a game.

Pearson Correlation was conducted and results showed that there were no statistically significant correlations between post-test and either of the two factors (video game background/experience (Factor 1) and video game preference (Factor 2), $p > .05$ (Tables 4.10 and 4.11), suggesting that encountering technical glitches did not affect exam score. There was a positive moderate statistically significant correlation between video game background and preference for video games, Pearson's $r(45) = .466$, $p = .001$.

Table 4.5

Factor correlation matrix

Factor	1	2
1	1.00	.56
2	.56	1.00

Table 4.6

KMO and Bartlett's test for video game questionnaire (Appendix G)

Kaiser-Meyer-Olkin measure of sampling adequacy		.88
Bartlett's test of sphericity	Approx. Chi- square	624.09
	<i>df</i>	66
	Sig.	<.001

Table 4.7

Anti-image matrices for video game survey (Appendix G)

	Survey item	Q ₁	Q ₂	Q ₃	Q ₄	Q _{5a}	Q _{5b}	Q _{5c}	Q _{6a}	Q _{6b}	Q _{6c}	Q _{6d}	Q _{6e}
Anti-image covariance	Q ₁	.66	-.06	.07	.02	-.05	.08	.013	-.10	.04	.02	-.03	.01
	Q ₂	-.06	.11	-.02	-.02	-.01	.01	.003	.01	-.03	-.01	-.02	.01
	Q ₃	.07	-.02	.22	-.03	-.02	.03	.002	-.07	.00	-.01	.01	-.04
	Q ₄	.02	-.02	-.03	.17	-.01	.02	-.020	.00	-.01	.03	-.05	-.01
	Q _{5a}	-.05	-.01	-.02	-.01	.13	-.08	-.062	.02	-.02	.01	.02	.05
	Q _{5b}	.08	.01	.03	.02	-.08	.14	-.048	-.06	.02	-.00	-.03	-.03
	Q _{5c}	.01	.00	.00	-.02	-.06	-.05	.161	.02	.00	-.02	.03	-.05
	Q _{6a}	-.10	.01	-.07	.00	.02	-.06	.020	.22	-.05	.01	.03	.02
	Q _{6b}	.04	-.03	.00	-.01	-.02	.02	.004	-.05	.05	-.03	-.00	-.04
	Q _{6c}	.02	-.01	-.012	.03	.01	-.00	-.021	.01	-.03	.09	-.05	.05
	Q _{6d}	-.03	-.02	.01	-.05	.02	-.03	.025	.03	-.00	-.05	.09	-.03
	Q _{6e}	.01	.01	-.04	-.01	.05	-.03	-.053	.02	-.04	.05	-.03	.20
Anti-image correlation	Q ₁	.83	-.23	.19	.047	-.16	.25	.039	-.25	.23	.08	-.11	.02
	Q ₂	-.23	.95	-.12	-.142	-.08	.05	.019	.056	-.40	-.12	-.15	.09
	Q ₃	.19	-.12	.95	-.156	-.14	.15	.011	-.33	.00	-.09	.05	-.21
	Q ₄	.05	-.14	-.16	.936	-.09	.13	-.125	.01	-.16	.26	-.44	-.04
	Q _{5a}	-.16	-.08	-.14	-.091	.83	-.59	-.423	.13	-.24	.07	.19	.28
	Q _{5b}	.25	.05	.15	.128	-.59	.79	-.326	-.36	.30	-.01	-.30	-.19
	Q _{5c}	.04	.02	.01	-.125	-.42	-.33	.889	.11	.04	-.18	.21	-.30
	Q _{6a}	-.25	.06	-.33	.012	.13	-.36	.105	.88	-.50	.05	.23	.09
	Q _{6b}	.23	-.40	.00	-.158	-.24	.30	.043	-.50	.87	-.40	-.02	-.41
	Q _{6c}	.08	-.12	-.09	.256	.07	-.01	-.176	.05	-.40	.88	-.59	.34
	Q _{6d}	-.11	-.15	.05	-.437	.19	-.30	.205	.23	-.02	-.59	.86	-.24
	Q _{6e}	.02	.10	-.21	-.039	.28	-.19	-.299	.09	-.41	.34	-.24	.89

Table 4.8

Principal axis factoring with Promax rotation for 12 variables of video game questionnaire (Appendix G)
Total variance explained

Factor	Initial Eigenvalues			Extraction sums of squared loadings		Rotation sums of squared loadings	
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %	Total
1	7.95	66.26	66.26	7.76	64.70	64.70	7.37
2	1.71	14.26	80.51	1.56	13.04	77.74	5.08
3	.79	6.55	87.07				
4	.44	3.65	90.71				
5	.31	2.56	93.27				
6	.21	1.79	95.05				
7	.17	1.40	96.45				
8	.15	1.21	97.67				
9	.11	.95	98.61				
10	.08	.68	99.30				
11	.05	.42	99.72				
12	.03	.28	100.00				

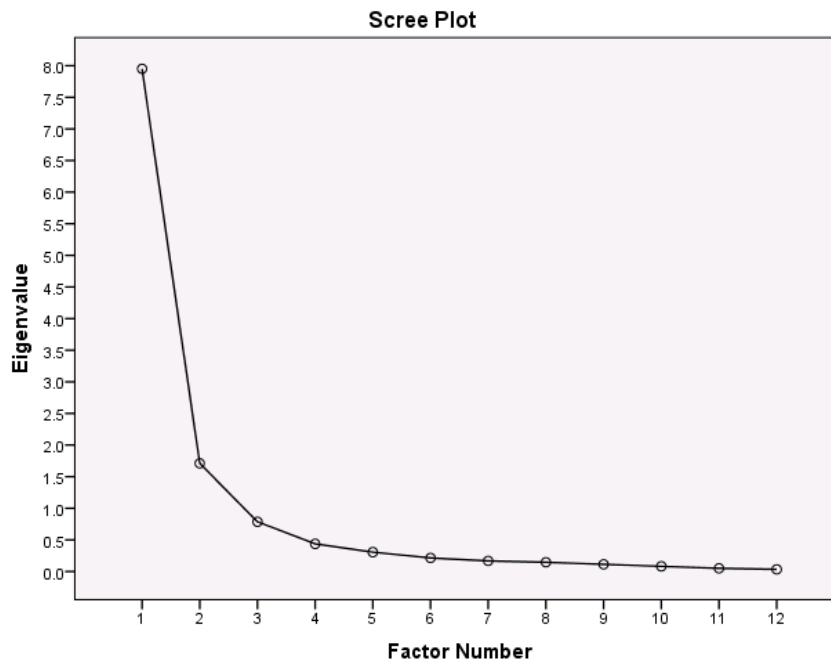


Figure 4.2. Scree Plot for Exploratory Factor Analysis of 12 variables on the video game questionnaire (Appendix G).

