A CHAT Analysis of the Use of Educational Video Games to Teach Physical Science to Middle School Girls

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A CHAT ANALYSIS OF THE USE OF EDUCATIONAL VIDEO GAMES TO TEACH PHYSICAL SCIENCE TO MIDDLE SCHOOL GIRLS

by

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A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Education in the Department of Learning Science and Educational Research in the College of Community Innovation and Education at the University of Central Florida Orlando, Florida

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Major Professor: David N. Boote
ABSTRACT

As students transition into middle school science courses, their interest and engagement in the subject declines. This decline is most significant among girls, particularly for topics in physical science. While several factors have been identified that contribute to the decline, one area that is emerging as a new way to help improve girls’ view of science is the use of educational video games to improve engagement and interest in science content, particularly as video games have been steadily rising in popularity with girls. This study used Cultural Historical Activity Theory to understand how middle school girls engage with an educational video game designed to teach physical science concepts and how game design influences engagement. Ten participants played three games. Games were chosen to reflect diverse designs and mechanics. Participants were observed and audio recorded during the play and debriefed after the play. Games designs like open exploration, an in-game story, and gradually increasing challenges connected to content all supported engagement. Game design that used low cognitive demand, repetitive tasks, and increasing difficulty connected to game mechanics discouraged engagement. The enjoyment of the game itself increased interest in physical science topics. By better understanding the perspective of female students, these findings guide educators in selecting educative games for middle school girls and support game designers to better engage girls in the games and interest them in science.
ACKNOWLEDGMENTS

First, I would like to express my deepest gratitude to my dissertation chair, Dr. David Boote, for guiding me through this process and being one of my biggest supporters on this journey. Thank you for educating me and helping me to grow as an educator and a researcher. Despite the stress and anxiety that this whole process has brought, you have always helped me to keep focus and relax providing constant advice and encouragement. Our weekly meetings have always been fun and insightful whether we were discussing topics related to the dissertation, program stories, or K-12 education. I do not think I would have made it this far without your help. I would also like to thank my committee, Dr. Su Gao, Dr. Richard Hartshorne, and Dr. Jonathan Hall, for the support and insight you have given me with this study. Though it was tough at times you all helped me to grow and pushed me to improve. Thank you for all your advice. Additionally, I would also like to thank Dr. Gao for introducing me to this program. I would not have been here today if it were not for your advice and guidance.

I would like to acknowledge my peers who have supported me along this journey. I still remember the anxiety that came with realizing I was not only starting one of the most difficult journeys of my life, but I would be starting this journey fully online as we were in the first year of the pandemic. Despite it being out of my comfort zone, I pushed myself to reach out and join one of the study groups that were forming, then during the second semester I found another support group thanks to the semester project, and you all became a rock that helped me to keep focus and not give up no matter how hard things got. Ashleigh, Carrie, Greta, Joe, Megan, Patti, and Vanessa I could not have made it this far without you all. Thank you for all the texts, inspiration, and just taking time to check-in. Having others going through the same ups and downs, stressful moments, and successes, and seeing that I was not alone meant so much to me.
Finally, I would like to acknowledge the people who have supported me through my whole educational journey. To my mother and father, thank you for raising me and being my first teachers setting me on this path. You have always been there with advice and guidance, and I am truly grateful to have you in my life. To my wonderful wife Sabrina and my kids, Rachel, Michael, and Melanie, thank you for putting up with me during this long journey. I know it has been rough at times, but your love and support have kept me focused to the end.
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CHAPTER ONE: PROBLEM STATEMENT AND PURPOSE

Problem Statement

Within science education, a significant concern across many studies and locations has been the sharp decline in student interest and engagement in science courses and willingness to continue studying science in high school and college. This decline in interest becomes particularly sharp during the middle school years (Barton et al., 2013; Falk et al., 2017; Makransky et al., 2020). Studies have shown that the sharpest decline in engagement and decrease in positive attitudes about science occurs between the ages of 10-14 during their time in middle school (Archer et al., 2010; Osborne et al., 2003). There is also an indication that these decreases in interest in science classes are more prominent among female middle schoolers than their male counterparts (Desy et al., 2011; Sorge, 2007). Many sources and mechanisms have been proposed through which this belief is learned. Examples of these include a feeling of inferiority in their science abilities by parents, peers, or teachers, different influences on their identities that may be shaped by their gender, race, and relations in class, or their self-perception of their abilities in science (Archer et al., 2010; Barton et al., 2013).

Within the Central Florida area, the low interest of girls in science has become a problem because it impacts the number of female students choosing to pursue science and take additional science courses that they take in their high school careers. As a science teacher in the Seminole County School District, part of the Central Florida area, I hear from administrators that we are trying to encourage more students to enroll in science courses and, more generally, improve science literacy. The significant decline in interest during middle school significantly impacts female students' willingness to pursue additional science courses in high school. Fewer students pursuing science will impact the goals of the school and the county.
Organizational Context

The study participants came from the Seminole County School District in Central Florida. Seminole County Public Schools serves over 66,000 students from Pre-K to 12th grade. 51% of current students are male and 49% are female. 45% are white, 30% are Hispanic/Latino, 15% are African American, 6% are Asian or Asian/Pacific Islander, and less than 1% are Alaskan Native, Native Hawaiian, or other Pacific Islander. There are 26 middle schools within the district serving grades 6-8. The Florida Department of Education selects the standards and benchmarks for the curriculum with the specific pacing and decision of what topic each grade level will learn, with each standard being chosen by the individual districts. For the science curriculum, the state of Florida uses the Next Generation Sunshine State Standards (2008), a state-created set of standards not aligned with the Next Generation Science Standards (2013). The topics are divided by specific grade levels at the state level; however, Seminole County Public Schools has rearranged it into a timeline they feel is more beneficial for their students. Decisions on how to teach each standard are left up to the individual teachers within their classrooms. Teachers must teach the same topics around the same time, but deciding how specific standards and clusters will be taught is left up to them and their school-level teams. No official textbook series is currently in use; however, the district provides online materials and instructional resources for each topic with input from teachers across the county to assist with gathering materials to use in class. There are quite a few digital resources that the county has tried to incorporate, including online lab demonstrations and even some digital teaching tools. Examples of digital learning materials include websites such as BrainPOP, which gives lessons on various topics for all ages; Gizmos, which provides virtual labs in science and mathematics; and Phet Labs, which provides hands-on digital labs and simulations to cover various topics.
Significance of the Study

Because of the persistent disparity within specific scientific fields, the problem of practice that this Dissertation in Practice will address is the decreasing or stagnant sense of belonging among female middle school students in science. This problem is significant because many studies have shown that it is during the middle school grades 6th – 8th that students, particularly females, lose interest in science-related topics. Research has shown that declining interest in science was much more pronounced in female students than in male students, particularly in physical science-related courses (Barmby et al., 2008; Falk et al., 2017; Hunt et al., 2021). This continued disinterest draws women away from careers within physical sciences, creating a cycle where there are few role models for younger students to see within those disciplines. In looking for ways to improve female middle school student’s interest in science class, many studies have explored different strategies that can be implemented. Among those include giving girls a chance to use their creativity, providing specific positive feedback, and socializing/interacting with other peers (Billington et al., 2014; Roberts & Hughes, 2022). One method that can tailor all these strategies through an engaging medium is the use of serious video games. The use of serious or educational games in the classroom has been found to have a positive impact in science classrooms for both learning achievement and behavioral concerns in the classroom such as engagement (Arztmann et al., 2022; Cole et al., 2022; Riopel et al., 2020). This study will examine different designs in serious video games to highlight how these designs affect the engagement of female middle school students. Through the lens of Cultural Historical Activity Theory, CHAT, this study will analyze how these serious games influence girls’ engagement and interest in science content, the societal and cultural influences that may be built within the games, and how they also affect girls' learning of science.
This study aims to evaluate the usefulness of educational video games from the perspective of middle school girls about potential benefits or drawbacks. Video games themselves have been shown in prior research to make positive impacts on student learning in a variety of disciplines and have had positive effects in areas such as cognition, motivation, and behavior (Arztmann et al., 2022; Cole et al., 2022). Despite this, video games can still be an underutilized method of instruction due to a variety of issues including funding, complexity, and stigma. Chapter 2 will describe what prior research has shown about the teacher perspective on using educational video games, but there is often a stigma about using them due to views that lead people and teachers to think video games waste time, are just addictive, or are too difficult to incorporate into a lesson (Kirriemuir & Ceangal, 2004; Pastore & Falvo, 2010). Additionally, there are still gaps in the research about educational video games and their impacts on classroom learning, particularly research that focuses on middle school girls’ perspectives. A large part of the research into serious games usage in science classrooms focuses primarily on fields such as academic achievement, motivation, and engagement, but not many have examined this from the perspective of middle school girls (Kara, N., 2021). The data from this study will explore how educational video games can reach students in a way that standard instruction or other educational technologies cannot. While these games provide an opportunity to reach all students, it is especially important for middle school girls who have been shown in prior research to lose interest in science classes in greater rates. This study will provide a unique perspective for the female participants to express how using an educational video game impacts their learning of physical science concepts. The findings from this study will benefit both teachers trying to engage their students or game designers trying to improve their games.
Purpose of this Study

This study aims to describe how assumptions about student learning are embedded in the design of educational video games used to teach physical science and how these games influence how middle school girls engage with the content and develop their interest in the subject.

Research Questions

Central Question: How do the assumptions about student learning embedded in the design of a serious game used to teach physical science influence the engagement and interest of 6th—8th-grade girls in that content?

Research Question 1: How does the design of an educational game influence the engagement of 6th – 8th-grade girls learning physical science concepts?

Research Question 2: How does playing an educational game influence the interest of 6th – 8th grade girls in physical science?

Conceptual Framework

The Cultural Historical Activity Theory Framework by Engeström (1987) will guide the data collection and analysis used in this study to answer the research questions. At the core of CHAT is viewing different activity systems. An activity system is a collection of interacting parts that all work towards some goal. Describing an activity system starts with a subject who interacts with an object within a specific community. Tools mediate the interaction between the subject and object in the system, socially defined rules mediate the interaction between the subject and the community, and a division of labor mediates the interaction between the
community and the object. For this study, the activity system will have the one goal of learning a science lesson using serious science video games.

Using this framework, this study will give insights into 6-8th grade female student’s culturally influenced interactions within the activity system of a science class, especially cultural expectations for the rules of social interactions and the division of labor when learning science – i.e., who is allowed and required to do what activities within the activity system. This will also allow an analysis of how these influences may also be impacted through the use of a serious game, which also carries additional cultural and social influences.

This study will examine the design of a serious video game and observe how it influences students as they engage in a science lesson. It will focus on the different components of a serious video game and how those components from the framework, such as the rules, division of labor, and community built into the game, all influence the learner’s engagement in the lesson.

In Chapter 2, I review the literature on the relationship between middle school girls and science and research potential ways to better engage girls in science. I will also further discuss what is defined as a serious game, the characteristics of effective serious games, and how serious games can be an effective multimedia learning tool. Next, I will discuss the relationship between girls and video games and potential cultural and societal influences and messages regarding girls who want to play video games. I will also discuss serious game designs that are the most effective in engaging girls. The chapter will conclude with a deeper look at CHAT and its uses within an educational setting. In Chapter 3, I describe the research methods that will be used to answer these questions, the sampling method for this study, how data will be collected and analyzed, and discuss potential threats to the study’s trustworthiness. Chapter 4 will analyze the
data and discuss the findings that answer the research questions. Chapter 5 will discuss the findings related to prior research and present recommendations for future research and practice.
CHAPTER TWO: LITERATURE REVIEW

As stated previously, this study aims to describe how the assumptions about student learning are embedded in the design of educational video games that teach physical science and how these games influence how middle school girls engage with the content and develop their interest in the subject. To better understand the components of this study, this literature review will cover three main topics. The first section discusses current research on middle school girls and their experiences in science classes. This will include research looking at the declining interest in science that occurs most frequently in the middle school age group, 6th – 8th grade, everyday issues girls face when participating in science classes, and issues girls may have to find their identity within a science class. The second section will focus on research into educational games. It will define what is considered a serious or educational game versus a commercial game. Before describing the different characteristics found in effective serious games, there will be a discussion of shared beliefs about video games and educational games in the classroom. The final section will describe the relationship between girls and video games, which has changed significantly. To understand this relationship more, this review will discuss research into perceptions and beliefs that some girls may hold about video games, some of the misconceptions that many people have about video games in general, and how that might interfere with the desire to use educational games, and the section will also describe what research shows about the characteristic’s girls find most appealing about different video games.

Science Education and Girls

Within science education, a significant concern across many studies and organizations has been the sharp decline in student interest and engagement in science courses and the desire to continue studying science in high school and college. This decline has been shown among male
and female students, becoming particularly sharp during middle school (Barton et al., 2013; Falk et al., 2017; Makransky et al., 2020). Studies have shown that the sharpest decline in engagement and decrease in positive attitudes about science occurs between the ages of 10-14 during their time in middle school (Archer et al., 2010; Osborne et al., 2003). On top of the general decline in science interest among middle schoolers, there is also an indication that these decreases in interest are more prominent among female middle schoolers than their male counterparts (Desy et al., 2011; Sorge, 2007). Some reasons for this disparity include the view by many girls that science is masculine, a belief bolstered by essential figures in their lives. Additionally, different influences on their identities may cause them to drift away from interest in science classes. Often, a lack of out-of-school experiences in science can also cause this disparity to grow (Archer et al., 2010; Barton et al., 2013).

Understanding the role of attitudes and engagement is essential when contextualizing the activity system for girls in a science classroom. In any class they enter, students will always have existing attitudes that will impact how they view a course and how they engage with the content. Attitudes and engagement play a significant role in how students work with class materials and learn in their classroom environments. Significant gender differences have been found in science experiences, attitudes, and perceptions of science courses and careers (Jones et al., 2000). Researchers found that females tended to have more experiences and better attitudes towards activities around life experiences and biological sciences. In contrast, boys typically had better attitudes towards activities related to physical sciences. They also noted that females typically wanted a career that would help people. Girls favored activities involving more social contexts than isolated ones (Baker & Leary, 1995). The same study also found that girls wanted to see the connections between science and real life more often.
Identity is essential to this research as it is critical to understanding how students will see themselves in a science class. How students engage in school science is directly influenced by how they view themselves and whether they view themselves as the person who engages in science (Brickhouse et al., 2000). Students’ identities and teacher responses to those identities are shaped by gender, race, class, and other factors. The girls most engaged with science class were not alienated from science, believed they were good at it, and had other identities that overlapped with science. A recent study in physics education found that female students who participated in informal science experiences such as tinkering at home, attending physics-based competitions, or having conversations with family or peers about science had improved physics identities (Hazari et al., 2022).

Physical sciences form a core part of science literacy and content, even going back to the early 1900s. Physical science topics, particularly chemistry and physics, have always been a significant part of science education, and many early science educators thought they should be taught to all, particularly those seeking admission into college (DeBoer, 1991). Despite this, interest in studying physical science has persistently been low, particularly among female students. Today, there is a significant imbalance between the number of men and women interested in and pursuing careers in STEM, specifically in careers that focus on the physical sciences. This loss of interest has been seen going back, in some cases, to primary school (Hunt et al., 2021). A significant driver for many researchers is trying to understand the possible reasons why there is such a significant disparity between men and women in the STEM fields and seeing how interest in physical science and mathematics has been playing a role in maintaining this divide (Eren, 2021; Hunt et al., 2021; Tellhed et al., 2016). Whether it is for career reasons or to try and build more interest and understanding of the natural world, we must
try to bridge the gap between females and physical science.

**Improving Female Students’ Interest in Science**

Research into ways to improve girls' view of science classes in general and physical science-related topics such as STEM has shown many strategies to potentially improve both the interest and identity of female students. One approach has been to design an after-school program based on helping girls develop their identities as scientists. Some critical strategies employed were including much collaboration with peers, creating projects that girls will find personally relevant, allowing for the use of creativity and applying their talents, giving specific positive feedback to promote self-confidence, and encouraging girls to identify and push back against stereotypes within not just science, but all STEM-related fields (Billington et al., 2014; Roberts & Hughes, 2019).

Along with these strategies, many indicators presenting girls with a challenge they can overcome significantly influence their self-confidence and promote an interest in science (Billington et al., 2014; Roberts & Hughes, 2019). Another major factor shown in the research is the impact of girls having exposure to programs and experiences with science and STEM-related activities both in and out of school (Kang et al., 2018; Todd & Zvoch, 2017). Exposure helps capture students' interest and is consistently cited as why girls are interested in science. Along with outside influences, the thoughts of peers and family can determine how much girls are interested in science (Todd & Zvoch, 2017). Having like-minded peers who engage in science and a family supporting scientific interests can significantly foster interest and identity in science classes.
Table 1

*Research-Based Strategies to Improve Girl’s Interest in Science*

- Collaboration with peers
- Projects that are personally relevant
- Allowing for creativity
- Specific positive feedback
- Encouragement to push back against stereotypes
- Presenting challenges that can be overcome to boost self-confidence
- Exposure to science-related programs and experiences both in and out of school
- Family and peer support

**Definition and Characteristics of Effective Serious Games**

For this study, it is essential to understand what a serious game means. A serious game, also known as an educational game, is designed to meet an educational or training goal instead of an entertainment game only designed around the user's enjoyment (Anetta, 2010; Hamari et al., 2016.) Serious digital games combine the elements and fun of a regular entertainment game while still meeting the goals of increasing engagement and motivation while learning the content. This study will focus on serious digital games, or video games, as opposed to other games, including digital games whose primary purpose is entertainment.

As video games have grown in popularity over the years, much research has been done to examine how video games might be helpful in the classroom. The primary benefit of video games is increased student engagement and motivation to learn (Anetta, 2010; Coller & Shernoff, 2009; Hamari et al., 2016). When it comes to serious video games, the design of an
educational game can be challenging for any developer. A game must be entertaining enough to keep students engaged while not losing focus on the educational content. Another study used educational video game designs to create an educational escape room and found that designs that focused on collaboration and debriefing correlated with greater appreciation and engagement for the game itself, and immersion through a story correlated with increased engagement and made a direct contribution to knowledge gains (Veldkamp et al., 2022).

When looking at game designs, research has shown that engagement with the game increases as the level of challenge or skill in the game increases, and when engagement increases, there is a positive effect on learning (Hamari et al., 2016). Though the challenge must be gradual, a sharp increase in difficulty can cause disengagement. It is also essential that the game's challenge be created by students struggling with relevant concepts to mandated standards and not because of something like reflexes. When designing games, designers must make many assumptions about their audience and determine what will appeal to them. Another area that has begun to be explored in the research is the effects of video games as a multimedia tool to teach language acquisition to English Language Learners. One study compared the learning benefits of educational online games, educational videos, and conventional teaching methods. Their results showed a significant difference, with online educational games creating the biggest impact (Katembera, 2022). The researchers pointed out that the essential design features were how the games fostered interactions among learners and how the games increased the difficulty as they progressed, which helped to keep them engaged with the material. A recent meta-analysis synthesized 26 studies to analyze how successful video games were at teaching language acquisition (Dixon et al., 2022). What was found is that the body of research corroborates that using video games is an effective way to support those who are language learners. Interestingly,
it was also found that games made for entertainment had a much more significant effect than those made specifically for education and that results varied from game to game (Dixon et al., 2022). The researchers hypothesize that this may be due to the different game designs and features, which would highlight the importance of finding the best design to engage students and benefit their learning most.

Table 2

Research-Based Characteristics of Effective Serious Games

<table>
<thead>
<tr>
<th>Characteristics of Effective Serious Games</th>
<th>Details</th>
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</thead>
<tbody>
<tr>
<td>Increasing difficulty as gameplay continues</td>
<td></td>
</tr>
<tr>
<td>Interactions among learners</td>
<td></td>
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<tr>
<td>The increased difficulty is connected to standard mastery.</td>
<td></td>
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<tr>
<td>Considers player interests</td>
<td></td>
</tr>
<tr>
<td>Entertaining enough to be engaging but not distracting</td>
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</tr>
</tbody>
</table>

Beliefs About Serious Video Games in the Classroom

Since becoming prominent in the 70s and 80s, there has been some debate about the potential usefulness of video games as a learning tool. One of the primary focuses of research into beliefs about using video games in the classroom is the teachers themselves. Some initial research into video games in the classroom during the early 2000s found that many teachers saw video games as distracting and inappropriate in classroom lessons. This belief was held by both pre-service and in-service teachers (Kirriemuir & Ceangal, 2004; Pastore & Falvo, 2010). Despite this belief, more and more studies have emerged showing different ways to change perceptions about video games in the classroom and their potential usage, with much of this
belief coming from a fear of attempting to use something that the teacher is unfamiliar with. Research by Huizenga, Dam, Voogt, and Admiraal (2017) provided evidence that teacher perceptions were improved when teachers used games in the classroom and had a chance to alter their views of the usefulness of digital games. Other studies attempted to test a method that would assist teachers in adopting game-based learning, focusing on video games. The researchers had teachers research and find a game that would fit their curriculum. They had to test the game and then create a way to integrate it into a lesson. Through exposure to this process, they saw an improvement in attitudes towards video games and game-based learning (Emin-Martinez & Ney, 2013). Another study found that teachers were most likely to consider using a video game primarily based on its usefulness for a particular lesson or standard. Ease of use indirectly affected their intention to use a video game (Sanchez-Mena et al., 2017). While there is still evidence of hesitation to incorporate video games in the classroom, opinion has continued to sway as teachers gain more experience with them and see their value.

Video Games and Learning

Not only are video games a method to raise engagement within a classroom environment, but they also offer benefits that can be found when using any other type of instructional media. Digital media has become an integral part of the lives of students and the use of digital media, including the use of educational video games has had a positive impact for students in areas such as learning and interest in STEM careers (Chen et al., 2023). According to Mayer (2019), learning can be improved using words and pictures. This is referred to as the multimedia principle. This principle indicates that words can be considered anything written or spoken, and pictures can be either static, such as a chart, illustration, or photo, or dynamic, like what you
would find in an animation where the images are moving. An important caveat to this learning is that the words and images must be closely related and reinforce each other.

Figure 1

Cognitive Theory of Multimedia Learning (Mayer, 2019)

The cognitive theory of multimedia learning (Mayer, 2019) focuses on three basic principles. First, humans process information using two different channels, one for verbal information and one for pictorial information. This is called the dual-channel principle. Second, each channel can only process a few inputs simultaneously, called the limited capacity principle. Third, for learning to be meaningful, appropriate cognitive processes need to occur during the learning process, such as organizing relevant information into a coherent structure and integrating the new information with prior knowledge. As a multimedia tool, serious video games can provide a new method for explaining complex concepts or teaching new skills to students. Video games are another primary tool for multimedia learning, combining words and pictures to present the user with new learning opportunities to interact.

As mentioned in Dixon (2022), when looking at several different games to see their effects on language acquisition, the effect sizes varied wildly, showing the importance of proper design in a game conducive to learning. A possible explanation for the variance could be the
cognitive load theory (Mayer, 2014). This theory views learning as a process where the mind can only handle so much information simultaneously. Within this theory, three types of information can either help or hinder learning. Intrinisc cognitive load is the set difficulty in processing information you are learning. Extraneous cognitive load is the part of a tool that makes it more difficult for the learner to process and is irrelevant to what the learners are intended to learn. These items are unnecessary and often become distractions. With video games, this balance with cognitive load can be challenging as an engaging game needs content that will hold the user’s attention. However, if not designed carefully, features could distract from the game's learning goals as extraneous information may be added. One recent study looked at how cognitive load may be affected when the speed of a serious game was adjusted between fast, medium, and slow (Petko et al., 2022). Their findings showed that the fast speed impacted the perception of task difficulty, raising their intrinsic cognitive load. The slower speed increased the extraneous cognitive load, which led to more distraction as the player tried navigating through the game. It was the middle speed that showed to have the highest learning gains for the users. This highlights the importance of game design for even minor features, such as the speed setting, to ensure that the player will benefit most from the learning tool.

Another multimedia principle that needs to be considered when designing and using an educational video game is the coherence principle of multimedia learning (Mayer, 2019.) This principle states that people learn better when extraneous material is excluded. This can be very difficult when using video games as a tool. Depending on how a game is built or the environment the player is in, there is a potential for much extraneous material to be included that will end up distracting the players and getting them off task. It is vital that the game design has the lesson at
the forefront of the game and avoids potential distractions that could take away from the learning.

**Girls and Video Games**

While reading the literature, it became apparent that there is a blurry line between gender stereotypes and girls’ preferences in game design. There are subtle differences, but this tension in the literature shows that the distinction between the two is not always clear. The relationship between girls and video games has not always been favorable. Since video games became a significant industry, gaming has been seen for quite some time as an activity for boys, making it difficult for girls to see gaming as enjoyable. Despite increasing interest in gaming among girls and women, there is still a prevalent belief that video games are masculine (Cunningham, 2018). Recent studies into gender differences in gaming focused on middle school-aged students found that boys around fourteen use video games five times more than female peers. Girls were found to prefer social media. The studies have also shown that girls feel less encouraged to play video games due to gender-related experiences (Leonhardt & Overa, 2021). Despite an increase in female consumption of video games, gaming still has problems with reinforcing gender stereotypes that are prevalent within the industry (Hughes, 2022; Lima & Gouveia, 2020). Many companies still create games that are supposed to be made for girls. However, they focus on girls’ stereotypical interest in activities such as make-up, clothes, and shopping, as well as promoting femininity, which is wholesome, compliant, and domesticated (Hughes, 2022). Though this problem is primarily found in commercial games and rarely seen in serious ones, it still can present an image that designers are less aware of girls’ true interests and focus more on stereotypical ideas. One area that is still a significant issue in many commercial games is how
female characters may be portrayed, with girls seeing gender stereotyping as one of the significant reasons why female players dislike certain games (Hartmann & Klimmt, 2006).

With so many issues with how girls view video games or the messages they may communicate to female students, it is essential to understand what types of designs or games would most likely attract a female audience. When looking at the types of games that girls are interested in, it has been shown that active play, which includes games where a player must quickly respond, such as fighting games or first-person shooters, and strategic type games were more appealing to boys over girls and girls had a stronger preference for explorative and creative type video games (Kinzie & Joseph, 2008). Research into elements of video games that tend to be most appealing shows that girls tend to prefer games that encourage social interaction and communication (Alserri et al., 2017; Cunningham, 2018; Hartmann & Klimmt, 2006; Mozelius & Humble, 2022).

Additional research shows that females tend to prefer creativity and customization, collaborative interactions, and exploration that does not involve violence (Alserri et al., 2017; Mozelius & Humble, 2022; Mozelius et al., 2022; Vermeulen et al., 2011). In this research, creativity refers to the ability of the user to make their appearance however they like rather than having a set avatar. Some examples of this would be games that allow the player to have a strong female avatar that is not shown in a hyper-sexualized or stereotypical manner. This can also refer to activities that allow the player to express themselves within the game, such as by being able to create some artwork or musical pieces. Collaboration and social interaction can include interactions with other players or even with computer-controlled characters that allow the player to have a deeper story rather than just having a game that revolves solely around combat. A famous example of exploration without violence is games such as Journey (Thatgameplay,
2012), where players explore across a desert to reach a goal by completing different puzzles and activities. When coming across other players in the game, there are no rewards or ability to hinder the other players’ progress, and it is encouraged to assist one another to keep moving forward in the game.

A game's complexity is another essential design to consider when looking at a serious game. Complexity can be viewed in various ways when it comes to video games. The first is the complexity of the gameplay mechanics, which involves what the player needs to do to play and progress. Research indicates that female players preferred easy-to-master and less complex gameplay and interface mechanics (Alserri et al., 2017; Mozelius & Humble, 2022; Vermeulen et al., 2011). On the other hand, complexity in a video game can also refer to the story's complexity or the characters within the story. Regarding complexity in the game narrative, females overwhelmingly prefer a rich, complex story and characters (Alserri et al., 2017; Heeter et al., 2009; Mozelius & Humble, 2022). This indicates that girls prefer a design typically found in genres such as role-playing games (RPGs) rather than something more combat-oriented. Another type of design that also has to be considered is the mechanics of how the player can progress and eventually complete the game. What has been shown is that girls prefer winning conditions that do not come at the expense of other characters or players. (Heeter et al., 2009; Mozelius & Humble, 2022; Ray, 2004). Rather than winning a game by defeating an opponent, girls prefer games where the player achieves victory through methods such as diplomacy, puzzle solving, or working with allies. An additional factor that must be considered is the role that prior knowledge and video game experience play in the design of the game. A recent study into the use of digital game-based learning showed that the use of a simulation-type game led to improvements in performance and engagement with both male and female students (Yeo et al., 2022). However, it
also pointed out that accommodations were necessary when using digital games based on gender and prior knowledge of the content.

Table 3

*Research-Based Game Designs for Girls*

<table>
<thead>
<tr>
<th>Game Designs Girls Enjoy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exploratory gameplay</td>
</tr>
<tr>
<td>A chance to express themselves creatively</td>
</tr>
<tr>
<td>Encourages social interaction and communication</td>
</tr>
<tr>
<td>Positive interactions rather than hindering others</td>
</tr>
<tr>
<td>Easy to master gameplay mechanics and interface</td>
</tr>
<tr>
<td>A rich and complex story</td>
</tr>
<tr>
<td>Win conditions through diplomacy, puzzle-solving, or working with allies.</td>
</tr>
</tbody>
</table>

*Cultural Historical Activity Theory*

Cultural Historical Activity Theory (CHAT) was developed by Yrjö Engeström (1987). Engeström based his CHAT model on the works of Vygotsky and Leontiev, who focused primarily on the influences of society, culture, and history on the development and learning of humans. According to CHAT, humans collaborate, learn by doing, and communicate through their actions. Humans use tools of all kinds, such as physical objects or even something non-physical, such as language, to learn and communicate with others. Finally, community is central to humans making and interpreting meaning. Engeström expanded upon this original model from Vygotsky, which focused on the individual and how subject, object, and tools interacted, and expanded it by adding in the work of Leontiev, which focused more on the influence of the larger
community. This second generation was expanded to include rules, social norms, and division of labor within the activity system. Learning within CHAT involves different contradictions that may occur within an activity system. As different parts of the activity interact, such as the subject using tools, a contradiction may occur in what the subject may have known or thought. How they resolve this contradiction results in learning.

Figure 2
Second Generation CHAT Model (Engeström, 1987)

To better understand the CHAT model, readers need to understand what each piece of the model refers to and how these pieces interact (see Figure 2.) To start, we need to define what an activity means. Engeström (1987) defines activity as a subject interacting with an object to reach some form of outcome. This outcome is the activity's overall goal, such as learning a particular science standard. These steps to reach the outcome are all part of the overall activity. The activity system combines the interactions between the subject, object, and community as a specific outcome or goal is trying to be reached. The activity system is a choice based on how the researcher decides to view how the goal is being reached. The choice of activity system used in data analysis allows us to make various observations within the data collected. The subject is
often an individual or a group who will serve as the lens through which to look at the activity system and is the one trying to accomplish the goal of the activity. However, a subject can also apply to something such as a piece of software if that is what you use as your focus on the system. The subject serves as the point of view you will use to analyze the activity system. The object can take on various forms, such as a physical object being built, plans for a lesson, or any other manner of item that helps lead to the overall goals of the activity. Individuals or groups can also be considered objects depending on your subject. The most significant importance of the object is that it is what the subject needs to act upon to reach its goal within the activity system. Community refers to the larger group that may all be interacting with the same object and represents the larger group's influence on the activity. The culture and history of that community shape the influence of the community on the activity system. The different characteristics of the community must be understood so that how the community influences the interactions within the system can be understood.