Table 4.9

Structure matrix for video game questionnaire (Appendix G)

Survey item	Factor	
	1	2
Q _{6b}	.98	.55
Q ₂	.94	.47
Q _{6c}	.92	.48
Q _{6d}	.92	.44
Q ₄	.90	.53
Q ₃	.87	.57
Q _{6e}	.84	.63
Q _{6a}	.79	.58
Q _{5b}	.48	.94
Q _{5c}	.55	.93
Q _{5a}	.53	.92
Q ₁	-.39	-.43

Table 4.10

Correlations between video game question 1(Q₁) (Appendix G) and chemistry content post-test and delayed post-test (Appendix I)

		Post-test	Delayed post-test	Q ₁
Post-test	Pearson Correlation	1	.16	-.06
	Sig. (2-tailed)		.30	.69
	N	44	44	44
Delayed post-test	Pearson Correlation	.16	1	-.07
	Sig. (2-tailed)	.30		.66
	N	44	45	45
Q ₁	Pearson Correlation	-.06	-.07	1
	Sig. (2-tailed)	.69	.66	
	N	44	45	45

Table 4.11

Correlations between video game background/experience (Factor 1), video game preference (Factor 2) of video game questionnaire (Appendix G) and chemistry content post-test and delayed post-test (Appendix I)

		Post-test	Delayed post-test	Video game background/ Experience	Video game preference
Post-test	Pearson Correlation	1	.16	.13	.10
	Sig. (2-tailed)				
	N		.30	.41	.54
	Pearson Correlation	44	44	44	44
Delayed post- test	Sig. (2-tailed)	.16	1	.09	-.03
	N	.30		.54	.84
	Pearson Correlation	44	45	45	45
	Sig. (2-tailed)				
Video game background/ experience	N	.13	.09	1	.47
	Pearson Correlation	.41	.54		.001
	Sig. (2-tailed)	44	45	45	45
	N				
Video game preference		.10	-.03	.47	1
		.54	.84	.001	
		44	45	45	45

Research Question 2. Do Student Attitudes Towards Chemistry Change as a Result of Participating in a Chemistry gGme-Based Learning Environment?

Chemistry attitudinal survey. Principal Component Analysis (PCA) with Varimax (orthogonal) rotation was conducted on the 20-item chemistry attitudinal survey that was developed by Mahdi (2014) (Appendix C and H) in order to determine the number of underlying factors (subscales) in the questionnaire. Data was gathered from 45 respondents on both the pre- and post-attitudinal surveys. According to Bartlett's Test of Sphericity for the pre-attitudinal survey, the correlation matrix is significant, $\chi^2(190, N = 45) = 376.960, p < .001$ (Table 4.12), and the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy ($KMO = .610 > .60$) (Table 4.12), which warrants factor analysis.

The Scree Plot for the pre-attitudinal survey (Figure 4.3) suggests three factors to retain as there is a leveling off of Eigenvalues after the third factor. The examination of the Rotated Component Matrix under the Varimax rotation for the pre-attitudinal survey (Table 4.13), reveals that the first factor, Factor 1, has higher loadings (correlations) with 13 items (questions 1A – 8A, 1B – 2B, 4B, 1C – 2C). The second factor, Factor 2, has higher loadings (correlations) with three items (questions 3A, 3D, 4D). The third factor, Factor 3, has higher loadings (correlations) with four items (questions 3B, 4B, 4C, 1D).

Table 4.12

KMO and Bartlett's test for chemistry pre-attitudinal survey (Appendix C)

Kaiser-Meyer-Olkin measure of sampling adequacy		.61
Bartlett's test of sphericity	Approx. Chi- square	376.96
	<i>df</i>	190
	Sig.	<.001

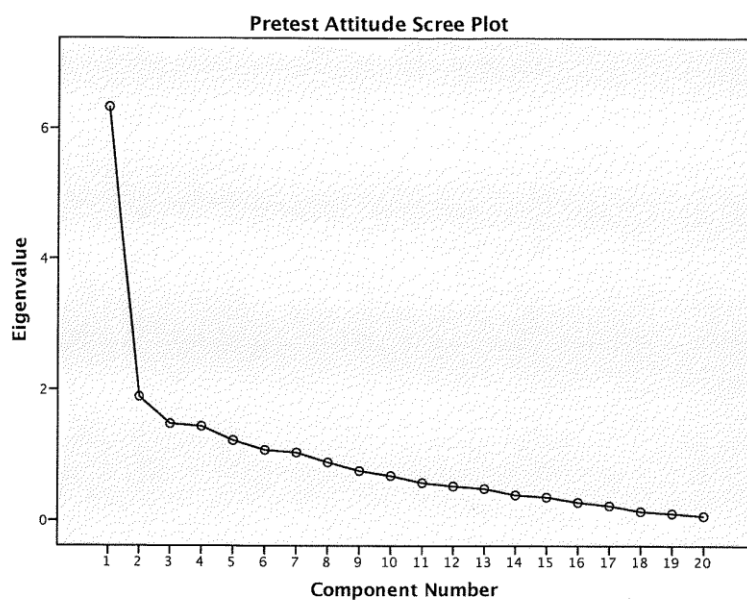


Figure 4.3. Scree Plot for Principal Component Analysis of 20 variables on the chemistry pre-attitudinal survey (Appendix C).

Table 4.13

Rotated component matrix for chemistry pre-attitudinal survey (Appendix C)

Survey item	Factor		
	1	2	3
Q _{2A}	.83		
Q _{1C}	.71		
Q _{5A}	.71		
Q _{1A}	-.66		
Q _{6A}	-.65		
Q _{4A}	.62		
Q _{8A}	.61		
Q _{2C}	.59		
Q _{7A}	-.58		
Q _{2B}	.56		
Q _{1B}	.55		
Q _{4B}	.51		.45
Q _{3A}	-.47	-.46	
Q _{4D}		-.77	
Q _{3D}		-.61	
Q _{3C}			
Q _{2D}			
Q _{1D}			-.71
Q _{4C}			.68
Q _{3B}			.40

According to Bartlett's Test of Sphericity for the post-attitudinal survey, the correlation matrix is significant, $\chi^2(190, N = 45) = 418.239, p < .001$ (Table 4.14), which warrants factor analysis. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy ($KMO = .568 < .60$) (Table 4.14). While the KMO value is low for both the pre- and post-attitudinal surveys, factor analysis is acceptable to conduct since Bartlett's Test of Sphericity is significant. The low KMO value may potentially be attributed to low sample size ($N = 45$).

The scree plot for the post-attitudinal survey (Figure 4.4) suggests three factors to retain as there is a leveling off of Eigenvalues after the third factor. The examination of the Rotated Component Matrix under the Varimax rotation for the post-attitudinal survey (Table 4.15), reveals that the first factor, Factor 1, has higher loadings (correlations) with 9 items (questions 1A – 4A, 6A – 8A, 4C, 4D). The second factor, Factor 2, has higher loadings (correlations) with 7 items (questions 5A, 1B – 4B, 1C – 2C). The third factor, Factor 3, has higher loadings (correlations) with four items (questions 3C, 1D, 3D, 4D).

Table 4.14

KMO and Bartlett's test for chemistry post-attitudinal survey (Appendix H)

Kaiser-Meyer-Olkin measure of sampling adequacy		.57
Bartlett's test of sphericity	Approx. Chi- square	418.24
	<i>df</i>	190
	Sig.	<.001

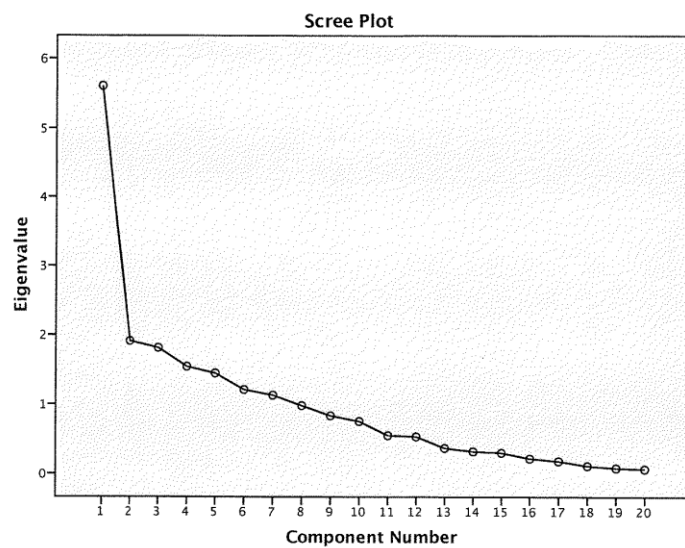


Figure 4.4. Scree Plot for Principal Component Analysis of 20 variables on the chemistry post-attitudinal survey (Appendix H).