To help clarify how to look at the activity system through CHAT, we can look at an example of a teacher using an educational game in a science classroom. In this example, one way of defining the activity system for analysis is to say that the students are the subjects whose viewpoints we use to analyze the system and see how they interact with the object and the community. The object could be considered an educational game as it holds the material needed for the student to meet the overall goal of the activity, learning the standards for that lesson. In this example, the community is the classroom environment created by the teacher and the other students within the class who are all working towards the goal. We could also change this depending on what we focus on within this activity system. Another way to define the activity system would be using the game itself as the subject if we are analyzing what the game is trying
to do for the student. In this scenario, the students would be the objects the game is interacting with, and the community would be the environment set up by the game and the players (students) who are playing the game. Within the classroom, we can also use CHAT to look at data on a micro-level within the central activity system and view a smaller piece. In this example, we could look at a female student in a larger classroom. The student would be the subject as we look at the data from her point of view. The object could be the game itself or the designs built within the game that allow her to learn the lessons. The community could also be different in this more minor system. The community could be any group that might influence her thoughts on science and her attitude toward games. Members of this community could involve family, other members of her group (assuming the game is allowing for group play), and especially peers who may pressure her into feeling a certain way about the class or activity.

As each of the three main pieces of CHAT (subject, object, and community) interacts, additional pieces mediate these interactions. For example, subjects use tools to interact with objects. In CHAT, we say that the interaction between subject and object is “mediated” by the tools. Tools are also varied and can be anything from something verbal, such as a lesson, or physical, such as a computer or paper. Every tool a subject uses to interact with an object was created and used within a particular cultural and historical context. As the community interacts with the object, this creates a division of labor. This division can be either horizontal or vertical. A horizontal division occurs between members of the community who are of equal standing, such as the students within a classroom. A vertical division occurs between members with different statuses, such as students and teachers. A key point to remember is that the division of labor will change when the community changes. A math teacher will have different student expectations than a science teacher. As those expectations change, the division of labor will also
be different. Similarly, video games may have different expectations for certain activities. The final mediation, rules, norms, and conventions are created as the subject interacts with the community. Rules, norms, and conventions can take on the form of items like classroom interaction rules and norms, rules for a game that must be followed, or any other boundary set up that members of the community are expected to follow. They can also be affordances or expectations that tell the subject what they are allowed to do and what they may be required to do.

For example, to better illustrate an activity system, we can view it using a hypothetical student in a science course. Kelly (subject) is working with her group (community) on a class lab assignment (object) to achieve a better understanding of the concepts they are learning. Kelly’s teacher, Ms. A, has each group (community) separate into different roles to have the lab run smoothly (division of labor.) Each role has an assigned task (rules) that they oversee for the duration of the experiment. Kelly has been assigned to gather the required materials (tools) used in the lab and assist in data collection (rules.) Another way we could view this example when analyzing the data is to look at Ms. A as the subject and the lab assignment as one of the tools used to assist student learning. Within this larger activity system, we can also see it as a smaller chunk from within by looking at Kelly’s effort to collect and interpret data from the lab they are given. Kelly (subject) works with her partners (community) following their set roles (division of labor) to complete a lab that the teacher has given. For this example, the students study some ideas behind radioactive dating and half-lives (outcome) by flipping pennies and observing the rate of change through several rounds (rules.) Assisting her group in collecting the data, she copies the needed information on a chart (tool) to help organize the data (object). The group works together to answer concluding questions about the overall lesson using the collected data.
It is also essential to understand the contradictions that occur within activity systems. Contradictions and tensions help lead to changes within the activity system as those within the system are working towards reaching their goal by overcoming those tensions. The most meaningful kind of change that occurs due to these contradictions within the activity system is what would be called learning. Engeström (1987) described four different types of contradictions. Primary contradictions occur within one node of the activity. For example, Kelly has been assigned the role of collecting the data into the given data sheet, but after looking at it, she is confused about what to do, creating a contradiction in the system. The next contradiction Engeström describes is secondary tensions, which occur when there is a contradiction between two different sections within the activity. For example, Kelly’s group needs to finish the lab assignment (object), but they are coming dangerously close to running out of time (rules). Additionally, analyzing a situation can be viewed as a different kind or level of activity. This can lead to the third and fourth types of contradiction. The third type of contradiction occurs between one form of activity and a more advanced version of the same activity as community members adjust to the new rules. For example, what students may be expected to do in the current lab versus what they were expected to do in a previous one. The teacher may have changed the rules for this new lab because they are trying to teach their students something new. Engeström (1987) describes the final type as quaternary, with contradictions or tensions between nearby activities. An example of this could occur when there are differences between class and teacher expectations that students must adjust to as they move from one classroom to another.

CHAT has become a central qualitative framework for viewing educational activity systems since the mid-90’s. Researchers have found its various uses by examining the tensions and learning within different situations. One study examined a socioscientific issues classroom
using CHAT by examining the tensions that occurred when different communities discussed issues where they held very different opinions (Lee et al., 2019). Within a classroom setting, CHAT has also been used with other theories to assist in data collection. Research by Kajamaa and Kumpulainen (2019) used the CHAT lens to examine student transformative agency as they interacted with a digital program. CHAT has been used to examine teacher induction programs for new science educators to examine how pre-service teachers implement language and literacy within a science classroom and how the mediating elements of the different teacher activity systems impact student learning (Saka et al., 2009). CHAT is also used to find ways to assist educators with technology integration in their class activities (Koszalka & Wu, 1995). The CHAT framework has also become popular for analyzing, designing, and evaluating educational science video games and digital media. One study used the CHAT framework as a lens in the design of a serious game (Lazarou, 2011). In this study, the researchers used several phases to identify the different activity systems within the target learning group. Using information from the different groups, the researchers identified different contradictions within the activity systems that were hindering the objectives of the systems. Using those contradictions, the researchers sought to find resolutions that could be used to create game elements (Lazarou, 2011). Other researchers used CHAT to demonstrate how computer games are a product of social collaboration and can work as both objects and tools for both learning and entertainment (Amory, 2006.) Many studies into the impacts of video games, both educational and commercial, use the CHAT model to study activity systems that involve different types of learning using video games. For example, a study on commercial games looked at how a commercial game allowed students to engage in various skills and experiences that were like twenty-first-century skills and showed how video games could provide valuable learning experiences within a
classroom (Engerman et al., 2019). Another study used the CHAT framework to analyze student-designed games revolving around youth civic programs that used critical computational literacy (Yu et al., 2020).

Summary

In summary, serious video games present a unique and engaging way to interact with science content. This study addresses how these game designs influence the interest and engagement in the learning being presented in the game. Using CHAT provides an optimal way to analyze the data from different perspectives and angles as I look at the activity system and see the contradictions that arise and how those are overcome, leading to some form of learning. The methods for collecting and analyzing data are discussed in the next chapter.
CHAPTER THREE: METHODOLOGY

This study was conducted using an ethnographic approach, as described by Creswell and Poth (2018). An ethnographic approach was chosen for its ability to surface and describe implicit cultural assumptions and dynamics in the design of everyday objects used within a culture-sharing group. Based upon those internal and external ideas of how to make science more engaging for girls, the goals of the study design were to observe and compare how different serious game designs that use those elements influence how the students engage with the science content and how these digital games may have any influence on their interest in physical science. The central research question that will be guiding this study asks: how do the assumptions about student learning embedded in the design of a serious game used to teach physical science influence the engagement and interest of 6th—8th-grade girls in that content? This question will be further broken down into two sub-questions that will focus on engagement with the game and interest in the science content. Sub-question 1 asks: How does the design of an educational game influence the engagement of 6th – 8th-grade girls learning physical science concepts? Sub-question 2 asks: How does playing an educational game influence the interest of 6th – 8th grade girls in physical science? Table 4 highlights these three questions, the data sources being used to answer each question, and evidence that will be taken from these data sources.
### Table 4:

**Study Blueprint Connecting Questions to Evidence**

<table>
<thead>
<tr>
<th>Question</th>
<th>Data Source</th>
<th>Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central Question: How do the assumptions about student learning embedded in the design of a serious game used to teach physical science influence the engagement and interest of 6th—8th-grade girls in that content?</td>
<td>• Answered based on a synthesis of the analysis for the two sub-questions.</td>
<td>• Answered based on a synthesis of the analysis for the two sub-questions.</td>
</tr>
<tr>
<td>Sub-Question 1: How does the design of an educational game influence the engagement of 6th – 8th-grade girls learning physical science concepts?</td>
<td>• Observations of participant behavior • Debriefing interview • Think aloud verbalizations during gameplay</td>
<td>• Body language and behavior during gameplay • Factors in game design that affected their engagement with each game • Cognitive processes during game play</td>
</tr>
<tr>
<td>Sub-Question 2: How does playing an educational game influence the interest of 6th – 8th grade girls in physical science?</td>
<td>• Scores on Attitudes Towards Science in School Assessment • Debriefing interview</td>
<td>• Attitudes toward science instruction in school • Experiences in science class • Opinions of physical science • Experience with each games</td>
</tr>
</tbody>
</table>
Sample and Recruitment

The population being studied is the cis-gendered girls in middle school in a mid-sized school district in Central Florida. Middle school refers to students in grades 6-8 in this school district. The original goal of the sample selection was to have a diverse enough sample to represent the social diversity of the district as best as possible while also considering experience with games and attitudes toward science. Students who identify as boys or express their gender identity in other ways were excluded from the sample. This sampling choice is because I want to see how the typical female student interacts with the program and the activity system. Initially, the sampling was meant to be done in a single school district. However, complications with the district itself resulted in the sampling being more random and based on convenience.

Due to issues getting permission from the district, the original plan to recruit within a single school had to be altered. Volunteers were found through advertising on social media, with flyers posted in local libraries and churches within the district that were willing to assist, and through word of mouth by reaching out to anyone who might have a student who met the requirements for participation in the study. Direct family or family friends were excluded to avoid a conflict of interest. Potential subjects were sent a digital parent consent letter to receive approval from their parent or guardian, explaining the study, the research goals, and the methods that will be used. The consent form explained what the participants were expected to do and other important information the parents needed to know before giving consent.

The study aimed to find at least six to eight participants with at least two volunteers per grade level. In the end, twelve participants joined the study, four from each grade level. Based on parental request, the study was conducted at either the UCF library or a local library near the participant’s home. After receiving parental consent, a date and time were established for
conducting the study. Before any data collection began, participants were asked to give verbal assent. Once parental consent and participant assent were given, participants were asked to complete the Attitudes Toward Science in School Assessment (Germann, 1988). The survey took around 2-3 minutes to complete. Once finished, participants were presented with the three games and topics they would learn. They were given between 20-30 minutes to play each game. The time allotted was based on the amount of time the program estimated it would take to complete the game and the amount of time needed to complete the entire session.

Data collection

As with other studies that have used CHAT, this ethnographic study had a variety of data collection methods to answer the research questions. Data sources included responses to the Attitudes Toward Science in School Assessment (Germann, 1988), observations of students playing the game and engaging with the lesson, reviews of the game itself and examining possible influences on its creation, and interviews with the students before and after gameplay to establish interest in science-related topics and gather their thoughts about the gameplay.

Data collection was primarily done through observations of the participants as they interacted with the educational game. Participants were asked to think aloud where they would narrate their decisions about the choices they would make as they played the games. Observations were made while monitoring student gameplay and taking notes of decisions or courses of action. Video recording was used to capture gameplay as the students interacted with the program, and audio recordings were used to gather verbal comments as the game was being played. The video recording used screen-capturing software that recorded what was happening directly on the screen while the game was being played.
During gameplay, any behaviors or decisions were noted and timestamped to ask informal follow-up questions about the student’s thoughts on a particular decision. If needed, recordings taken during gameplay were used to help stimulate a reminder about the event.

Interviews were conducted before and after gameplay to analyze the subjects’ thoughts on their experience further. The questions were designed to learn more about the students’ perspectives on science and video games. Audio recording was used to help during any interview questions to better collect as much data as possible.

After gameplay was completed, a debriefing interview was used to collect additional information about the participant’s experiences with the games. Specific decisions and design elements were brought up to give the participants a chance to further explain what elements of the programs helped them the most and what design elements they struggled with. Participants were also asked about different decisions made about their gameplay and what led them to those decisions. The interview was also used to further elaborate on their personal experiences with video games and their experiences in science classes. Participants were given a chance to present their views on what a typical science class looked like to them and further explain their answers to the initial survey.

**Data analysis**

Analysis of the research questions has been centered around CHAT to examine the trends in the data and discuss tensions within the system and how the participants resolved those tensions. The different parts of the activity system are described in Chapter 4, along with the different tensions that occur when the different parts of the system interact. After describing the different parts of the activity system, the research questions are answered from the data collected during the study. Research question 1 focuses on the designs of the three different games and
how those designs impacted the engagement of the participants. Tensions between the subjects (participants) and the tools (mechanics) are further analyzed to describe what the participants learned to overcome the tensions and progress in the game. The learning is examined to see how this also impacted game engagement. Research question 2 focuses on how the game influenced the participants’ interest in learning the game's content through this medium. Tensions between the subjects and the rules (content) are further analyzed to see how overcoming these tensions and learning the content influenced the participants' interest in the topic.

**Attitudes, Interest, and Engagement**

The research questions and data analysis rely on the distinction among three concepts – attitudes, interest, and engagement – that are easily confused. For this study, when analyzing these three concepts, student attitudes will refer to their attitudes toward learning science in school. Attitude Theory states that beliefs about something, such as science classes, form the building blocks that shape a person's attitude toward that thing (Eagly & Chaiken, 1993). Engagement will refer to their engagement with the games they are playing. Defining engagement can be much more challenging as it can refer to a wide range of areas, for this study will focus on behavioral engagement and more specifically it is defined as involvement in academic tasks (Heddy et al., 2014). Engaging with the game can be indicated by looking at the participant’s body language, comments they make during the game, and their decision on whether to continue the game to the end or to give up early. Interest is defined as specific preferences for an area of knowledge or an activity (Roellke, 2022). Interests are tied to what a person values and are shaped by their attitude. Interests in this study will focus on the participants' interest in learning the specific physical science content that each game is teaching them.
Before beginning the gameplay, the students were asked to take a survey to give a general idea about their general attitude towards science as a class. This is important as their attitudes about science have been shaped through their different experiences in class, with their peers and teachers, and with their families. These attitudes about science class create a foundation for how they will feel about learning a science lesson and greatly impact whether they will be interested in what they are asked to do and if they will be willing to engage with the lesson. Attitudes help to shape the participants' interest as they will be more likely to want to learn about topics that they have a more positive attitude towards. Similarly, they will be more likely to want to engage with a lesson they have a more positive attitude about. By understanding how the participants generally feel about science classes a comparison can be made about how using the educational video games makes a difference from what they see as a normal lesson.

**Analysis of Tensions**

As previously mentioned, a large part of the analysis for this study will focus on the tensions found within the activity system for this study and how the resolution of those tensions demonstrated what the participants learned from these interactions. This learning will give insight into how the participants' interest in the topic and engagement with the game was impacted during their experiences. As each of these educational video games was developed, each was created with a plan that the designer felt was the best way to engage students and help them learn about the topic. We can see some indication of how the game designers assumed would be the best way for students to learn through how they combined both gameplay and content into the designs of the overall game. Features such as reading the content to the student or having the student read the content instead, having separate games to reinforce the lessons, or how much exploration the student has control over all show what the designers assume is the best way to make an engaging lesson. However, during gameplay, participants became frustrated by some of these features or, more generally, they were not able to proceed with the game. Some of these
tensions were likely intentional in the game design because resolving the tensions lead to the learning outcomes the designer expected. However, it also seems likely that some of the tensions experienced by the players were not intended by the game designers because they led to unexpected and even undesirable learning outcomes. By analyzing the tensions created through game play we can better understand what students learned about both the game mechanics and the content. We can also see how interactions in the activity system can either support or discourage engagement with the game and interest in the topic.