Table 4.15

Rotated component matrix for chemistry post-attitudinal survey (Appendix H)

Survey item	Factor		
	1	2	3
Q _{3A}	.81		
Q _{6A}	.77		
Q _{7A}	.76		
Q _{4C}	-.58		
Q _{1A}	.56		
Q _{4D}	.51		.51
Q _{8A}	-.51		
Q _{2A}	-.50		
Q _{4A}	-.50		
Q _{2C}		.75	
Q _{4B}		.71	
Q _{1C}		.66	
Q _{1B}		.57	
Q _{2B}		.57	
Q _{3B}		.55	
Q _{5A}		.52	
Q _{3C}			.64
Q _{3D}			.58
Q _{1D}			-.55
Q _{2D}			

Based on the research study conducted by Mahdi (2014) from which the chemistry attitudinal survey was obtained and from the results of this study between the pre- and post-attitudinal survey results, Factor 1 can be labeled students perceptions into chemistry (questions 1A – 4A, 6A – 8A), Factor 2 can be labeled application of chemical knowledge (questions 1C – 2C), and Factor 3 can be labeled understanding, career, help, and school (questions 1D, 3D – 4D).

A paired samples *t*-test was conducted using the chemistry attitudinal survey by Mahdi (2014) as the pre- and post-test to evaluate if students' positive attitude towards chemistry increased as a result of participating in a chemistry game-based learning

environment. Overall, results of the paired-samples *t*-test indicated that there was no significant difference in pre-attitudinal scores ($M = 38.40$, $SD = 4.70$) and post-attitudinal scores ($M = 37.69$, $SD = 4.53$), $t(44) = .801$, $p > .05$ (Tables 4.16 – 4.18).

Table 4.16

Descriptive statistics for chemistry attitudinal surveys. Means are represented as overall sums of survey results

	Mean	N	Std. deviation	Std. error mean
Pre-attitude	38.40	45	4.70	.70
Post- attitude	37.69	45	4.53	.67

Table 4.17

Paired samples correlations for chemistry attitudinal surveys for overall survey results

	N	Correlation	Sig.
Pre-attitude and Post-attitude	45	.17	.27

Table 4.18

Paired samples t-test for chemistry attitudinal surveys for overall survey results

	Mean	Std. deviation	Std. error mean	Lower	95% confidence interval	Upper	T	df	Sig. (2- tailed)
Pre- attitude	.71	5.95	.89	-1.08		2.50	.80	44	.43
Post- attitude									

Additionally, paired samples *t*-tests were conducted for each sub-scale (factor) that was determined for the chemistry attitudinal survey by Mahdi (2014). Results of the paired-samples *t*-test indicated that there was no significant difference in pre-attitudinal scores ($M = 14.38$, $SD = 1.27$) and post-attitudinal scores for students' perceptions into chemistry (Factor 1) sub-scale ($M = 13.89$, $SD = 1.82$), $t(44) = 1.65$, $p > .05$ (Tables 4.19 – 4.21).

A paired-samples *t*-test indicated that there was no significant difference in pre-attitudinal scores ($M = 3.44$, $SD = 1.36$) and post-attitudinal scores for application of chemical knowledge (Factor 2) sub-scale ($M = 3.20$, $SD = 1.56$), $t(44) = .968$, $p > .05$ (Tables 4.22 – 4.24).

A paired-samples *t*-test indicated that there was no significant difference in pre-attitudinal scores ($M = 2.64$, $SD = 1.15$) and post-attitudinal scores for understanding,

career, help, and school (Factor 3) sub-scale ($M = 2.96$, $SD = 1.31$), $t(44) = -1.43$, $p > .05$ (Tables 4.25 – 4.27).

Table 4.19

Descriptive statistics for students' perceptions into chemistry (Factor 1) sub-scale of chemistry attitudinal surveys. Means are represented as overall sums of Factor 1 sub-scale survey results

	Mean	N	Std. deviation	Std. error mean
Pre-attitude perceptions of chemistry	14.38	45	1.27	.19
Post-attitude perceptions of chemistry	13.89	45	1.82	.27

Table 4.20

Paired samples correlations for students' perceptions into chemistry (Factor 1) sub-scale of chemistry attitudinal surveys

	N	Correlation	Sig.
Pre-attitude perceptions of chemistry and Post-attitude perceptions of chemistry	45	.22	.16

Table 4.21

Paired samples t-test for students' perceptions into chemistry (Factor 1) sub-scale of chemistry attitudinal surveys

	Mean	Std. deviation	Std. error mean	Lower	95% confidence interval	Upper	T	df	Sig. (2- tailed)
Pre-attitude perceptions of chemistry	.49	1.98	.30	-.11		1.09	1.65	44	.11
Post-attitude perceptions of chemistry									

Table 4.22

Descriptive statistics for application of chemical knowledge (Factor 2) sub-scale of chemistry attitudinal surveys. Means are represented as overall sums of Factor 2 sub-scale survey results

	Mean	N	Std. deviation	Std. error mean
Pre-attitude application of chemical knowledge	3.44	45	1.36	.20
Post-attitude application of chemical knowledge	3.20	45	1.56	.23

Table 4.23

Paired samples correlations for application of chemical knowledge (Factor 2) sub-scale of chemistry attitudinal surveys

	N	Correlation	Sig.
Pre-attitude application of chemical knowledge and Post-attitude application of chemical knowledge	45	.33	.03

Table 4.24

Paired samples t-test for application of chemical knowledge (Factor 2) sub-scale of chemistry attitudinal surveys

	Mean	Std. deviation	Std. error mean	Lower	95% confidence interval	Upper	T	df	Sig. (2- tailed)
Pre-attitude application of chemical knowledge	.24	1.69	.25	-.26		.75	.97	44	.34
Post-attitude application of chemical knowledge									

Table 4.25

Descriptive statistics for understanding, career, help, and school (Factor 3) sub-scale of chemistry attitudinal survey. Means are represented as overall sums of Factor 3 sub-scale survey results

	Mean	N	Std. deviation	Std. error mean
Pre-attitude understanding, career, help, school	2.64	45	1.15	.17
Post-attitude understanding, career, help, school	2.96	45	1.31	.20

Table 4.26

Paired samples correlations for understanding, career, help, and school (Factor 3) sub-scale of chemistry attitudinal surveys

	N	Correlation	Sig.
Pre-attitude understanding, career, help, school and Post-attitude understanding, career, help, school	45	.31	.04

Table 4.27

Paired samples t-test for understanding, career, help, and school (Factor 3) sub-scale of chemistry attitudinal surveys

	Mean	Std. deviation	Std. error mean	95% confidence interval		T	df	Sig. (2- tailed)
				Lower	Upper			
Pre-attitude understanding, career, help, school	-.31	1.46	.22	-.75	.13	-	44	.16
Post-attitude understanding, career, help, school						1.43		

Chapter Five

Discussion

Research Question 1. Do Students Who Participate in a Chemistry Game-Based Learning Environment Score Higher on Assessments of Chemistry Content?

Overall, results showed that there was a statistically significant increase in chemistry content knowledge scores between pre-test (first day of class) and delayed post-test (final exam). It is important to remember that for the topics that were taught in the chemistry video game, no additional classroom instruction of content was provided outside of the game. Therefore, it can be inferred that playing the Critical Mass video game increased students' content knowledge of chemistry. While there was an increase in chemistry content exam scores from pre-, post-, and delayed post-test, the fact that a significant increase in chemistry content exam scores was not found between the pre-test and post-test and post-test and delayed post-test may be attributed to several factors.