**Threats to Validity**

Potential threats to the trustworthiness of the study include researcher bias and positionality. I cannot truly understand what being a middle school girl in a science class means. After collecting data from playing the game, I initially debriefed the participants to clarify potential data points and gain further insight into their gameplay. Assistance from mentors when analyzing the data has also helped to potentially reduce researcher bias to make sure that I am not just seeing what I want.
CHAPTER FOUR: FINDINGS AND DATA ANALYSIS

Purpose and Summary of Methods

This study aims to describe how the assumptions about student learning are embedded in the design of educational video games that teach physical science and how these games influence how middle school girls engage with the content and develop their interest in the subject. The research methods for this study were qualitative, with protocol analysis (See Appendix G) initially chosen to better understand the participants’ thought processes and mindsets during gameplay. One of the significant data collected was meant to be audio-recorded, having the students narrate what they were thinking and doing as they played the game. The qualitative data collected during the research sessions were the audio recordings of the participants as they played, video recordings of the gameplay itself, field notes observing participant behavior while playing, and exit interviews to discuss the participants' experiences with the games. Students also responded to the Attitudes Toward Science in School Survey (Germann, 1988) to better understand the participants’ feelings towards science as a subject. The primary research question of this study was, “How do the assumptions about student learning embedded in the design of a serious game used to teach physical science influence the interest of 6th – 8th-grade girls in that content?” To address and answer this question fully, this data analysis will break down the main question into four parts. First, looking at the games themselves through the lens of the Cognitive Theory of Multimedia Learning (Mayer, 2019), the analysis addresses how the games intended to teach the required lessons while attempting to engage their potential learners. Using data from interviewing the students, the analysis addresses the participants' feelings and views about science class and their view on physical science as a subject. Data from the gameplay, field observations, and interviews address general engagement with the game and the participant's
interest in the topic while learning it using the games. Analysis of the collected data uses CHAT as a focal lens to examine the different pieces of the activity and how the students overcame different tensions that arose so that they could make continued progress.

**Overview of Data Analysis**

The central research question along with research sub-questions 1 and 2 are broken down more by using the CHAT framework as a guide to interpret the data as the interaction between the subjects, objects, and community are examined to understand the experiences of the students trying to reach the outcome. Data looks at the different game designs implemented by the three games and how the participants responded to each. It also gathers their thoughts on how the different game designs influenced their engagement with the program and interest in learning the science content through that video game. Tensions are analyzed within this activity, and how the participants overcame these tensions demonstrates what they learned from the games. What they learned will help to understand better how the game may have influenced engagement and interest. As previously mentioned, data analysis relies on the distinction between attitudes, interests, and engagement. Attitudes will primarily focus on the participants’ attitudes towards learning science in school, interest will focus on their interest in learning the specific content being provided by each game, and engagement will focus on their maintained involvement with the games themselves.

**The CHAT Framework**

As I prepare to answer the research questions established for this study, I must look at the Activity System this study creates to see how each piece fits within the CHAT Framework. This section will give an overview of the CHAT Framework and the different pieces of the study that fit into each section of CHAT.
The Subjects

Twelve participants from the Seminole County area in Central Florida volunteered to participate in the study. One participant chose to withdraw at the beginning of the session, and another did not provide enough usable data to be included in the findings, leaving ten subjects included in the analysis. Three participants were 6th-grade girls, three were in 7th grade, and four were in 8th grade. All the participants attended public school in Seminole County (the same county), though some had different elementary experiences, and not all attended the same middle school. An additional 6th grader was invited to participate but expressed frustration with the first game and decided to withdraw from the study without completing any other games. Additionally, another participant reacted hostilely towards the games and intensely disliked science, so she refused to complete more than a few minutes of each game, resulting in very little data being gathered from her experiences. She later expressed a radically different background of education than any other participant, and it became apparent that she had almost no proper science education as her previous schools seemed to put no focus on it. Because of this, she has also been excluded from this study. Each participant expressed differing interests in science as a whole and with physical science specifically, and each had a wide variety of video game experiences. Most of the participants’ video game experiences were primarily with building games such as Minecraft or games that provide various options to play, such as Roblox. The participants in the study were Ava, Bobbie, Bridget, Caroline, Corrine, Elodie, Isabel, Mary, Stella, and Violet. Participant summaries are based on their responses to questions during the debriefing interview.

Ava. Ava is a 7th grader who has attended public school throughout her elementary and middle school careers. She expressed a positive interest in science classes overall but was more
neutral about topics related to physical science. She only had minimal experience with video games, stating that it was something her brother primarily did.

**Bobbie.** Bobbie is a 6th grader who has attended public school throughout elementary school. She expressed positive attitudes in science class as a whole and also expressed interest in topics relating specifically to physical science. She had moderate gaming experience, primarily through programs such as Roblox or Minecraft, but did not consider herself a frequent gamer.

**Bridget.** Bridget is a current 8th grader who attended public elementary and middle school. She also expressed a strong negative attitude towards science class as a whole and physical science. She explained she had no video game experience as her mother forbids her from playing video games. This research study was an exception that was being made.

**Caroline.** Caroline is an 8th grader who has attended public school throughout elementary and middle school. She expressed the strongest positive attitudes towards science classes and physical science topics, even discussing in detail how she would like to pursue a career in astrophysics. She stated she only had minimal video game experience and did not frequently play many games.

**Corrine.** Corrine is a 6th grader who has attended public school for elementary and middle school. She stated that she generally enjoyed science classes but had very little interest in physical science topics, even showing facial expressions demonstrating extreme dislike when examples of those topics were mentioned. She has minimal video game experience and stated she was more into physical activities such as sports.
Elodie. Elodie is a current 6th grader who spent some of her time in public school, some of her time online as a homeschool student, and finished her elementary career in a private school. She was starting her middle school education in a public school magnet program. She expressed strong negative attitudes towards science class as a whole and notably did not care for topics related to physical science. She also stated she had minimal game experience, primarily playing some lesser-known games on the phone or Minecraft (though not frequently).

Isabel. Isabel is an 8th grader who attended public school for her elementary and middle school years. She expressed very positive attitudes towards science class and some physical science-related topics, though there were others that she indicated she did not enjoy as much. She has decent gaming experience, primarily with computer games such as Minecraft, which involve building and some team play. She did not have much interest or experience in console games.

Mary. Mary is a current 7th grader who has attended public school throughout elementary and middle school. She expressed positive attitudes towards science classes as a whole and towards physical science-related topics. She has far greater experience with video games than many of the others, playing several major console games and frequently playing as a hobby.

Stella. Stella is a current 7th grader who has attended public school for both elementary and middle school. She was very neutral regarding science classes, though she leaned slightly more toward disliking them. She had a similar response when discussing her interest in physical science-related topics. She expressed minimal experience with video games, only playing games such as Minecraft and Roblox very infrequently.
Violet. Violet is an 8th grader who has attended public school throughout elementary and middle school. She expressed positive attitudes towards science classes, though she was more neutral on physical science-related topics. She is another who has a great deal of experience playing video games, including many found on major consoles.

For clarity, the participants have been clustered into groups based on shared characteristics while discussing results and observations. These clusters are based on their expressed interest in science class and their level of experience when it comes to video games. From these groups, one of the participants will be highlighted as a focal point for the cluster, though some comments or highlights from the others in that group may be used as well. When grouping them, they were clustered, focusing primarily on their interest in science class combined with their video game experience. Interest in science is the primary factor, with video game experience helping to group them, creating four primary groups.
Table 5

Comparison of Interest in Science to Experience with Video Games

<table>
<thead>
<tr>
<th>High Interest in Science</th>
<th>High Interest in Science</th>
<th>Neutral Interest in Science</th>
<th>Low Interest in Science</th>
</tr>
</thead>
<tbody>
<tr>
<td>-Very Experienced with Video Games</td>
<td>-Moderate to Minimal Experience with Video Games</td>
<td>-Minimal to No Experience with Video Games</td>
<td>-Minimal to No Experience with Video Games</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mary</th>
<th>Caroline</th>
<th>Stella</th>
<th>Bridget</th>
</tr>
</thead>
<tbody>
<tr>
<td>Violet</td>
<td>Corrine</td>
<td>Ava</td>
<td>Elodie</td>
</tr>
<tr>
<td>Isabel</td>
<td>Bobbie</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Types of Engagement.

It is helpful to divide participants’ observed engagement into two broad categories to understand how game design affected participants' engagement. Sometimes, participants’ engagement was due to authority, meaning they engaged with the program. They knew they were expected to be engaged because they were participating in the research. Other times, participants were engaged from within, meaning they were engaged because they were enjoying what they were doing and allowing themselves to be immersed in the experience. For example, participants such as Caroline, Corrine, and Isabel seemed excited to be playing and showed increased enjoyment as new gameplay mechanics were introduced or as they mastered certain concepts. They made frequent comments stating that the game was fun or exciting, and a few of them would even respond to the game’s prompts, such as greeting the narrator after it said hello to...
them. For many games, they became more focused when the difficulty increased and were
determined to figure out the correct solution. Even when time ended, they did not wish to move
on until the game was complete. Body posture and facial expressions ranged from fidgety to
excitement, and they became more animated and focused, tuning out other things around them so
they could progress in the game. By contrast, Elodie and Stella showed signs that their
engagement was more of a requirement and less internal. Both seemed rigid or nervous as they
began playing. They were less animated and often had to be reminded to think aloud as they
played. They rarely smiled as they played and just went through the motions to complete each
task. They often looked disinterested or groaned at specific tasks to complete, showing they were
doing what was expected and not doing it for their benefit. Both participants ended each game as
early as possible. They put much effort into each one but were quick to end the games and move
on to the next, regardless of whether the difficulty increased.

**Participants' Levels of Interest.**

Before the participants began playing the games, each was asked about their general
interest in science and physical science topics. Using this information, I compared how they felt
about the topics before playing the games to their interest level in the specific topics while
playing the games to see exactly how the game may have influenced their interest.

Using the results from the Attitudes Toward Science in School Assessment (Germann,
1988) along with their expressions during the gameplay and debrief, seven of the participants
showed a highly positive attitude towards science as a subject, with three being either neutral or
having a stronger dislike of science in general as a subject. Further, each was asked about their
interest in physical science, specifically with different topics within the described subject. Of the
ten participants, only two expressed an interest in physical science, two expressed a strong
disinterest in physical science as a subject, and the other six were more neutral. When explicitly asked about the topics covered in the games, the majority expressed similar interest levels for the game-specific topics as they did for physical science content. However, it was noted that the topic of heat transfer did have a more elevated interest for some participants than they had initially expressed for physical science topics in general.

Table 6

*Participant Expressed Interest in Physical Science Topics*

<table>
<thead>
<tr>
<th>Expressed Interest in Physical Science Prior to Gameplay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive</td>
</tr>
<tr>
<td>----------</td>
</tr>
<tr>
<td>Bobbie</td>
</tr>
<tr>
<td>Caroline</td>
</tr>
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<td></td>
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</tr>
</tbody>
</table>

*Object*

The object is what the subjects will interact with to reach this activity's outcome. The object can be viewed differently when considering the different viewpoints of those involved. For the game makers and teachers, the object would be the gameplay and game mechanics used by the subjects to learn the material the game is based on. For the students, many saw the mechanics and the lesson as objects needed to reach their personal goal of beating the game. For research sub-questions 1 and 2, the object this study focuses on would be the gameplay and presentation of the lesson, which is helping to lead us towards our outcomes of interest in physical science lessons and overall engagement.
For this study, three games were chosen from the online platform Legends of Learning. These three games were selected because they displayed three very different types of games, each focused on different learning strategies and approached teaching the content in different ways.

**Game 1: Space Repair.**

**Game Description and Theme.** Space Repair is a story-driven game that has the player create different atoms using a futuristic machine that would allow the player to save several satellites and a space station damaged during a major solar storm. Everything about the game is based around a space environment to help get the player more engaged and interested in the lesson. The game combines elements of a story-driven narrative and puzzle-type games designed to teach students about the basic structures of atoms. The premise of Space Repair is that the player/student is the captain of a spaceship designed to repair satellites and space stations damaged from a solar event. They are tasked with using a matter replicator to create different atoms necessary to fix the damaged equipment. The player is given a helper robot that guides them in their various tasks, explains how to play the game, and teaches the actual lesson. The robot helps encourage each time the player succeeds in a task.
**Figure 3**

*Screen Capture of Narrator for Space Repair*


**Game Mechanics.** Initially, the player is taken through a narration of the story before being dropped into the game itself. The robot helper then teaches a lesson explaining how to read the periodic table and use that information to create an atom of a specific element.
After the introductory lesson, the player is dropped into the game, though they can access a written version using the help button. Initial instructions are given for creating the parts of the atom as the robot explains how to add protons, neutrons, and electrons. There are buttons for each sub-atomic particle, and they can either drag to add that particle or click on the particle to increase a multiplier (so they drop five at a time instead of 1). There are options to un-do or completely delete the current atom, which is explained after the player builds the required element. Once they complete their attempt at the element, the player must click the submit button to see if they are accurate. No submission instructions are given during gameplay; they must figure it out independently. After completing an atom, a few more different elements are given to have them practice.
After the first level is complete, the second level has them play a mini-game that has them continue to practice the newly learned information in different ways, such as identifying the numbers that go on the chart only using the number of sub-atomic particles.
Midway through the game, new content is added as the player learns about charged atoms and how to adjust the number of electrons based on the charge. A new number is added to the chart, indicating the charge of the atom they are building. After completing this new skill, a new mini-game is used to reinforce that lesson by identifying positively and negatively charged atoms in another type of matching game, and a final one has them complete a pipe connection style game where they identify the missing information and try to connect the pipes to the correct answer. There are five primary levels that the player must complete to finish the game, each represented by a clickable satellite.
Science Content. The primary objective of Space Repair is to help students understand the basic structure of an atom and how to read the parts of the periodic table to know how many protons, neutrons, and electrons each element has. The introductory lesson is given before the player begins, and it teaches them how to read an element chart and what the different numbers indicate. This lesson is available throughout the rest of the game whenever the player clicks on the hint icon. Using their knowledge, the player must read an element chart from the periodic table and select the appropriate number of protons, neutrons, and electrons to create the assigned atom. The lesson focuses primarily on the atomic number and atomic mass and how to use those to calculate the appropriate number of sub-atomic particles. In the game's later stages, an additional concept is taught as the player learns about negatively charged and positively charged
atoms. This new information is then applied to the regular gameplay as the player must adjust the number of electrons based on whether the atom has a charge.

**Game 2: Study Escape Room – Changing Temperature.**

*Game Description and Theme.* Study Escape Room puts the players in a maze-based game that requires them to find yellow sticky notes containing information about heat transfer. The game is simply designed as it only consists of a maze with various branching paths and dead ends, and there is no storyline or other central theme. There is no music or background noise. The player’s main objective is to find the sticky notes that have the relevant information and use that to answer a question at a door that stops them from making progress. They must complete six levels, each with different required lessons to find and doors to unlock.
Figure 8

Screen Capture of The Study Escape Room – Map and Gameplay

Game Mechanics. The player is in control of a small ball that they can move by dragging an on-screen joystick. No initial instructions on how to move or play the game are given right at the start, but once the player figures out how to move, they will immediately grab the first sticky note, which gives the game's primary objectives and discusses the topic they will be learning. Next, they will arrive at their first door, where it will explain the mechanics of how the doors work and how to proceed to the rest of the level. The levels are designed to require the player to collect every sticky note in an area, or the door will not allow them to attempt to open it. Once they have done this, the door will ask them questions based on the information they have learned. If they do not remember, they can click on the sticky notes at any time to review the information
they have collected for that level. The game requires the player to read the information to themselves; it does not have a text-to-voice option.

![Image of The Study Escape Room Instructions](https://www.legendsoflearning.com/)

**Figure 9**

*Screen Capture of The Study Escape Room Instructions*


**Science Content.** This game focuses on heat transfer. The information can be found on the sticky notes around each maze level. Each level will follow a heat transfer theme; for example, one maze focuses on thermometers, conversions between Fahrenheit, Celsius, and Kelvin, and the different melting and boiling points for those units. On the other, it focuses on the amount of heat energy within an object and how the size of an object can impact the total
amount of heat energy within the object. The lesson is directly embedded in the game, as players must read and use the information to progress. This game takes the approach of having students read the information themselves rather than reading it to them.