One explanation for how students obtained a significantly higher score on the delayed post-test may be attributed to the fact that the game persuaded students to think about the material that they needed to learn for the exam. Therefore, students most likely learned the content that was presented in the game via textbook. Perhaps it can be thought that the game worked successfully as a self-teaching tool for the students to get them interested in and thinking about how best to prepare for the exam.

Additionally, the timing of the post-test may not have been the best time to administer the exam. When traditional course content is taught, exams and quizzes are usually given at least one week after the content has been taught, rather than at the end of class on the same day. In this study, students were given the post-test right after playing the Critical Mass video game that did not leave much time for students to reflect and think about the content that was presented in the game. Given that students took the post-test right after they played the chemistry video game, a possible explanation for why students did not achieve significantly higher post-test scores could be because students may have been tired, experienced dizziness, and may not have fully been able to focus and concentrate on the post-test. The game did have technical glitches. If students got stuck in a corner then they were not able to navigate their way out as that was one of the technical glitches that students encountered in the game. However, results of the Pearson Correlation that was conducted in this study showed that there were no statistically significant correlations between post-test and the number of times students had to restart the game, whether it was due to technical glitches or “dying” in the game and then having to start over. Therefore, it can be inferred that encountering technical glitches did not affect exam score. However, in order to get a better idea for understanding if this is the case the questionnaire would have to include additional questions that ask about the number of times students had to restart the game due to technical glitches and a separate question for having to restart the game due to experiencing “game over” in that part of the game. Several students also stated that they experienced dizziness from playing the game. Perhaps a more plausible explanation for no significant increase in post-exam

score could be due to the fact that students may not have been feeling well when they were taking the post-test, especially if they experienced dizziness or motion sickness causing them to not focus their full attention on the post-test. In order to learn if this is the case, a future study could be conducted where students are administered the post-test at a later time (few weeks after playing the game) similar to how content is traditionally taught in class and then exams are given on a different day and students then take the exam at the beginning of class rather than an hour later like in this study where students spent between 20 minutes to 1 hour to play the video game and then they immediately took the post-test right after.

It could also be inferred that the game wasn't very effective at teaching the content but it got the students thinking about how they should study to learn the content for the final exam (delayed post-test). Students may have reached a level of cognitive dissonance. In other words, the game could have changed the students' internal consistency of beliefs about the concepts portrayed in the game similar to how a teacher can cause confusion/cognitive dissonance as well if the material is not presented clearly. While the chemistry video game most likely caused the dissonance, it did get students thinking about what content they have to study and learn for their final exam. The students could have then used the textbook and/or other outside sources to clarify the content. This is one of the limitations of the study. However, In order to understand if this was really the case further research studies that utilize qualitative interviews would have to be conducted in order to learn about the process that students went through that caused them to receive a significantly higher score on the final exam (delayed post-test).

Research Question 2. Do Student Attitudes Towards Chemistry Change as a Result of Participating in a Chemistry Game-Based Learning Environment?

Overall, results showed that there was no significant difference in attitude towards chemistry before and after playing the Critical Mass video game. The pre-attitudinal survey was given on the first day of class while the post-attitudinal survey was administered right after students finished playing the video game. Perhaps the explanations described above for the content knowledge exams and lack of significant increase in the post-test of chemistry content, can also be applied to this situation. If students experienced motion sickness that may have impacted their performance while taking the chemistry content post-test, the same factors may have also swayed their attitudes if they weren't feeling well while completing the post-test surveys. To better understand this, future research studies would have to be conducted where the attitudinal post-test is given during a different time and day than when students play the video game, such as during the last day of class.

Additionally, the fact that attitudinal increase was not obtained may be attributed to the student population in the course with which this study was conducted. The General Chemistry I lecture course is targeted toward students who are chemistry or other science majors. If students choose to pursue chemistry as their field of study then they most likely already demonstrate a positive attitude toward chemistry. If one enters a course with a high attitudinal score then it is not likely that an increase effect will be observed by the end of the semester.

Another probable explanation for not observing significant change in attitude may be justified by the length of the intervention. In this study, students played the Critical Mass video game one day in the computer lab for one hour. Perhaps if the length of the intervention were to be increased then there is a possibility for a significant increase in attitude toward chemistry to be observed. This opens the gateway into additional studies that would have to be conducted where the length of the intervention would have to be increased in order to better understand if increasing the time during which students play chemistry video games would enable a significant effect to be obtained. The length of the intervention could be setup in multiple ways. Either students could play the same or similar game multiple times, which would require having students in the computer lab during additional days in order for them to have access to repetitive practice and mastery of the content or a game-based learning environment would have to be setup that would be increased in length where students would play SEGs throughout the semester where each SEG or part of a larger SEG would be used to teach multiple chemistry topics throughout the semester. In order to gain a deeper understanding into which option would be more feasible and would benefit students greater, additional studies would have to be conducted to better learn how best to structure undergraduate college chemistry curricula.

Limitations of the Study

As described in chapter 2 above, limitations can arise if SEGs are not designed well with important learning principles that can lead to and evaluate content knowledge. The lack of chemistry video games presented a limitation as it was very difficult to find

SEGs in the field of chemistry. The Critical Mass video game was designed more than 10 years ago (Morales et al., 2006). Careful attention has to be given to developing more modern chemistry SEGs where technical glitches and motion sickness is prevented as much as possible. The lack of chemistry and SEG attitudinal surveys as well as research studies evaluating attitudinal change toward chemistry as a result of implementing SEGs also presented a great limitation for this study.

Additional limitations include the way how the course was taught. The instructor of the course did not have control over additional resources that students may have utilized outside of the course that may have led to the results found in this study. For instance, there could be an additional outside factor that may have influenced one's attitude towards chemistry or increase in content knowledge during the particular semester when the study was being conducted. Similarly, the instructor did not have control over which laboratory instructor each of the students had who were enrolled in the lecture sections with which the study was being conducted and how the lab instructors delivered course content. As described in chapter 3, under fidelity of treatment, the General Chemistry laboratory curriculum has become standardized with all lab sections performing the same lab experiments, completing the same lab assignments, and ultimately following the same lab syllabus. However, each of the lab instructors may still differ in their teaching approach in terms of how they deliver the course content during pre-lab lecture. Nevertheless, this would be the most realistic environment that would most closely resemble the General Chemistry curriculum if a game-based curriculum were to become implemented into the undergraduate college chemistry curriculum, as the

lecture and laboratory courses are not always taught by the same professors. Another study limitation includes the lecture instructor not truly being able to know from lecture if the students are actually comprehending what is being taught by just attending lecture each class period. It could be that they are later learning the material via outside resources.

Additionally, due to the fact that the researcher works at the research setting and the researcher of the study conducted the research with their students; there is the potential threat of backyard research. According to Glesne (2011), backyard research is known as research that is conducted by researchers who study their institution or place of employment. While there may be numerous benefits to conducting backyard research, such as easy access to subjects and data collection, there are also disadvantages to backyard research, which include ethical and political conflicts (Glesne, 2011). However, in order to minimize the risks of these disadvantages from taking place in this research study, the researcher, who was also the instructor of the General Chemistry I lecture course, only had access to the data after the semester ended and the grades had been submitted. The chemistry attitudinal surveys were administered to students by one of the researcher's colleagues from the chemistry department who then collected the surveys and placed them in a sealed envelope. The researcher did not have access to the material until after grades had been submitted. By taking these steps, the goal was to minimize the threat that students may be hesitant to voice their true opinions in fear of negative impact toward their grade.

Additional study limitations include the small sample size, which decreased power on statistical analysis and lack of a control group. However, it would be very difficult to setup a true control group as the instructor of the lecture course would not be able to strictly control for how students are learning the chemistry content. It would be nearly impossible to test for whether the students' content knowledge was obtained via the lecture course alone without additional outside resources.

Implications and Future Research

Research shows that SEGs can lead to increase in students' positive attitudes, motivation, and content knowledge of the material being taught in the game (Bennett, Rollnick, Green, & White, 2001; Berg, 2005; Cheng, Annetta, Foltz, & Holmes, 2011; Daubenfeld & Zenker, 2015; Freedman, 1997; House & Prison, 1998; Levin, Sabar, & Libman, 1991; Oliver & Simpson, 1988; Ruggiero, 2015; Salen, 2008; Sharritt & Suthers, 2011; Salta & Tzougraki, 2004; Weinburgh, 1995; Wilson, 1983). Consequently, by leading to positive attitudes towards chemistry, we will also most likely see in increase in knowledge, motivation, and engagement for learning chemistry concepts at the college level. Since there is a lack of chemistry SEGs and attitudinal instruments, more research studies need to be conducted in which careful attention is given to the development of chemistry SEGs that align with the learning structures described in chapter 2 and in which technical glitches are avoided as much as possible, as well as scales for measuring attitude towards chemistry.

Overall, the findings of this research study show that there are implications for implementing SEGs into the undergraduate college chemistry curricula as teaching and

learning tools, particularly if the SEGs align with the learning structures described in chapter 2, as well as the experiential learning and constructivist learning approach. In terms of incorporating SEGs into the classroom, results of this study suggest that SEGs may better serve as learning tools as a compliment to traditional teaching techniques rather than fully replacing hands-on learning such as traditional laboratory experiments. SEGs can provide supplemental instruction to what traditional teaching methods and laboratory techniques are not able to provide, such as learning in a risk free environment and the ability to explore and virtually manipulate subatomic particles that one is not able to accomplish via traditional textbooks. Hands-on laboratory experiments are still a necessity for preparing students to enter the work force in chemistry based disciplines and be ready to work as a chemist or other scientist whose work draws upon chemistry. However, SEGs can be used to further help students understand why they are observing what they see in the lab and what is occurring at the subatomic level that can be used to explain these effects. Nevertheless, this leaves room for further research studies to be conducted in order to investigate the most effective methods for how to utilize SEGs in conjunction with current undergraduate college chemistry curricula. One dilemma that may arise from both students and faculty is the use of additional class time for the same number of credit hours if this method were to be added in addition to the traditional lecture teaching method. One option may be to incorporate a recitation period into the current number of credit hours for these courses, such as replacing one hour of traditional lecture instruction with having students in a computer lab where they are playing the SEG as part of their learning and instruction.

Additional implications include developing a game-based learning environment to teach each topic/unit of chemistry. Since chemistry is a cumulative subject that builds upon prior knowledge that students learn early in the semester, a comprehensive multi-level SEG in which conquering the entire game would require students to draw upon previous content knowledge that they learned, can be utilized as a teaching tool where for each level of the game students are in the computer once a week. Each level or world in the game can correspond to each unit or chapter in chemistry such as acids/bases, oxidation-reduction reactions, and other topics of chemistry. Then as a final project for the course, students could demonstrate their content knowledge by having to defeat the entire game which would contain content from the entire semester. In this way the comprehensive game-based learning environment would serve as an assessment tool and this leaves for further research to be conducted that would evaluate the effect of the SEG on motivation, engagement, attitude, and knowledge gains.

One of the limitations of this study was that the Critical Mass video game was only limited to teaching the topics described in chapter 3. The findings of this study also show implications for developing additional SEGs in which students can relate the scenarios to their everyday lives to better see how chemistry applies to their lives as well. For instance, the video game can be designed as a story that the avatar lives, works, and/or navigates through, while simulating real world experiences to application of similar types of problems in different scenarios where the student will have to be able to apply what they have learned in order to succeed in that video game.

Conclusions

Overall, it can be seen that there is potential for implementing SEGs into undergraduate college chemistry curricula as there was a significant overall increase in content knowledge scores between chemistry pre-test and delayed post-test (final exam) without additional classroom instruction being provided to teach the topics that were presented in the Critical Mass video game. However, more studies would have to be conducted to further investigate SEGs on student learning and attitude. Lack of chemistry SEGs made it difficult for choosing an SEG for this study. However, this also leaves room for future research for designing chemistry SEGs and then evaluating their effect on student learning and attitudes towards chemistry. When developing SEGs, careful attention would have to be given to prevention of technical glitches as much as possible. Additionally, research into the development and evaluation of attitudinal scales would have to be conducted, as it was also difficult to find an attitudinal scale for chemistry when conducting this study.

Appendix A



Office of Research Integrity and Assurance

Research Hall, 4400 University Drive, MS 6D5, Fairfax, Virginia 22030
Phone: 703-993-5445; Fax: 703-993-9590

DATE: October 30, 2015
TO: Leonard Annetta
FROM: George Mason University IRB
Project Title: [806163-1] Evaluating the Efficacy of a Chemistry Video Game
SUBMISSION TYPE: New Project
ACTION: APPROVED
APPROVAL DATE: October 30, 2015
EXPIRATION DATE: October 29, 2016
REVIEW TYPE: Expedited Review
REVIEW TYPE: Expedited review category #7

Thank you for your submission of New Project materials for this project. The George Mason University IRB has APPROVED your submission. This submission has received Expedited Review based on applicable federal regulations.

Please remember that all research must be conducted as described in the submitted materials.

Please remember that informed consent is a process beginning with a description of the project and insurance of participant understanding followed by a signed consent form. Informed consent must continue throughout the project via a dialogue between the researcher and research participant. Federal regulations require that each participant receives a copy of the consent document.

Please note that any revision to previously approved materials must be approved by the IRB prior to initiation. Please use the appropriate revision forms for this procedure.

All UNANTICIPATED PROBLEMS involving risks to subjects or others and SERIOUS and UNEXPECTED adverse events must be reported promptly to the Office of Research Integrity & Assurance (ORIA). Please use the appropriate reporting forms for this procedure. All FDA and sponsor reporting requirements should also be followed (if applicable).

All NON-COMPLIANCE issues or COMPLAINTS regarding this project must be reported promptly to the ORIA.

The anniversary date of this study is October 29, 2016. This project requires continuing review by this committee on an annual basis. You may not collect data beyond this date without prior IRB approval. A continuing review form must be completed and submitted to the ORIA at least 30 days prior to the anniversary date or upon completion of this project. Prior to the anniversary date, the ORIA will send you a reminder regarding continuing review procedures.

- 1 -

Generated on IRBNet

Please note that all research records must be retained for a minimum of five years, or as described in your submission, after the completion of the project.

If you have any questions, please contact Bess Dieffenbach at 703-993-5593 or edieffen@gmu.edu. Please include your project title and reference number in all correspondence with this committee.

This letter has been electronically signed in accordance with all applicable regulations, and a copy is retained within George Mason University IRB's records.



EXEMPTION NUMBER: 16-X050

To: Marina Shapiro
From: Institutional Review Board for the Protection of Human
Subjects, Debi Gartland, Chair
Date: Thursday, December 03, 2015
RE: Application for Approval of Research Involving the Use of
Human Participants

Office of Sponsored Programs
& Research

Towson University
8000 York Road
Towson, MD 21252-0001

t. 410 704-2236
f. 410 704-4494
www.towson.edu/ospr

Thank you for submitting an application for approval of the research
Evaluating the efficacy of a chemistry video game

to the Institutional Review Board for the Protection of Human Participants
(IRB) at Towson University.