**Game 3: Guiding Lights.**

**Game Description and Theme.** Guiding Lights is a puzzle-based game in which the player uses lenses and mirrors to reflect and refract light to hit a target placed randomly around a map. The game has a flashlight to project a “ball” of light that needs to hit a diamond-shaped target on the map. It does not have a specific theme or story built around it, but instead, it uses music to set a tone for the game and make it more exciting. The map’s layout is straightforward, with a regular brown background and spots indicating where things can be placed.

**Game Mechanics.** Not much is given regarding direct instruction on how to play the game. The player presses a launch button, sending a ball of light. The motion of the light is tracked through dotted lines that remain after the launch, which can help the player strategize their next move. The game features two different lenses: convex and concave. Initially, only one lens is allowed to be used at a time so the player can get familiar with each and how they cause the light’s path to change depending on how it hits the lens. They unlock a mirror to learn how to angle and reflect the light as they progress. All the lessons and instructions for playing are embedded in the help button, which can be pressed at any time. The hint changes on almost every level and will explain essential game mechanics and lesson topics. Later levels allow the player to use all the items at their disposal and permit them to change the refractive index for the lenses to create different effects and paths for the light. Experimentation is highly encouraged as multiple potential ways to hit the target depend on how the player positions their equipment. The game does create some unintended challenges for the players as the directions on the mechanics
are not clearly stated at any point. The player must always remember to click the hint; if they never think to do that, they can progress through the entire game without getting all the instructions.

Figure 10

Screen Capture of Guiding Lights Gameplay

**Science Content.** This lesson's main topic is the movement of light, focusing primarily on reflection, refraction, and absorption. The lesson is embedded in the hint button, and players can learn more about each type of motion at the levels where that type becomes relevant. A robotic voice will read the new information to the players each time the hint button is pressed. The lesson is presented in relatively short chunks describing one main topic. Initially, there is a focus on refraction and how the density of the lens can either increase or decrease the angle at which the light will bend. After a few levels, a mirror tool is introduced, and lessons on reflection are presented, mentioning how light travels in a straight line and how if light rays hit a mirror, they
bounce off it at the same angle. Absorption comes later in the game as a new barrier will fully absorb the light if the light runs into it. The main difficulty the game creates in teaching the content is that the player does not ever need to interact with or receive the content to play the game. If players are not directed to click on the hint button by someone else, they can play the entire game without hitting it. Additionally, if they skip a level without listening to the hint, they cannot return later to re-read what they may have missed.

**Analysis of Game Designs based on Assumptions about Student Learning.** As the primary focus of this study is looking at how the designs of these games impact engagement and interest, we will need to compare what is known about digital learning, the best methods for students to learn through digital media, and what is most effective for educational video games in the classroom. From there, we can look at the games themselves to see how those ideas may or may not have been built into the games through the various mechanics and features.

As previously stated, this study used three games, each with its own design and gameplay mechanics, to teach a physical science topic. Each game approached learning in a different way that it felt was best for maintaining engagement and educating students.

Space Repair had a few key features to teach the concept of atoms and sub-atomic particles. Like any standard game, a tutorial mechanic helps walk the player through how to play the game and their objective. The only thing that seemed to be missing was a direction on how the element chart was connected to their task, and it seemed to be assumed that the player would understand this, which most of the participants struggled to connect until it was pointed out to them. There was also no explicit instruction on submitting their responses, which at least half the participants took some time to figure out independently. The participants who struggled initially expressed a lot about how it would have helped if they had walked through the first task to
understand their goal better. However, once they understood the basics, they could continue steadily. Considering player interests, this game was given a space theme and story meant to help the player get more into the game. The storyline had the player acting as the captain, telling them it was up to them to repair many damaged satellites by producing the necessary materials. Many of the participants seemed to like this story element as they even would respond to instructions given by the robot narrator who worked with them throughout the game. Like many mobile games, Space Repair had a reward system that ranked how well the player performed with several stars each time they completed a level. The better they performed, the more stars they earned. It also allowed them to retry any previous missions to try and earn the maximum number of stars. Finally, in considering player interests, this game included adding mini-games that changed the gameplay to keep the player engaged and interested. It incorporated a couple of matching-style games and a pipe-style game that each reinforced the same concept in a new way.

As the participants progressed, the game steadily increased the difficulty, giving them more difficult atoms to build to ensure that they understood the makeup of the atoms. The difficulty continued to increase as progress was made with adding new tasks that tested the players' understanding of the key concepts and the addition of charged atoms, forcing them to reconsider how many electrons there were based on the charge. While there was not a sharp increase in difficulty, the challenge of the standard itself seemed to be enough to hold the players' attention. Connected to this was how the designers ensured that all changes in difficulty were always tied to standards mastery. The gameplay was changed to increase the challenge but was tied to mastering the specific standard from a new angle every time.

The Study Escape Room did not seem to have quite as many features as seen in the first game. This game was much closer to something purely educational and seemed to lack many
features that would intertwine it more with entertainment-based video games. There were almost no instructions on how to play the game until after the player figured out basic movement; then, there was a small walkthrough that gave the fundamental goals of the game, though there were no formal instructions on the primary mechanics. There was a slight increase in difficulty as each new maze added new dead ends and random paths to make searching for the needed clues and doors harder each time, though none of these difficulty increases were tied to standards mastery. The gameplay itself was more standards-driven, though, as the player could not progress without finding clues that had educational material about heat and heat transfer and then had a quiz on the material to be able to open the door to move on to the next section or level.

Guiding Lights took a different approach to its mechanics than the other two. Unlike the first two, this one leaned far more on the entertainment side of video games and a lot less on the mastery of the standards. For starters, almost no instruction is given on how to play the game. Instead, the player must find the directions by clicking the hint button. This created some complications as those with less video game experience were unsure of what to do, and it took them a bit of time before they thought to click the hint button. This game highlighted the importance of increasing difficulty, considering player interests, and being entertaining enough to maintain engagement. It focused on challenging the participants with bending a light beam to hit a target using different lenses to refract the beam. Each level became more difficult, drawing in almost all the participants, even those less interested in the other two games. Many also expressed their enjoyment of the puzzle aspect of the game, which drew them in more. It also was an excellent example of not increasing the difficulty too much, especially halfway through. One level provided so much of a challenge that most of those who gave up on this game ended their play.
As far as the educational standards were concerned, this game did not highlight them as much. Just like the instructions on how to play, the lesson instructions can only be accessed by clicking on the hint button. If the participant had no interest in the lesson, they could easily bypass it by never selecting a hint. It became problematic as no information about the movement of light was ever given unless the player chose to learn it on their own. This approach did seem to be more of one that let the player decide to learn independently. However, participant observation showed that most would not actively seek out the lesson by their initiative.

**Analysis of Game Designs Using the Cognitive Theory of Multimedia Learning.** As mentioned, the Cognitive Theory of Multimedia Learning (Mayer, 2019) focuses on three basic principles. Humans process information using two different channels: verbal and pictorial. Each channel can only process a few inputs at one time, and for learning to be meaningful, appropriate cognitive processes need to occur during the learning.

Regarding the first principle, Space Repair and Guiding Lights incorporated verbal and pictorial information in their game designs. Space Repair blended both together throughout the gameplay, using a narrator to review materials and give directions and pictorial information using hints and visuals in the gameplay mechanics. Guiding Lights focused more on pictorial information, with the participants learning through the visual representations of the refraction of light. Verbal information was also included in the hints, which were read to the students by another narrator, but this could be bypassed if the participant chose not to use the hints. The Study Escape Room only focused on visual inputs, with everything only being read by the participant and some picture representations of the content included in some of the information provided.
Regarding principle two, none of the games were too overwhelming in terms of their audio and pictorial information, but there were some differences in each game's approaches. Space Repair used the audio information to guide the player with the directions for each game and set up the plot line for the game. It became apparent that much information was overwhelming in the visuals, first given when the participant reached the main gameplay. The design of the primary game (see Figure 5) caused a bit of a struggle as there were quite a few visuals that the participants needed to absorb, and many of them became unsure at first what to do. The game attempted to mitigate this by providing some basic verbal instructions when the player attempted to interact with one of the mechanics on the screen (such as adding a subatomic particle). However, the visual overload created confusion at the beginning of the game, which the participants needed to work through. The Study Escape Room and Guiding Lights took a much more simplistic approach with some basic visuals that the participants needed to absorb while they learned the game's mechanics. This was helpful as players had a much easier time learning how to play these two games at the start, as there was not quite as much visual information they needed to absorb at the beginning.

Each of the games took its own approach to make the learning meaningful. Space Repair’s design had the game build the later levels off earlier ones, allowing the participant to incorporate prior knowledge into the later levels. It also had the participants organize the information they were learning in different ways through the mini-games, having them review the previous content to provide different ways to understand the lesson. The Study Escape Room organized the material by having the early levels begin with simpler content and having each level build from the previous one with more complex information. It also used the information on each level to form the barriers that stopped the player from progressing unless they
understood the lesson. Guiding Lights had players incorporate prior knowledge of the movement of light and build that into the use of lenses to refract the light in new directions to achieve the goals of each level. Additionally, the information learned about the lenses at each level was incorporated into later levels to help the participants solve increasingly complex puzzles.

Another essential detail to consider when looking at the designs of the games is the principles of cognitive load theory (Mayer, 2014). The intrinsic cognitive load was connected to the difficulty of each game in the lessons. Space Repair was the most challenging, as those without some prior knowledge of atoms struggled the most with the difficulty of this new material. Heat transfer and refraction proved to be the easiest in cognitive load, most likely because those lessons are covered much more in earlier grade levels and are easier to visualize as they are not as abstract. Guiding Lights also made the intrinsic load easier because it was much more exploratory, where players did not need much prior knowledge to figure out how to manipulate the light as the program provided the visuals participants needed to see what happened. Extrinsic cognitive load for the games would include things such as mechanics needed to play the game but not tied to the content, as well as extra things such as background music. The Study Escape Room and Guiding Lights avoided any issues with the mechanics as the gameplay was not too challenging, meaning the participants were not overloaded when trying to learn the content. Space Repair suffered a bit from its mechanics as the main gameplay was not as straightforward, and participants without prior knowledge about atoms struggled with understanding the content and trying to figure out how to play the game. This mainly resulted in them needing my direct help to ease the gameplay load so they could better grasp the content. There were some very different responses for each game regarding the extrinsic overload from other sources, such as the music. Space Repair saw most participants not feeling as if the

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background music created any extra load issues, as most found it enjoyable and helped to set the
game's story better. There were quite a few comments that The Study Escape Room ended up
being too quiet, and a few would have preferred subtle music while they played the game.
Though no additional load was created from distracting music, it also seemed to increase the
players’ boredom somewhat, with many beginning to fidget or hum to themselves to occupy the
silence. Guiding Lights provided the best example of an extrinsic load being harmed by
background music, as many participants did not enjoy the loudness of the music. There were no
options to lower the volume or mute the music through the game itself, and many lowered the
volume on the computer instead. While not the most significant factor in why participants ended
up struggling with Guiding Lights, the loud music was something that many felt distracted them
from the tasks they were completing.

Community

There are a multitude of communities that will influence the subjects as they engage with
educational video games. In a broad sense, their classroom community, including teachers and
peers, impacts how each participant views science as a class, whether positive or negative and
influences how they may feel about learning science topics. Other community influences, such as
family and home life, can impact how they view science or learning through video games.
Within this study, there are a few community dynamics at play. First, each participant is brought
into the community of their science classrooms, as this has shaped a significant amount of their
views on science classes in general. This can be beneficial or harmful in many ways, as the class
dynamics can cause students to enjoy or dislike science classes. Another community pulling on
the participants is the one with their friends and family. Participants encouraged to study science
by supportive families or peers and given additional opportunities may have a different outlook
than students who are either met with pushback or indifference when trying to study science.
Within this study, there is an additional community that the participants have been brought into; this would be the one created by both me and the game itself. While much smaller and with much more limited time, this community sets the expectations for the girls participating and may impact their behavior. This community sets up its requirements for what the participants will be doing now and helps establish the study's participation rules.

**Division of Labor**

We have the Division of Labor within CHAT, where Community and Objects connect. Typically, when looking at the community, labor can be divided horizontally by those of equal status or vertically among those of differing status. For this study, the division of labor occurs vertically as labor is divided between the program, the researcher, and the participant (student), who are not equal in status.

Within this study, the program's job is to teach science lessons to students. Within that job, the program and, by extension, the programmer who created the game must build in lessons about how the game itself functions so that the participant may progress from one stage to the next. The object must also have the lesson embedded so the participant can learn the intended lesson. There are many ways that this goal can be accomplished, but it is the programmer’s job to ensure that the lesson is at the forefront of the game.

It is the participant's responsibility to progress through the game, learn the lessons being presented, and follow the study rules. They will first need to learn and understand the game mechanics so that they can function within the game. From there, they will need to master the content so that they can complete the different goals and objectives that are being presented.
For the researcher, it is their responsibility to instruct the students on how they are to act during the study, such as instructing them to talk out loud about their decision-making to ensure that the technology and program are functioning and running tech support when they were not, and to observe and take notes about what was happening while the games were being played. An additional job arose as participants began to play and get particularly stuck and sometimes needed guidance to make any progress. These were usually due to trouble understanding the lesson they were presented with, so different hints and reminders were needed to be given to those who did not have enough foundational knowledge on specific topics.

**Rules**

Where Subjects and Community connect, the CHAT Framework has where the rules are established in the Activity System. For this study, a couple of sources for rules have been established for the participants. First, the rules are created by the game itself. Each game has its own set of rules that the participants must follow to make progress. The rules can involve both game mechanics, establishing what the participant can and cannot do, and rules about how different tasks work and what is required to complete a task and progress within the game. Additionally, within the study context, some rules have been established between the researcher and the participant. The students were required to dictate their thoughts as they played, adhere to certain time restraints as they progressed, and discuss their experiences at the end of the study.

However, the focus we will use for discussing the rules piece in this study will be on the rules required to complete each game. The rules for each game are unique because they are directly tied to the science content that the participants will be learning while playing each game. The rules for success in each game require that the players both learn and master, to some degree, the content they are being taught to be able to make progress. Game 1 requires the player
to understand the essential parts and construction of an atom and the atomic number and mass before progress can be made. Game 2 directly tests the players on what they have learned from the notes they have to collect before they can progress to the next section or level, and game 3 requires they learn some basic ideas about the refraction of light and how different lenses can bend light in different ways to be able to complete the needed puzzle for each level.

**Tools**

Tools are found at the intersection of the Subject and the Object. Tools can be viewed in a few different ways. For this study, the primary tools used are the computer and internet programs that house the game. The participants needed to be familiar with using this technology to play the games and make progress. Additionally, the games came with built-in tools, primarily from the game's mechanics, that the players had to learn to accomplish their goals. An example is the joystick used to move the player in the maze game. Also, the hint button of the light game provided tools that explained how to play and gave hints about what to do. The tools enable the subject to access the information they need and help them reach their outcome.

**Findings**

*Central Question: How do the assumptions about student learning embedded in the design of an educational video game used to teach physical science influence the engagement and interest of 6th-8th grade girls in that content?*

Each game used in this study was designed with specific features meant to help educate students based on the assumptions the game designers had about student learning. As each participant engaged with one of the games tensions emerged within the activity due to these assumptions and that affected the participants’ engagement with the games and interest in learning physical science. The four primary areas where tensions were shown during gameplay
were between the Subjects and the Tools, Subjects and the Rules, Subjects and the Division of Labor, and Subjects and the Community. Analyzing the tensions that occurred between each of these areas showed how the interplay of game mechanics and science content either supported or discouraged participant engagement with the game and interest in learning the science content. What was primarily highlighted was that games that provided adequate support for game mechanics and content while gradually increasing the difficulty of the science content during gameplay supported engagement and interest. Additionally, allowing students to explore science phenomena during game play support interest and engagement and alleviated some difficulties with game mechanics and prior content knowledge. Another takeaway from this analysis is how different game styles work best depending on what the goals for a lesson are. For example, Guiding Lights worked best to introduce a topic before formal instruction, while Space Repair worked best to review major concepts after formal instruction.