Your research is exempt from general Human Participants requirements
according to 45 CFR 46.101(b)(1). No further review of this project is
required from year to year provided it does not deviate from the submitted
research design.

If you substantially change your research project or your survey
instrument, please notify the Board immediately.

We wish you every success in your research project.

CC: Leonard Annetta
File

Appendix B

Pre-test survey packet for first day of class

INFORMED CONSENT FORM

Research Study: Efficacy of Chemistry Video Game Study

RESEARCH PROCEDURES

This research is being conducted to evaluate the efficacy of using a chemistry educational video game to enhance student learning of chemistry concepts as well as improve attitude towards chemistry for undergraduate college students. If you agree to participate, you will be asked to complete a 20-item Chemistry Attitudinal Survey by Mahdi (2014), a 5-item basic demographic questionnaire, an 11-item Chemistry Content Survey that should take no more than approximately 25 minutes of your time. However, for confidentiality reasons, no identifying information will be published (no names, social security numbers, or semester enrollment dates will be published or shared with outside parties) as it will not be collected during survey administration. Additionally, if you agree to participate in this study, then your scores from the extra credit quiz, exam 3, and final exam will be used for statistical analysis for research purposes. However, for confidentiality reasons, no identifying information will be published (no names, social security numbers, or semester enrollment dates will be published or shared with outside parties). All student identifying information will remain property of the professor's grade book who teaches this course (as traditionally occurs).

RISKS

There are no foreseeable risks for participating in this research.

BENEFITS

There are no direct benefits to you for participating in the research. Participation in this research study may help to further research in teaching and learning processes.

CONFIDENTIALITY

The data in this study will be confidential. If this study will become published, then your chemistry attitudinal survey scores will be used for statistical analysis. However, for confidentiality reasons, no identifying information will be published as it will not be collected (no names, social security numbers, or semester enrollment dates will be published or shared with outside parties).

PARTICIPATION

Participants must be at least 18 years old to participate in this research study. Your participation is voluntary, and you may withdraw from the study at any time and for any reason. If you decide not to participate or if you withdraw from the study, there is no penalty or loss of benefits to which you are otherwise entitled. There are no costs to you or any other party. Your decision about whether or not to participate in this study will not affect your standing in the course or your grade in the course. Additionally, your instructor will not view the surveys or know who agreed to participate in the research until after the course has ended and grades have been posted.

ALTERNATIVES TO PARTICIPATION

If you choose not to participate in the research study, then your chemistry attitudinal survey scores, demographic survey scores, chemistry content survey scores, video game survey scores, and extra credit quiz scores, Exam 3, Final Exam scores will not be used for statistical analysis for research purposes. If you choose not to participate in this study then this will not in any way affect your grade, as participation in this research study is strictly voluntary. As stated on our course syllabus, participation in this research study is one of the opportunities that may be used to earn 5 extra credit points that will be added to your overall grade at the end of the semester. The syllabus also describes another possible option for earning 5 extra credit points as an alternative to participation in this research study, which is as follows: you may choose any of the chapters that are covered this semester and design a safe lab activity that can be conducted at home based on any of the topics covered this semester. You do not actually have to carry out the lab activity in class. However, you can either write a 1 page laboratory step-by-step procedure, similar to one seen in a lab manual or write a 1 page summary of how the experiment would be conducted, including materials required, as well as any necessary safety precautions, etc... Examples of topics include the following: there are many fun kitchen chemistry types of hands-on lab activities that one may safely conduct, which utilize various chemistry topics that are covered this semester. For example: homemade lava lamps (related to the topics of density, solubility/miscibility, etc...), baking soda/vinegar volcano (chemical reactions, etc...), rock candy (food chemistry, etc...), as well as others.

CONTACT

This research is being conducted by Marina Shapiro who is a Ph.D student in the College of Education and Human Development Science Education program at George Mason University. Marina may be reached at 410-370-9479 for questions or to report a research-related problem. In addition, the principle investigator, Dr. Len Annetta may be reached at 703-993-5249. You may contact the George Mason University Office of Research Integrity & Assurance at 703-993-4121 if you have questions or comments regarding your rights as a participant in the research.

This research has been reviewed according to George Mason University procedures governing your participation in this research.

CONSENT

I have read this form and agree to participate in this study.

Name and Signature

Date of Signature

Version date:

Appendix C

Demographic Survey

1. What is your age?
 - a. under 18 years of age
 - b. 18 – 19 years old
 - c. 20 – 21 years old
 - d. 22 – 23 years old
 - e. over 24 years old

2. What is your ethnicity (or race)?
 - a. Caucasian
 - b. Hispanic or Latino
 - c. African American
 - d. Asian / Pacific Islander
 - e. Native American or American Indian
 - f. Other

3. Are you male or female?
 - a. Male
 - b. Female

4. What is your current academic status in your undergraduate studies?
 - a. Freshman
 - b. Sophomore
 - c. Junior
 - d. Senior
 - e. Other (i.e. working on second degree or non-degree student)

5. Which of the following is your academic major:
- a. Biology
 - b. Chemistry
 - c. Physics or Astronomy
 - d. Geosciences
 - e. Exercise Science
 - f. Math, Economics, or Business
 - g. Computer Science
 - h. Social Sciences (Psychology, Anthropology, Communication etc...)
 - i. Humanities

Appendix D

Chemistry Attitudinal Survey

Mahdi, 2014

1- agree; 2- not sure; 3- disagree

- 1A. Chemistry is an easy subject. ____
- 2A. Chemistry is a difficult subject. ____
- 3A. Chemistry is an interesting subject. ____
- 4A. The mathematics involved makes it not easy to understand. ____
- 5A. There are too many chemical formulas that are difficult to remember. ____
- 6A. The practical part of a chemistry lesson encouraged me to take it. ____
- 7A. Chemistry is a challenging subject that is why I like it. ____
- 8A. Chemistry is a boring subject that is why I do not like it. ____
- 1B. It is not easy to recall facts, terminology and relationships. ____
- 2B. It is tricky to understand chemical principles and concepts. ____
- 3B. It is difficult to draw on existing knowledge to show an understanding of the responsible use of Chemistry in society. ____
- 4B. It is not easy to select, organize and present chemical information clearly and logically. ____
- 1C. Explaining and interpreting chemical principles and concepts are not easy.

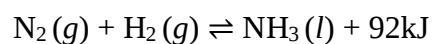
- 2C. Chemistry is a complex subject and data are not easy to present. ____
- 3C. To apply chemical knowledge and understand familiar and unfamiliar situations require long hours of studying. ____
- 4C. It is complicated to make connections between different topics. ____
- 1D. I considered taking Chemistry because there will be help offered at home.

- 2D. I considered taking Chemistry for a future career. ____
- 3D. Having a good teacher persuades me to carry on with Chemistry. ____
- 4D. Knowing that there will be a lot of help offered by the teachers and the school helps me to decide whether to take Chemistry. ____

Appendix E

Chemistry Content Survey

For questions # 1 and 2 refer to the following chemical reaction:



- 1) Is the reaction above exothermic or endothermic?
 - a) Endothermic
 - b) Exothermic
- 2) Balance the chemical reaction above by selecting which of the following choices are correct (the coefficients in the answer choices are written in order of the reactants and products as shown in the reaction above):
 - a) The chemical reaction is balanced as written
 - b) 1, 1, 1
 - c) 1, 3, 2
 - d) 3, 1, 2
 - e) 2, 2, 3
- 3) Ammonia (NH_3) is a (an):
 - a) Acid
 - b) Base
 - c) Amphoteric substance
- 4) The Haber-Bosch reaction produces:
 - a) Water

- b) Nitrogen
- c) Carbon dioxide
- d) Ammonia
- e) Hydrogen

5) Liquid Nitrogen (LN₂) helps to _____ substances.

- a) Lower the temperature of substances
- b) Increase the temperature of substances
- c) Maintain the temperature of substances

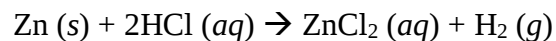
6) What happens to H₂O (l) when liquid nitrogen (LN₂) is added to it?

- a) Water freezes
- b) Water boils
- c) Water vaporizes
- d) Condensation occurs
- e) Water sublimates

7) The electrolysis of water produces which of the following gases?:

- a) Carbon dioxide gas
- b) Nitrogen gas
- c) Hydrogen gas
- d) Oxygen gas
- e) Both c and d above

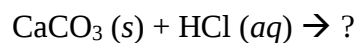
For question #8 refer to the following chemical reaction:



8) What is produced in the reaction above?

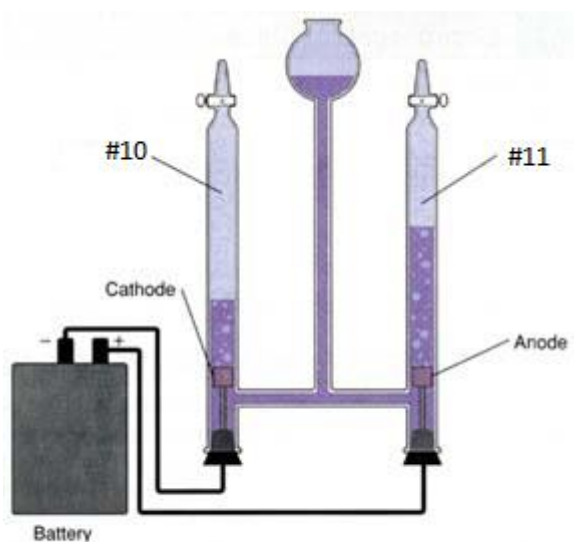
- a) A flammable gas
- b) Water
- c) Hydrogen gas
- d) Ammonia
- e) Both a and c above

For question #9 refer to the following chemical reaction:



- 9) The chemical equation above shows the reactants for the reaction between marble and acid. What is released as one of the products from the reaction between marble and acid?
- a) Ammonia
 - b) Carbon dioxide gas
 - c) Hydrogen gas
 - d) Water vapor
 - e) Hydrochloric acid

For question #10 and 11 refer to the following diagram:



- 10) The diagram above represents the electrolysis process of water. Fill in the missing blanks in the diagram above for #10 by selecting from the options below:
- a) Carbon dioxide
 - b) Nitrogen
 - c) Hydrogen
 - d) Oxygen
 - e) Ammonia

11) The diagram above represents the electrolysis process of water. Fill in the missing blanks in the diagram above for **#11** by selecting from the options below:

- a) Carbon dioxide
- b) Nitrogen
- c) Hydrogen
- d) Oxygen
- e) Ammonia

Appendix F

Post-test survey packet for computer lab (after video game play)

INFORMED CONSENT FORM

Research Study: Efficacy of Chemistry Video Game Study

RESEARCH PROCEDURES

This research is being conducted to evaluate the efficacy of using a chemistry educational video game to enhance student learning of chemistry concepts as well as improve attitude towards chemistry for undergraduate college students. If you agree to participate, you will be asked to complete a 20-item Chemistry Attitudinal Survey by Mahdi (2014), a 5-item basic demographic questionnaire, an 11-item Chemistry Content Survey, and a 12-item Video Game Survey by Kim and Shute (2015) and Bourgonjon, Valcke, Soetaert, and Schellens (2010) that should take no more than approximately 25 minutes of your time. However, for confidentiality reasons, no identifying information will be published (no names, social security numbers, or semester enrollment dates will be published or shared with outside parties) as it will not be collected during survey administration. Additionally, if you agree to participate in this study, then your scores from the extra credit quiz, exam 3, and final exam will be used for statistical analysis for research purposes. However, for confidentiality reasons, no identifying information will be published (no names, social security numbers, or semester enrollment dates will be published or shared with outside parties). All student identifying information will remain property of the professor's grade book who teaches this course (as traditionally occurs).

RISKS

There are no foreseeable risks for participating in this research.

BENEFITS

There are no direct benefits to you for participating in the research. Participation in this research study may help to further research in teaching and learning processes.

CONFIDENTIALITY

The data in this study will be confidential. If this study will become published, then your chemistry attitudinal survey scores will be used for statistical analysis. However, for confidentiality reasons, no identifying information will be published as it will not be collected (no names, social security numbers, or semester enrollment dates will be published or shared with outside parties).

PARTICIPATION

Participants must be at least 18 years old to participate in this research study. Your participation is voluntary, and you may withdraw from the study at any time and for any reason. If you decide not to participate or if you withdraw from the study, there is no penalty or loss of benefits to which you are otherwise entitled. There are no costs to you or any other party. Your decision about whether or not to participate in this study will not affect your standing in the course or your grade in the course. Additionally, your instructor will not view the surveys or know who agreed to participate in the research until after the course has ended and grades have been posted.

ALTERNATIVES TO PARTICIPATION

If you choose not to participate in the research study, then your chemistry attitudinal survey scores, demographic survey scores, chemistry content survey scores, video game survey scores, and extra credit quiz scores, Exam 3, Final Exam scores will not be used for statistical analysis for research purposes. If you choose not to participate in this study then this will not in any way affect your grade, as participation in this research study is strictly voluntary. As stated on our course syllabus, participation in this research study is one of the opportunities that may be used to earn 5 extra credit points that will be added to your overall grade at the end of the semester. The syllabus also describes another possible option for earning 5 extra credit points as an alternative to participation in this research study, which is as follows: you may choose any of the chapters that are covered this semester and design a safe lab activity that can be conducted at home based on any of the topics covered this semester. You do not actually have to carry out the lab activity in class. However, you can either write a 1 page laboratory step-by-step procedure, similar to one seen in a lab manual or write a 1 page summary of how the experiment would be conducted, including materials required, as well as any necessary safety precautions, etc... Examples of topics include the following: there are many fun kitchen chemistry types of hands-on lab activities that one may safely conduct, which utilize various chemistry topics that are covered this semester. For example: homemade lava lamps (related to the topics of density, solubility/miscibility, etc...), baking soda/vinegar volcano (chemical reactions, etc...), rock candy (food chemistry, etc...), as well as others.

CONTACT

This research is being conducted by Marina Shapiro who is a Ph.D student in the College of Education and Human Development Science Education program at George Mason University. Marina may be reached at 410-370-9479 for questions or to report a research-related problem. In addition, the principle investigator, Dr. Len Annetta may be reached at 703-993-5249. You may contact the George Mason University Office of Research Integrity & Assurance at 703-993-4121 if you have questions or comments regarding your rights as a participant in the research.

This research has been reviewed according to George Mason University procedures governing your participation in this research.

CONSENT

I have read this form and agree to participate in this study.