Research Sub-Question 1: How does the design of an educational game influence the engagement of 6th – 8th-grade girls learning physical science concepts?

To analyze how the game designs influenced engagement for the girls playing the chosen games, it is essential to look at what designs were shown to support engagement and which designs were shown to discourage engagement based on the data collected. To begin, it is essential to state that based on observation of their behavior during gameplay and statements made during the post-play interviews, using an educational video game improved the engagement of the 6th – 8th-grade girls when learning physical science concepts. However, this improvement depended heavily on the game's designs when teaching the content. The level of engagement varied across games and was influenced by the designs of the games. Space Repair and Guiding Lights had most, or all, in the case of Guiding Lights; participants became
immersed while playing those games. A much smaller minority of participants felt the same about The Study Escape Room, with most playing only as long as they felt they were expected to play. What was observed for all three games was that the design choices made for that game had a significant impact that either supported or discouraged engagement with the game.

Design choices that were shown to support more engagement with the programs include open exploration, increasing the challenge of the game in conjunction with the content itself, increasing the difficulty at a steady rate to avoid the game becoming too hard too early, engaging characters/narrators who guide the player through the game, a synthesized voice to go along with the narration, a plot the game is based on even if it is only minimal, new gameplay designs such as mini-games that reviews the content being learned and providing a break from the main game design, puzzle-like formats, games designed in a similar way to familiar mobile games, and positive feedback or rewards for gameplay. Additionally, while having a narrator reading the text helped support engagement, being given the option to read the text to themselves was mentioned by a few of the participants as a better way to engage them while playing.

Game designs that were shown to discourage engagement with the game included a lack of understanding of the actual game mechanics, not having some form of tutorial demonstrating how to play the game, increasing the challenge related to the game mechanics as opposed to the content, repetitive tasks, designs that focused on low cognitive demand such as overuse of multiple choice questions and factual recall, if the story or game itself is moving too slow, and no underlying the gameplay or not using the plot throughout the game. Additionally, some participants expressed that having a plot based around a topic they do not enjoy detracted from their engagement with the program.
Space Repair. The rules for this game were based on understanding how to calculate the number of sub-atomic particles of an atom based on the element's atomic number and atomic mass. The first feature that brought most players in was how the game created a story around what they were learning. Many girls would respond to the narrator when they asked questions on screen and seemed to enjoy having a figure to engage with. When asked how the story and the narrator helped with the game, Mary indicated that the backstory and narrator helped to engage more, “I think it helps. Because you are not just starting the game with nothing, it gives you a better understanding of what is happening.” The story and narrator helped to set the game's theme and tone, which helped draw the players into the game before they reached the lesson. This sentiment was shared by all but one of the participants who expressed in their own ways how the space-based story helped make the game more engaging. As mentioned earlier in the chapter, this game was primarily based on using the same mechanics you would find in many current popular mobile games. This includes a map showing the different levels and feedback given when completing a level in the form of earned stars. This design drew all but one of the participants into the game more, and even those with minimal video game experience recognized the design. The only one who did not recognize this design was Bridget, who had stated that she was not permitted to play video games other than for this study, so everything was generally new for her. “I don't really have any experience with them because I'm not allowed to play them, like at all at all. So on the phone or anything like computer games, anything that is a game that is like on the computer or like electronic, I'm not allowed to play it.” The feedback mechanism built into the game was a star rating where the player received 1-3 stars based on their performance. Each participant expressed joy at completing each level and earning stars expressing this through smiling or cheering when they achieved a perfect score; Corrine was even determined to have a
perfect score and returned to ensure she did a better job to get the maximum score for a level she struggled with.

This game also built new types of games within the main game that were used for review and would appear before moving on to the next level to check student progress on the content. These mini games changed the mechanics and gave the participants a new way to review the material (See Figure 6). Bobbie highlighted how adding review games helped her experience playing Space Repair, saying, “I do not consistently like doing one thing the whole time. So, I enjoyed, how it switched during the review.” The main levels become very repetitive and have the participants performing the same task repeatedly, but incorporating new games to review their understanding of the material gave them a quick break to try something new. As Bobbie mentions, it is more enjoyable and, therefore, more engaging when trying something new. This sentiment was expressed by most participants in the study though there were a few such as Bridget who did not enjoy the change the mini games added stating, “Well, for me, I feel like it's kind of like distracting in a way. Because it like, it's like I'm focusing on one thing, and then all of a sudden, it's just like a whole new thing. Then, oh, back to that one thing and I kind of like lost my train of thought.” While in the minority, her sentiment highlights how important it is to consider the personal preferences of those playing educational video games. Not everyone will enjoy learning in the same way, and some would prefer a more direct approach to a lesson.

The gameplay design was also made to carefully increase the difficulty with each level, giving the participants more complex challenges each time and trying to get them to master the basics of the content. At the game's halfway point, the rules added a new challenge. The participants had to determine whether the atom they were building was positively or negatively charged and adjust the number of electrons based on this new information. The participants with
a better foundation of the content had an easier time incorporating this new information, and the additional challenge helped maintain their engagement. Stella highlighted this when asked about her experiences with Space Repair, commenting, “It was hard because I’ve never done anything like that before, but it was also challenging, and I like challenges. So overall, it was good.” While the game was a real struggle before because she did not have enough of a foundation with the content, she enjoyed the challenge. Despite the difficulties some of the participants had with this game, the challenge of the game was something they all expressed as helping them to engage more, even if only for a certain amount of time.

The most significant element that discouraged engagement with Space Repair was the lack of a tutorial or examples on how to play the game by building atoms and what atoms they were expected to build. The tutorial focused more on calculating the number of subatomic particles using atomic number and atomic mass. From there, they jump the player into the first model building with very little assistance with what to do. Some minor hints are given after the player randomly clicks on certain buttons. However, it attempts to add an exploratory element to the game mechanics themselves, leaving most players confused and needing more explicit directions from me to figure out what they should be building. Caroline expressed her frustration with the lack of a better tutorial by saying, “I feel like the steps could have been a little more descriptive. I feel like he (the narrator) should have elaborated more and then I would have understood it quicker.” While she was quick to pick up the how to play with a bit of direction from me, she was still desiring something that would have better explained the gameplay. This was a sentiment that all the participants expressed and struggled with at the beginning of the game. Even those who managed to figure out the game mechanics through exploration quickly became stumped when looking for a button to submit their work, with most ignoring that they
needed to press a button that said synthesize and becoming lost on what to do. When combined with struggles about learning new content they may have never seen before, some of the participants, particularly the 6th and 7th graders, only became more frustrated, which may have helped them to end the game early.

**The Study Escape Room.** The primary thing that initially drew players into this game was the initial story and description of the gameplay. Most liked the idea of a maze game teaching heat transfer and presented the idea of this being some form of an escape room. Mary was one of the participants who expressed the most interest in the design of this game. When asked to describe what she liked, she said, “It was fun trying to find your way around. You didn't know where everything was, and it was kind of just like, it was fun to see what comes next and where everything would be and how it would be set up.” The game's design initially drew in participants with this idea of having a chance to explore and find the clues needed to escape, making it feel close to a puzzle that resonated with many of them. The main design that almost every participant pointed to as something they liked about the game was having it in the maze format. All but two became visibly excited once they learned they would be navigating a maze and demonstrated a similar sentiment to what Mary described.

For some participants, another aspect that helped keep them engaged was having to read the content themselves rather than having a voice read it to them. While there was no one correct answer, as each participant had their own opinion, for a few of them, this worked to maintain engagement with the game, especially knowing that the information would be needed later to pass through the door. Caroline described how reading to herself did help while playing this game: “When I read it out loud, I could process it a little bit better because I was seeing it. And then when somebody was reading, and I was just listening to it, I didn't really process that as
easily.” This was not the case with every participant, as some also preferred having a narrator read it for them such as Stella who mentioned it helped her to process what the lessons were about. A third group emerged who expressed that reading depended on the game itself and how much they needed to process content-wise. Corrine expressed a sentiment with a few of the participants saying, “I feel like if I like it worked both ways. Because if I read by myself, then I have to think about it after and I can also read faster than like, when it reads to me. But if something reads to me, then while I get through it slower, I can process it more.” This highlights the need to have both options available for those who would do better with a narrator and those who would have a better time reading the information for themselves.

Aside from these designs, this game had several features that discouraged engagement with the game. The game’s primary issue was that it never increased the challenge through content or gameplay. Several key design features were primarily responsible for this. First, the game was the most repetitive out of all three games. The gameplay involved finding yellow notes and then using the information gathered to answer a question at the door. No matter how far you progressed within the game, this never changed for the duration. This repetition in gameplay and with the simple tasks started to show more of the participants becoming bored and beginning to disengage from the game itself. Elodie and Stella ended the game on level 3 despite having no difficulties with it up until that point. When asked about why she chose to move on, Elodie expressed that she had lost interest and wanted to see what the next game was stating “It wasn't really fun. It was just kind of learning and clues and questions. I wanted to see what was next.” Others also showed body language that indicated their engagement beginning to deteriorate as they started to fidget more or speak and act in a way that showed they were no longer as interested in what they were doing. Caroline mentioned in her interview that this game was just a
bunch of questions and how that detracted from her enjoyment of the game. A couple, such as Stella, also commented that they wished they had some soft music or something similar playing in the background to help keep them focused more. One of the key gameplay elements was getting through the doors to make progress. The doors only involved multiple-choice questions and basic factual recall. Almost all the questions required low cognitive demand; only two required the player to apply the information they had learned rather than asking them to remember what the notes had said. While there was a minimal attempt at some form of a story at the beginning, no further plot was continued because of how the token was designed to move and the maze's setup. Gameplay pacing was languid, which a few participants commented on. Bridget had much trouble with the mechanics of how the token moved and commented during the interview, “It was hard to get around. I would rather have the information given to me. I would get lost a lot or stuck on a wall. So, I felt like it was wasting time. Like if I was in a classroom, having a specific amount of time, that would be almost a waste looking for stuff.” Many participants struggled with the game's pacing as they sometimes had to go back almost to the beginning of a level if they missed a particular note needed to make progress. It became common for some participants to wander the same areas repeatedly with nothing to direct them to where they might have missed something. Even those who enjoyed exploring the maze began to fidget more or show physical signs of boredom when they became stuck in a particular area.

**Guiding Lights.** Guiding Lights featured some designs that caused most participants to begin displaying outward signs of engagement. They would move closer to the computer, smile a lot more as they messed around and learned what each tool did, and most became excited upon completing the first level and realizing what the game entailed. Despite initially lacking a connection to the content, this game featured the most open exploration of all three games.
Players could technically go through the entire game without opening the lesson itself instead of having them explore the concept of light refraction using different lenses. This game was designed to be a puzzle-style game where the participants had to figure out how to use the lenses to bend the light correctly to hit a target. This design drew in most of the players, who enjoyed each new level's challenges and helped draw them in. Bridget expressed her enjoyment of Guiding Lights stating that this was the only game she did not have any negatives to say about it. She further stated, “It was it was hard. But I mean, that was also a good thing, because it challenged my brain. It was challenging so it like, actually made me think which I enjoyed.” This sentiment about the challenges of the puzzle designs in Guiding Lights was one that all the participants agreed with and helped keep them engaged.

The primary design feature that discouraged engagement with Guiding Lights was that the game's challenge increased too rapidly too soon and was not connected to content but was instead connected to game mechanics. Initially, the game featured a steady increase in difficulty with each completed level. This changed once participants made it to the 8th level.
Figure 11

*Screen Capture of Guiding Lights Level 8 Gameplay*


This level had players use the mirror in conjunction with both lenses to try and bend the light directly behind the starting position. The level required the players to figure out how to place the lenses just right to get the light to pass through them twice and narrow its path to hit the target perfectly. This level was particularly discouraging as participants struggled to figure out the solution and wasted much time trying to figure out new ways to use the lenses without any assistance from the game. Almost all the participants who made it to this level showed confusion with what to do and spent far more time trying to figure it out than any other level. Four participants began to show visible signs of frustration with the level due to its difficulty. While very few quit on this level, most who struggled with it quit not long after, as their frustration had already built up enough that they did not wish to continue soon after moving on. The challenge with this level also ties into another design issue that discouraged engagement with the game: the lack of tutorials about the game mechanics themselves. While this game's exploratory design was
a great way to draw in participants, not having any instruction or tutorial to help them with how
to use the lenses in different ways once the levels began to grow more difficult resulted in a lot of
confusion or frustration as they struggled in later levels. Caroline noted some frustration with the
lack of explanation with the gameplay saying, “I feel like it didn't really teach us about how to
use the lenses. Unless you had like previous experience with them It was kind of confusing.”

Despite outward signs observed during the study, at the end of the debrief interview, all
ten participants verbally stated that the games managed to increase their engagement in the
lesson. Mary expressed this by stating,

… we would never play any other game other than like a Nearpod. ... And they were only
like multiple choice, except you just had to, like, choose a character. And that was the
only part that was like, just like a little bit of like creativity. ... Because if you have that
class for, like, an hour and a half for like three times a week, it can, like, be just tiring to
kind of like hearing the same voice just keep like going. So, I feel like a thing like this a
couple of times would be a lot better to engage in and then just like get a break from the
regular run of class.

As she mentions, many students view class as not having many opportunities to engage
with something like a video game or other ways to enrich a lesson. A typical lesson is usually
seen as having something like a Nearpod, which is like a PowerPoint presentation with a few
extra features that students can interact with, such as filling in the blank, matching, or other
routine activities, and the idea of using a video game instead she highlights as a much better way
to engage with the content. Even those who stated they had less interest in science topics, Stella,
Bridget, and Elodie, all verbalized that the games did make the lesson more engaging. However,
they did not give additional details other than it was something new and exciting compared to
typical lessons. Even though the consensus of the participants was that the games made the lessons more engaging overall, a few pointed to specific games that they did not feel were as engaging as the other games. Violet, who was not as engaged with game 3, Guiding Lights, stated, “But game three, it didn't really feel like a lesson. It just felt more of like, oh, here's a game about this not, you're not really learning about it.” Caroline stated she was not as engaged with Game 2, The Study Escape Room, “Second one. It stayed the same. It was like, oh, like I'm just answering questions, finding clues.” Each student had something that drew them into the games, but the responses show that when the games are either too basic or not meeting expectations, they may put the student off, resulting in a loss of engagement.

**Analysis of the tensions between the Subject and the Tools.** Analysis of the interaction between the subjects and the tools focused on tensions arising from the design of the game mechanics, specifically as the participants attempted to play the game. While the computer itself may also be considered a tool and participants had varying degrees of video game experience, they all had enough experience using a laptop to play these games. They understood how to use it to engage with the program. Tensions were observed when looking at how they interacted with the tools provided by the program (i.e., the game mechanics). Each player had to approach each game without prior knowledge about how the mechanics of the three games worked and how to achieve the end goals to complete the game. However, some had previous experiences with video games, which could have helped them to have an easier time learning the new mechanics or even hindered their gameplay if what the game offered did not match their expectations for how they usually play games. This created tensions with the tools and game mechanics, as the players needed to learn how to use them to complete their tasks and progress. For all 10 participants, this tension was resolved as they learned how to play each of the games, but
additional, and in some cases negative, tensions came to light due to specific issues with the
games that the participants had to struggle with to move past.

One common tension came from the game not explaining how specific tools should be
used. For example, Space Repair never mentioned how to submit the finished product, and many
participants struggled for a few minutes, unsure of what to do. In the Study Escape room, the
game never explains how to move initially, which usually delayed them from starting the game
for close to 2 minutes, unsure of what to do. In Guiding Lights, no direct instructions are given;
students must click around the screen to figure out what worked. Out of the 10 participants, five
struggled with the mechanics of space repair, seven struggled to figure out the controls of The
Study Escape Room, and six were initially stuck on Guiding Lights. Interestingly, the primary
two, who had minimal struggle figuring out the controls and were some of the first to quickly
pick up on what to do for each game, were Mary and Violette, who rated themselves as
experienced gamers. While these tensions were generally easy enough to overcome as they
quickly were able to figure them out and continue, for 6 participants, they did provide a source of
frustration, and multiple complaints were made about them throughout the study. One example
of frustration with minor issues with Space Repair was highlighted by Caroline, who stated, “But
it’s the fact that it switched to like times one to times ten, then times one hundred, it was kind of
like they should have better addressed it. They should have specified between dragging and just
clicking X a lot more.” The issue she mentioned was that when selecting the sub-atomic
particles, players could increase the number chosen at once by clicking on it but could only place
the particles by dragging them from the box. This confusion about this specific mechanic
happened to all participants. However, some, such as Caroline, had it become a recurring
problem that would even lead to them wasting extra time cycling through the different options
multiple times. While Caroline pushed through this and finished the game, the combination of the difficulty in understanding the material and the frustration of some of the simple mechanics led to at least 4 participants wanting to end Space Repair early. While most of that may have been due to the content itself, the added frustration created by struggling with the mechanics did not help to keep them engaged with the game.

A few of the tensions with the tools were more challenging to overcome, with several participants needing additional assistance playing the game. Space Repair saw a particular issue since their help tool did not seem to provide as much help as the participants wanted or needed so they could be more successful at the game. Many participants wanted to have a tutorial level that walked them through the first atom’s creation and were more direct about completing the game's primary levels. In the end, most were either able to learn the proper way to play the game on their own or needed additional assistance from me to grasp the mechanics. However, a few learned that they could not figure out how the game properly worked and chose instead to move on before completing it.

Another central tension came from Guiding Lights, though it was like Space Repair's issues. The game offered relatively little explanation or demonstration of the mechanics, leaving it up to the player to figure out what to do. This left them struggling to figure out what the game's goal was, though all of them eventually learned how to play the game on their own and began figuring out how to use the different provided lenses to direct the light where they wanted it to go. Through this type of experimentation with the different features, all the participants were able to learn a basic understanding of how different lenses refract light and were able to make it at least halfway through the game.
Another tension that became apparent in this node was the levels of boredom or frustration that would appear with some of the gameplay. As the participants moved through a game, if their boredom or frustration became too much, it would push them to end the game early, and rather than learning the complete lesson, they would only learn what they had completed along with the fact that they did not enjoy or were incapable of playing that game. Boredom was a problem primarily with The Study Escape Room, as many participants did not seem to struggle with the game but would eventually decide to move on with no reason being established. For example, Stella ended early on that game and indicated it was not capturing her interest or keeping her engaged. “It was just like learning about school stuff. It wasn’t something I would want to do on a daily basis.” A similar comparison was made by a few others such as Elodie who also compared The Study Escape Room and regular school. The similarities between The Study Escape Room and what is perceived as a standard class lesson show that many participants could not get engaged because it did not offer something interesting or new in the gameplay. Even among those who finished the game, it seemed mainly out of a desire to finish what they had started and not because they found it interesting or engaging. Caroline stated, “The second one was basically just a Q&A. I guess it made the topic slightly less boring, but there still wasn’t enough going on.”

Frustration was seen in both Space Repair and Guiding Lights, with many participants giving up on the game when it became too difficult. Space Repair saw some participants becoming frustrated with the lesson and choosing to move on. In contrast, Guiding Lights saw a significant increase in their frustration with one or more levels of the game that they felt were too hard to complete, and they chose to end the game early. This shows that while some concepts of
refraction of light might have been learned as they played the game, they also learned that they could not complete that level and ended their session early.

**Analysis of Tensions with the Division of Labor.** Several tensions are observed in the division of labor when looking at the participant perspective. Their primary labor in this study was to follow the rules and play the games until they were either completed or until they wished to move on and attempt to learn the lessons being taught by the game. The tensions observed during their play time included new challenges and difficulties with learning the new topics, new challenges that the games would sometimes present, and tension with frustrations created by problems in the game design.

The initial tension that became apparent as the games started was the difficulty of the participants learning the lesson being taught by the game. This was a common problem with most of the participants when it came to Space Repair. Almost all the younger participants had never had any prior experience with atoms or reading the periodic table. All three 6th-grade participants directly stated during the interview they had no prior instruction on the periodic table and almost no instruction or very minimal instruction on atoms. This resulted in all the 6th-grade participants and two of the 7th-grade participants becoming stuck on the first level of the first game. This pushed most players to find help by attempting to use the help option. For one of the 7th and all the 8th-grade participants, when combined with their prior knowledge this proved to be helpful enough to guide them in learning the content and how to play the game so that they could make progress. For the 6th graders and some of the 7th graders, more direct intervention was needed as they struggled for a few rounds before being able to wrap their heads around what they needed to do. One of two learning outcomes came from this tension: either the student was able to sufficiently master the content and gameplay and reach the end of the game, or they
learned that they were unable to grasp the concept, and their frustration led them to decide to end it early.

**Research Sub-Question 2: How does playing an educational game influence the interest of 6th – 8th grade girls in physical science?**

After discussing their experiences and thoughts after playing the games, the participants indicated during their interviews that playing an educational game improved their interest in the physical science topic being covered, at least while playing the game. This change is not necessarily something that would necessarily make a permanent shift in their view, but it did present the material in a new and more enjoyable way. Regardless of prior initial interest in physical science or science class in general, 8 out of the 10 participants, including some with a more negative view of science class, felt the video games, in general, improved how they felt about learning that topic.

Like engagement, a few things helped to support the improvement of the participants’ interest in the topic they were learning, and specific designs within the games themselves discouraged interest in the topic. The first design feature that helped to support student interest in learning the physical science content was the ability given by the game to explore the content for themselves, such as with Guiding Lights, where the students were not given any tutorial or direct instruction but instead had to explore the features of the game and figure out how to use them to bend light to hit the target on their own. Despite the lack of tutorials and usually guides being something that discouraged engagement or interest, when presented in this format, it showed the opposite effect as it gave the students more of a chance to play with the content, and with the puzzle style format, it ended up supporting their interests. Stella said, “It was almost like I wasn’t playing a learning game.” She further described how she enjoyed figuring out how to place the
lenses and get the light to move the way she wanted. This sentiment was also expressed directly by six participants all agreeing that Guiding Lights felt more like a regular game and not an educational one. Allowing participants to explore is an excellent way to build their interest; exploring and playing around with content you usually cannot, such as atoms in Space Repair, also helped build interest in those playing the games. Having a chance to build and play around with something normally impossible to experiment with helped to build interest in a very abstract part of the curriculum. When asked what she liked about Space Repair, Stella mentioned that she liked that “I’ve never done that before, and it was challenging.” When asked to clarify what she meant, she referred to having the chance to build the atom. This enjoyment of the challenge despite difficulties with the content was expressed by almost all of the participants regardless of how easy or difficult they found Space Repair.

Another design feature of the games that was important to avoid discouraging interest was ensuring a slow increase in the difficulty of the presented science concepts. If the difficulty increased too sharply, this would lead to frustration for the participants and cause them to decide to end the game early, regardless, leaving a negative impression about the content. What determined how quickly was too quickly ended up being determined by the participants and the prior knowledge they brought into the game. For Space Repair, those who had enough of a foundation with the topic found the game to be moving slowly and increasing the difficulty at the right time to keep the game challenging, which was important. However, for those without enough prior knowledge, the simple jumps made from one level to the next provided a significant struggle as they still had not fully understood the lesson and needed more practice. Elodie and Stella ended the game near the same point, expressing how they stopped understanding what was being taught and just wished to move on. All these features were just
smaller pieces of what ended up being a greater whole in determining whether a game improved interest in learning the content connected to it. It primarily came down to whether the participants enjoyed the game overall. The participants who enjoyed playing the game expressed a much greater interest in learning the content associated with that game. This was best demonstrated by how participants both acted and spoke about Guiding Lights. This game was the main one that all the participants praised, and it was also the one they all expressed as feeling less like a learning game and more like a commercial one. The enjoyment they had from the game also translated into how interesting they found the content with Caroline, and a few others directly commented that they “enjoyed learning the different ways light could bend using different lenses.”

There were also quite a few designs within the games that discouraged interest in the game itself and, by extension, resulted in the participants being less interested in learning the content associated with the game. A few were already mentioned in the previous discussion about supporting interest, such as participants who did not have enough prior knowledge about a topic before starting the game and having difficulty with the content increasing too quickly before the student was ready to move forward. Other features that discouraged interest included emphasizing low-level recall style gameplay or game designs that acted more like notetaking. This was also seen as an issue for engagement as low-level recall tasks ruined the game experience, causing engagement with it and interest in learning the content to deteriorate. As previously mentioned, Caroline saw The Study Escape Room as “just a bunch of questions,” and others expressed how the game felt too much like a typical school lesson, which speaks not only to the goals of how to complete the game but also to how the content is only being presented in a basic low-level recall manner, which is not providing a challenge for the participants.
The next game design that was noted to discourage interest in learning the content was a lack of examples or tutorials on how to use the concepts themselves. This also goes along with issues with the gameplay tutorials while looking at engagement. Space Repair saw many participants desire some example level or something that acted more like handholding through the first few sections of the first level so they could better grasp how to apply the content. Frequently, participants would ask for help on the first two levels, particularly those in 6th and 7th grade, and need more direct intervention from me in explaining exactly how to apply what they learned in the content tutorial to the building gameplay.

One additional point during the interview was that there was no effect on interest level for the game when the participant already had a high level of interest in the topic. This was primarily highlighted during the discussion of The Study Escape Room, as many participants rated heat transfer as a higher level of interest in learning than the other two. It was noted that The Study Escape Room did not improve interest in the topic, primarily due to most participants' dislike of the game. It also did not deteriorate their interest in the topic overall. Caroline highlighted this stating, “There really was not enough going on with game two. My interest in the topic stayed the same. It was like, oh, like I'm just answering questions, and finding clues.” Only one participant, Mary, found that The Study Escape Room made the topic more interesting for her.

Speaking with the participants after completing the games, each was asked directly whether the game helped make the topic more interesting when learning through a video game compared to how they are typically taught in science classes. The consensus by most participants was that, overall, the games made the specific lesson topics more interesting. Only one participant, Stella, did not feel like any of the games improved her interest, and another, Bridget, stated that it was slightly interesting because it was new. However, she did not feel it truly
changed her interest in any of the topics. “Because I mean, it didn't make it more fun for me. I mean, yeah, it was like interesting because it was like a new thing. But, um, I think if like, that was like, repeated, it would just kind of become like a same old thing in a way.” Her view highlights one of the main issues to watch for when implementing this type of activity: how much of the interest is being improved due to the game design itself versus how much interest is developed only because it is something new to try and break the routine of what is seen as regular classes.

**Analysis of Tensions Between the Subject and the Rules.** The rules for any game, including video games, revolve around what the players must be able to do to complete the tasks given to them. For each game, the rules revolve around mastering the science content built into each game and completing tasks and puzzles using the knowledge they have acquired. Looking at tensions between the subjects and the rules means the analysis must look at the tensions between the subjects and the science they are expected to learn.

Each game had its rules that the players expected to learn and master. To review what was described earlier in the chapter, Space Repair focused on understanding the parts of an atom, how to use atomic mass and atomic number to calculate the number of subatomic particles for each element, and how to adjust the number of subatomic particles when an atom is either positively or negatively charged. The Study Escape Room focused on learning a variety of information about heat and the transfer of heat. Guiding Lights focused on refraction and how different types of lenses can bend and move light differently.

The primary tension between the rules and the subjects is also the entire purpose of the game; the students have different levels of understanding for each topic, and to resolve the tension, they will need to either learn the material in some capacity or they will learn they cannot
master the rules and decide to stop playing. The game that provided the most significant contrast between the participants and their different knowledge levels was Space Repair. The participants who struggled the most with this game were those in 6th grade and two 7th graders, Stella and Ava. These participants took the longest to understand the basics on the first level and needed more direct instruction from me after reading the hints several times. Even after completing the first level, the 6th graders needed constant reminders about the material. Stella provided a good perspective on this when asked what she did not like about Space Repair. She responded, “It was hard because I’ve never done that.” This referred to how she was required to find the number of subatomic particles using the atomic number and atomic mass. “It was good that it was hard, but it was just too confusing.” When asked why she ended that game early, Stella responded, “Because I stopped getting it. I just stopped understanding.”

The Study Escape Room and Guiding Lights made it easier for students to resolve the tensions and proceed through the game. The Study Escape Room focused on heat transfer, which is taught more frequently through elementary school, which showed in the participant's ability to get through the game as almost all the doors blocking their path were easy. Guiding lights provided an easy tension to get through, not because refraction of light is more heavily taught early on, but since the gameplay focused more on trial and error and puzzle-style gameplay instead of prior knowledge, it made it easier to learn how light will bend through different lenses. As the levels became more complex, this method of learning by exploration continued as new mechanics were introduced, such as new lenses that changed the light direction in different ways. The puzzles were made more and more difficult with the target being moved in various spots, making it harder to reach or adding obstacles that had to be avoided to keep the light moving. The participants continued learning new and interesting ways to manipulate light, trying many
combinations until something worked. They learned new ways to bend the light at new angles and often would stumble onto the correct answer by mistake, teaching them new ways for the lenses to bend the light. It was observed during the gameplay that 6 participants reached a point where they could not figure out a proper sequence to get the light to bend in just the right way. This became most apparent on level 8, where the light needed to be directed in the opposite direction just behind the starting point. This level became a significant stalling point for most participants as they tried to figure out the right strategy with the lenses to correctly angle the light (See Figure 11).

The biggest challenge during this level for the students to master how to use the lenses and mirror to refract the light came from the understanding and discovery that the lens could be used twice by reflecting the light from the mirror and back through the other side of the same lens. Once this discovery was made, most participants began experimenting with this new idea, trying to find new ways to narrow the angle to just the right spot to hit the light. Many of the participants began to gain an understanding of how to use the lenses more than once with the mirror, but quite a few struggled with this level for far longer than any other level. Ultimately, only one participant chose to end the game without solving this level. However, for the remaining 8 (one quit before level 8), the ones who struggled the most on this level quit early later in the game, with only 4 participants making it to the end. The ones who better understood how to use the lenses in new ways ended up resolving this tension by learning and completing the game, while the others reached a point where they could only resolve it by ending the game early.

Another tension that appeared explicitly in this study came from the rules for the think-aloud. This proved to be a significant struggle for the 6th and 7th-grade participants as the
complexity of the games often would lead them to go quiet and need much prompting to get them to resume their discussion. Most of this group never really learned how to talk while making decisions, so they needed constant prompting and reminders to talk about what they were doing. The 8th graders were the only ones who had far less trouble with this task. After some initial reminders were needed, they could get into the habit of talking about the decisions as they made them. Some of this could be attributed to personality and capability. However, this may also indicate that the older students, who had more experience with middle-grade science, did not have as much difficulty dealing with the complex tasks of the games and the complex directions of the study.

**Analysis of Tensions with the Community Node.** For the Community Node, the participants were asked to describe their experiences in a general science class and see how that compared to a lesson from a game instead of what they may usually experience in a typical lesson. In looking at the community of their science class, they were asked to discuss their experiences and touch on some of the more commonly seen problems with science classes in general, such as the idea that science is more geared towards boys or that many teachers primarily use note taking or lecture instead of hands-on instruction.

Discussing their own experiences in science class, one common perception shown in other research that did not present itself here is the idea that science is a subject geared more toward boys. Every participant unanimously disagreed with this. All of them strongly disagreed that science was a subject meant for boys, none of them felt that their teachers focused more on the male students than the female ones (ignoring behavior issues), and only one of them felt that their peers had the perception or had expressed that science was a subject geared more towards
males. Additionally, all of them generally expressed that their experiences with science classes have been positive overall.