Name and Signature

Date of Signature

Version date:

Appendix G

Demographic Survey

1. What is your age?
 - a. under 18 years of age
 - b. 18 – 19 years old
 - c. 20 – 21 years old
 - d. 22 – 23 years old
 - e. over 24 years old

2. What is your ethnicity (or race)?
 - a. Caucasian
 - b. Hispanic or Latino
 - c. African American
 - d. Asian / Pacific Islander
 - e. Native American or American Indian
 - f. Other

3. Are you male or female?
 - a. Male
 - b. Female

4. What is your current academic status in your undergraduate studies?
 - a. Freshman
 - b. Sophomore
 - c. Junior
 - d. Senior
 - e. Other (i.e. working on second degree or non-degree student)

5. Which of the following is your academic major:
- a. Biology
 - b. Chemistry
 - c. Physics or Astronomy
 - d. Geosciences
 - e. Exercise Science
 - f. Math, Economics, or Business
 - g. Computer Science
 - h. Social Sciences (Psychology, Anthropology, Communication etc...)
 - i. Humanities

Appendix H

Video Game Survey

1. How many times did you have to restart the game?
 - a. 1-2
 - b. 3-4
 - c. 5-6
 - d. 7-8
 - e. more than 9

Video Game Background Kim and Shute (2015)

2. How often do you play video games?
 - a. Not at all
 - b. About once a month
 - c. A few times a month
 - d. A few times a week
 - e. Every day, but for less than 1 hour
 - f. Every day, for 1–3 hours
 - g. Every day, for more than 3 hours
3. Do you prefer playing games to other activities (e.g., going out with friends, watching TV)?
 - a. Never
 - b. Seldom
 - c. Sometimes
 - d. Frequently
 - e. Often
4. Do you consider yourself:
 - a. A non-video game player
 - b. A novice video game player
 - c. An occasional video game player

- d. A frequent video game player
- e. An expert video game player

Preference for video games
Bourgonjon, Valcke, Soetaert, and Schellens (2010)

1- strongly disagree; 2- disagree; 3- neutral; 4- agree; 5- strongly agree

5a. If I had the choice, I would choose to follow courses in which video games are used

5b. If I had to vote, I would vote in favor of using video games in the classroom ____

5c. I am enthusiastic about using video games in the classroom ____

Experience with games
Bourgonjon, Valcke, Soetaert, and Schellens (2010)

1- strongly disagree; 2- disagree; 3- neutral; 4- agree; 5- strongly agree

6a. I like playing video games ____

6b. I often play video games ____

6c. Compared to people of my age, I play a lot of video games ____

6d. I would describe myself as a gamer ____

6e. I play different types of video games ____

Appendix I

Chemistry Attitudinal Survey

Mahdi, 2014

1- agree; 2- not sure; 3- disagree

- 1A. Chemistry is an easy subject. ____
- 2A. Chemistry is a difficult subject. ____
- 3A. Chemistry is an interesting subject. ____
- 4A. The mathematics involved makes it not easy to understand. ____
- 5A. There are too many chemical formulas that are difficult to remember. ____
- 6A. The practical part of a chemistry lesson encouraged me to take it. ____
- 7A. Chemistry is a challenging subject that is why I like it. ____
- 8A. Chemistry is a boring subject that is why I do not like it. ____
- 1B. It is not easy to recall facts, terminology and relationships. ____
- 2B. It is tricky to understand chemical principles and concepts. ____
- 3B. It is difficult to draw on existing knowledge to show an understanding of the responsible use of Chemistry in society. ____
- 4B. It is not easy to select, organize and present chemical information clearly and logically. ____
- 1C. Explaining and interpreting chemical principles and concepts are not easy.

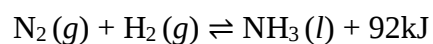
- 2C. Chemistry is a complex subject and data are not easy to present. ____
- 3C. To apply chemical knowledge and understand familiar and unfamiliar situations require long hours of studying. ____
- 4C. It is complicated to make connections between different topics. ____
- 1D. I considered taking Chemistry because there will be help offered at home.

- 2D. I considered taking Chemistry for a future career. ____
- 3D. Having a good teacher persuades me to carry on with Chemistry. ____
- 4D. Knowing that there will be a lot of help offered by the teachers and the school helps me to decide whether to take Chemistry. ____

Appendix J

Chemistry Content Survey

For questions # 1 and 2 refer to the following chemical reaction:



- 1) Is the reaction above exothermic or endothermic?
 - a) Endothermic
 - b) Exothermic

- 2) Balance the chemical reaction above by selecting which of the following choices are correct (the coefficients in the answer choices are written in order of the reactants and products as shown in the reaction above):
 - a) The chemical reaction is balanced as written
 - b) 1, 1, 1
 - c) 1, 3, 2
 - d) 3, 1, 2
 - e) 2, 2, 3

- 3) Ammonia (NH_3) is a (an):
 - a) Acid
 - b) Base
 - c) Amphoteric substance

4) The Haber-Bosch reaction produces:

- a) Water
- b) Nitrogen
- c) Carbon dioxide
- d) Ammonia
- e) Hydrogen

5) Liquid Nitrogen (LN₂) helps to _____ substances.

- a) Lower the temperature of substances
- b) Increase the temperature of substances
- c) Maintain the temperature of substances

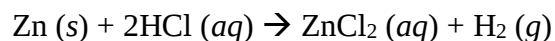
6) What happens to H₂O (l) when liquid nitrogen (LN₂) is added to it?

- a) Water freezes
- b) Water boils
- c) Water vaporizes
- d) Condensation occurs
- e) Water sublimates

7) The electrolysis of water produces which of the following gases?:

- a) Carbon dioxide gas
- b) Nitrogen gas
- c) Hydrogen gas
- d) Oxygen gas
- e) Both c and d above

For question #8 refer to the following chemical reaction:

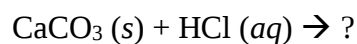


8) What is produced in the reaction above?

- a) A flammable gas
- b) Water

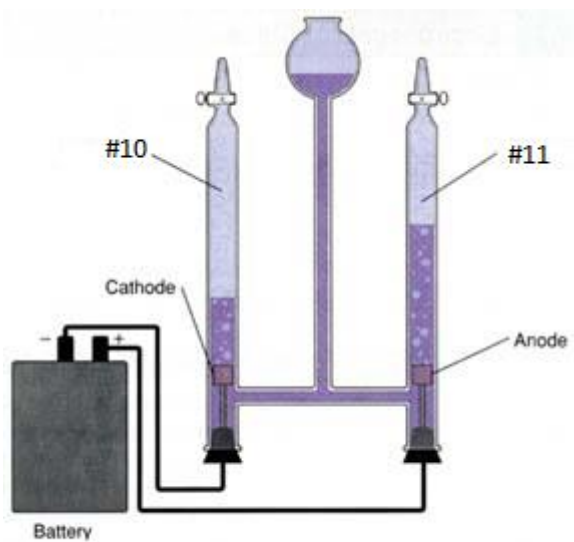
- c) Hydrogen gas
- d) Ammonia
- e) Both a and c above

For question #9 refer to the following chemical reaction:



- 9) The chemical equation above shows the reactants for the reaction between marble and acid. What is released as one of the products from the reaction between marble and acid?
- a) Ammonia
 - b) Carbon dioxide gas
 - c) Hydrogen gas
 - d) Water vapor
 - e) Hydrochloric acid

For question #10 and 11 refer to the following diagram:



10) The diagram above represents the electrolysis process of water. Fill in the missing blanks in the diagram above for **#10** by selecting from the options below:

- a) Carbon dioxide
- b) Nitrogen
- c) Hydrogen
- d) Oxygen
- e) Ammonia

11) The diagram above represents the electrolysis process of water. Fill in the missing blanks in the diagram above for **#11** by selecting from the options below:

- a) Carbon dioxide
- b) Nitrogen
- c) Hydrogen
- d) Oxygen
- e) Ammonia

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Biography

Marina Shapiro was born on January 21, 1984 in Baku, Azerbaijan. In 1990, Marina's family immigrated to the United States. Marina Shapiro graduated from Pikesville High School, Pikesville, Maryland, in 2002. She received her Bachelor of Science in Biology with Chemistry minor from Towson University in 2006 and Master of Science in Forensic Science under the direction of Dr. Cindy Zeller at Towson University in 2009. Upon completion of graduate school, Marina worked as Adjunct Professor of Chemistry prior to pursuing and during her doctoral studies.