Tensions were seen in the discussion of the class community regarding the topic of hands-on learning versus notes and lectures. While experiences varied based on the class teacher for each year, the primary view was that science classes focused much more on notes and lectures than hands-on activities. Only two of the participants expressed disagreement that their science classes were mostly lectures and notes, two expressed they felt their experiences in science mainly were notes and lectures, and the rest were more neutral with it primarily depending on what teacher they had each year. Comparing that to how they viewed the educational video games aligns with their views on their class experiences. All the participants expressed how the games improved their engagement and varying degrees of improvement in their interest in the subject. However, that was primarily for Space Repair and Guiding Lights, which were formatted more like a traditional video game. On the other hand, the Study Escape Room caused them to express less engagement and interest due to the game, with many of them stating that the game was too much like traditional school, relying primarily on notes. Another comparison was made with game 2 being like learning through Nearpod, like a PowerPoint slide with a couple of small activities such as matching, filling in the blank, or multiple-choice questions, but primarily based around note taking. While many stated that too much reliance on educational video games could get old for them, something different from traditional school created a positive experience with science lessons, even for those who expressed disinterest in science class.
CHAPTER FIVE: DISCUSSION AND CONCLUSION

Purpose and Overview of Methodology

This study aims to describe how the assumptions about student learning are embedded in the design of educational video games that are used to teach physical science and how these games influence how middle school girls engage with the content and develop their interest in the subject. Focusing on these designs, this study examines and describes how the educational game influences middle school girls' engagement with science content. The research methods for this study were qualitative. Data from ten participants were collected during observations of participant gameplay and decision-making. Before gameplay, participants were also asked to complete the Attitudes Toward Science in School Assessment (Germann, 1988) to understand their feelings and experiences with science in school. These survey data were elaborated upon in the post-interview when participants were asked to discuss their prior science class experiences in more detail. To collect audio data during gameplay, participants were instructed to conduct a think-aloud to narrate what was going on and their decisions as they played the game. Unfortunately, narrating while playing proved too difficult for most younger participants in 6th and 7th grades; they needed frequent prompting and reminders to talk about what was happening. Only a few 8th-grade students could think aloud, following the intended method while playing the three games. Despite the limitations, the participants were prompted and encouraged to describe their thoughts to enable enough data collection during the games. Along with the audio, screen capture software was used to capture the gameplay to help look at specific decisions made during gameplay. Additional data was collected in field notes in which observations of the participants were recorded, including comments and body language while playing the game.
Conceptual Framework

For research questions 1 and 2, data were analyzed and discussed through the lens of CHAT (sighting). The collected data identified and interpreted the different tensions within the activity system to understand what participants learned during gameplay. Each node in the activity system was examined to find participants’ struggles and how those struggles were overcome. From these struggles and how they were resolved, we can extrapolate how both engagement in the game and interest in the science topic may have been improved, diminished, or unaffected.
Table 7

Summary of Major Findings

<table>
<thead>
<tr>
<th>Question</th>
<th>Main Findings</th>
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| Research Question 1: How does the design of an educational game influence the engagement of 6th – 8th grade girls learning physical science concepts? | • Certain design features either supported or discouraged engagement with the games  
  • Examples of game designs that supported engagement include:  
    o Open exploration  
    o Increasing challenge, connected to content, but not getting too hard too quickly.  
    o Synthesized voice  
    o Engaging characters/narrators  
    o Plot, even a minimal plot.  
    o Reading the text to themselves kept some engaged, or at least the option.  
    o Puzzle-like format.  
    o New types of gameplay designs (mini-games) that review the content.  
    o Rewards (earning stars based on how well a player performs) or general positive feedback (encouraging words when a goal is met)  
    o Mobile format – Gameplay like those found in many different mobile games.  
  • Examples of game designs that discouraged engagement include:  
    o Not knowing game mechanics  
    o Not having a tutorial  
    o Increasing challenges related to game mechanics alone.  
    o Little to no increase in the challenge of the game  
    o Very repetitive tasks  
    o Low cognitive demand, especially multiple-choice questions – factual recall  
    o The plot does not continue in the game.  
    o Story or game pacing too slow  
    o If the plot is not something they enjoy  
    o Distracting background music/effects |
Research Question 2: How does playing an educational game influence the interest of 6th – 8th grade girls in physical science?

- Certain aspects of the games themselves helped to support the participant's interest in learning the topic, while other aspects discouraged interest in learning the topic through a game.

- Aspects of the game that helped to support interest in the topic itself include:
  - Being able to explore physical reactions such as light bending (sandbox)
  - Steady increase in the difficulty of the science concepts
  - Interest in-game mechanics and gameplay supported interest in the science

- Ultimately, if they are interested in the game, the science content is learned passively, as is the interest.

- Aspects of the game that discouraged interest in the content included:
  - Emphasis on low-level recall or note-taking.
  - Not having enough foundation or prior knowledge
  - Science content difficulty increases too quickly.
  - Lack of examples or tutorials for the science concept
  - Their prior interest in science did not help, and it would not hurt if they did not enjoy the game.

- If the gameplay was more stale or repetitive, participants stated that their interest level had not improved.
  - This was particularly true for those who already liked the topic and did not see anything added by the gameplay.
Discussion

**Similarities to Prior Research**

Findings in this study confirmed several findings from prior research into girls’ experiences with science and video games. When looking at participants’ interest in science, only 3 had a high interest in science, with the rest being more neutral, depending on the topic, or even expressing a general dislike of science. This result shows that, like prior research, there tends to be low interest in science during middle school with female students (Barton et al., 2013; Falk et al., 2017; Makransky et al., 2020). Additionally, the participants with the most substantial interest in science expressed greater exposure to science programs outside of school. Caroline talked at great length about her time at space camp and how it shaped her interests. Without these out-of-school experiences, girls often do not increase their interest in science (Archer et al., 2010; Barton et al., 2013; Hazari et al., 2022). Another similarity was how the girls viewed themselves as someone willing to engage in a science lesson and understand the content (Brickhouse et al., 2000). The participants whose interests and attitudes aligned more with this belief about themselves showed higher levels of interest and engagement than those who viewed themselves differently.

Another finding that aligned with prior research was the low levels of interest in topics related to physical science (Eren, 2021; Hunt et al., 2021; Tellhed et al., 2016). After describing topics related to physical science, all but three of the participants described being much less interested in them regardless of how they felt about science in general. Even some who expressed more positive attitudes toward science expressed less interest in topics like atoms, matter properties, and energy propagation.
More specifically, regarding girls and video games, this study also corroborated prior research related to participants’ level of gaming experiences. Despite the number of female gamers expanding in recent years, thanks partly to mobile games, males play video games five times more than females in the middle school age range (Leonhardt & Overa, 2021). Among the participants in this study, only two could be considered frequent gamers. The rest only had some experience, though it is not an everyday recreational activity, and one stated she is not allowed to play video games at all.

This study also confirmed points related to improving interest in science by looking at similar design strategies within the games to what others have tried in prior studies. One of these strategies involved presenting girls with a challenge they could overcome to boost their self-efficacy (Billington et al., 2014; Roberts & Hughes, 2019; Veldkamp et al., 2022). This point was very apparent with the first game, Space Repair, where the primary challenge came from trying to learn the required content about sub-atomic particles and how to calculate the number of particles needed. Those with enough background knowledge and determination could meet and overcome the challenges with the content of the game, followed by expressions indicating a greater interest in the topic even if they had initially ranked it low. By contrast, those unable to overcome the challenges with the content of this game showed signs of disinterest and would quickly want to end the game before too much time was spent on it. Guiding Lights also demonstrated a similar effect as each level continued to increase the challenge with each passing level, resulting in more engagement and interest in learning how to use the lenses better to bend light.

Comparing this study to research into effective serious video games also demonstrated some similarities. Previous research has shown that engagement increases as the challenge
increases throughout playing the game (Hamari et al., 2016). The best example of this came from the Guiding Lights, the third game, as 9 of the participants, aside from Stella, became fully immersed in figuring out the solution to each puzzle. Space Repair also had its levels increase in challenge as the player made progress by adding additional mechanics, such as the mini-games for review, and introducing new content at the halfway mark to make the basic gameplay more challenging. Many participants, such as Bobbie, expressed that they liked that the minigames provided a change and that the challenge kept them engaged while playing. Meanwhile, The Study Escape Room saw engagement taper off as participants became bored of the repetitiveness and lack of a real challenge from level to level. The only increase in the challenge came from slightly more complex mazes and two higher-level thinking questions towards the end of the game. Additionally, research shows that effective game design must have the challenge of being created by students struggling with the concepts and standards (Hamari et al., 2016). Space Repair and Guiding Lights both provided examples of raising difficulty with each level and had difficulty tied into the lesson's content. Space Repair was more direct, with the lesson being directly given and adding a challenging practice that changed with each new level. The mini-games were based on reviewing the concepts they were learning in new ways and with new mechanics. Adding new content, positively and negatively charged atoms, made the basic gameplay more challenging after the participant reached the halfway point. While the game ended up being a real struggle before because she did not have enough of a foundation with the content, she did enjoy the challenge of the game, resulting in her having some Guiding Lights was more exploratory and had the student learn more on the properties of light and the effects of lenses through more trial and error very similar to a simulation using puzzles. Each new level would test the players by using either new lenses or finding new ways to get the light to bend by
using the tools they had in new ways, such as having the light need to bounce backward first. The game could maintain steady engagement if it did not become overly difficult by increasing the difficulty while pairing it with discovering different ways to use the lenses to manipulate light differently.

Prior research also described different game designs that tend to be more appealing to girls, such as designs that encourage exploration (Kinzie & Joseph, 2008; Yeo et al., 2022), designs that use less complex gameplay and interface mechanics (Alserri et al., 2017; Mozelius & Humble, 2022; Vermeulen et al., 2011), and a preference for a complex story and characters (Alserri et al., 2017; Heeter et al., 2009; Mozelius & Humble, 2022; Veldkamp et al., 2022). The Study Escape Room primarily involved exploring a maze, and regardless of how the participants felt overall about the game, they all enjoyed exploring the different parts of the maze to look for clues. For game mechanics, all the participants expressed more enjoyment from The Study Escape Room and Guiding Lights, which were easier to figure out and control from the start. At the same time, Space Repair had some complications with the mechanics that led to confusion and a small amount of frustration for all the participants. For example, to add a subatomic particle, they needed to click on the picture of one and drag it to the center, while to increase how many subatomic particles could be placed at one time, you had to click directly on the particle without dragging it. This complication led to most participants expressing frustration at the mechanics and stating that they should be modified to prevent that from happening. Finally, the design for game 1 was very story-rich, unlike the other two, and almost all the participants expressed more enjoyment and interest in the game because of the story given to them. The only participants who did not like the story stated that it was due to the space theme, which was not a
topic they were interested in. Ultimately, each game included some designs that have been shown to interest girls, but none of them included all of them.

**Differences from Prior Research**

One finding that was very different from findings in prior research was when it came to describing science as a more masculine subject (Archer et al., 2010; Barton et al., 2013). Across the board, all the participants expressed that science was a subject for both boys and girls and did not feel that teachers or family members had left an impression that science was more for boys than girls. Only one of the participants expressed that other peers in her class felt that way, with the rest all stating that their peers did not view science as a primarily masculine subject. Their attitudes about science and physical science align with prior research, where this attitude was learned not from home or school, as shown previously.

An interesting note when comparing the games used in this study to designs shown in prior research that girls enjoy the most was how there seem to be specific game designs that have more of an impact than others. Guiding Lights, for example, features only two game designs that research shows girls prefer: exploration and puzzle solving. However, that was enough for the participants to rate the game as one of their favorite games despite lacking most other significant features. This seems to indicate that certain design features may have more of an impact on engagement than others will. Additionally, even when similar designs are used, if the other game designs create more significant issues, it may not be enough to maintain student engagement or interest. The Study Escape Room had exploration as a core design to its gameplay. However, the other issues with low-level recall and repetitive gameplay resulted in this game being received poorly. Based on what was seen in this study, some preferred designs seem to have a higher
impact on girls’ experiences than others. However, the game must have designs that are conducive to one another and promote support, interest, and overall engagement.

Another noted difference from what is shown in the research is the types of games that are found on the platform. Previous research shows that many companies will make games that feature stereotypical designs that girls are seen to love, such as hair, make-up, or fashion (Hughes, 2022). However, none of the games on this platform have designs based on this idea. This may be because they are trying to reach all students and not just one group, or if those designs do not match what would be expected from an educational game, one with those designs has not been attempted.

**Limitations and Delimitations**

As with any study, a few limitations need to be mentioned. The method of selecting participants had to change to a convenience sample rather than a more diverse group. Initially, I was hoping to find female students with a wider variety of video game experiences and potentially a more comprehensive range of views on science with the assistance of teachers who may know the students better. Due to this, the findings do not consider other diverse populations, as most of the volunteers who responded and signed up were of similar race, ethnicity, culture, and sociodemographic.

Another limitation came during game selection. While a few games were initially identified for use, several more ideal choices became unavailable just before the study began. A few designs that I wanted to use in the study were no longer options, so the study had to switch to one with a similar design and touched on the same topic. This meant certain design features, such as character customization, initially intended to be used in the study could not, as no replacement game was available. As a result, other features had to be chosen.
There were challenges with the think-aloud strategy that was being attempted as the girls played the games. Most younger participants struggled with this task, needing frequent reminders and assistance. Only the older participants seemed to be able to balance discussing their thought processes while engaging with the games, especially when the cognitive load needed to figure out a particular puzzle or understand a lesson was high. Some participants were just naturally quiet and would not talk unless they were prompted to do so. The main impact on the findings was due to the increased amount of intervention and guidance I needed to provide so that the younger participants could even make it past the first level, preventing a proper think-aloud.

Delimitations to the study came from the decision only to use middle school-aged females. This leaves out perspectives from older people and could provide more insight into their experiences throughout their education. It also leaves out younger participants who might be able to give their insights into what might draw or push them away from science or physical science. The study also only used participants from Seminole County in the Central Florida area, which limits the diversity of the study to just those within this area.

Another delimitation came from the participants playing the games in a very different setting from a typical science lesson. The study has the participants playing alone under direct supervision without other peers to provide any collaboration or socialization that can be a benefit to a lesson and to gaming. There were also no negative behaviors and other potential distractions creating a very different environment from what could be seen in a regular class. This study also was not part of an overall science unit that the participants were studying and there were no assessments evaluating their learning, making it different from what would be seen in a classroom.
Recommendations for Future Research

To address this study's limitations, future research should include a more diverse sample, view additional game designs that could not be addressed in this study, and expand more into elementary and high school to learn more about how educational video games can be a resource to help develop interest and engagement with science lessons for female students.

One route that future research can take would be to get more of a perspective from younger students in elementary school. This would allow for comparing experiences to those of middle schoolers and see if there are any differences in how educational video games may impact the interest and engagement of students at an earlier age.

Another avenue that would be beneficial would be to expand more on the games being used and seek out ones with additional game designs, such as customization of the player avatar to allow the students to invest more in the game or chances for peer interaction, such as through a multi-player style game. Additionally, many of these games would benefit by having some way to change the difficulty level of the game to enable it to reach more students of differing abilities and background knowledge. The games used in this study were simpler ones that focused on a solo player learning a lesson. However, it would be worthwhile to see how interaction with peers using some form of multi-player game would influence interest, engagement, and the learning of the topic.

Since the only recruitment method was social media, subjects were chosen based on availability and response to advertising. Future research should expand the sample to examine how student race, ethnicity, culture, or socio-economic status might affect learning through educational video games, as a more diverse group of girls who regularly play video games vs those who play them less often. Having greater diversity in research participants would allow for
a deeper analysis of the experiences of various students and give more significant insights into the impact educational video games may have.

This study’s design was also limited due to the age of the participants in the study. Initially, the intent had been for this to be a think-aloud entirely, but that proved too challenging for most participants. Looking at the data, the 8th graders were more successful at discussing their thought processes as they played the game. However, the complexities of the science and game mechanics while remembering to discuss their thoughts created too much cognitive overload for the younger participants. When working with younger students, future research might benefit more from using only general observation, clinical interviews, and other similar approaches when working with younger participants who might struggle with something like a think-aloud.

Another approach that future research could take would be a more detailed analysis of the usability of the games themselves and how issues with the interface may also be impacting player experiences. One of the primary areas that participants spoke out about were some of the common issues that made the gameplay difficult. Possible usability issues included the player token slowing to a crawl if they touched the wall in The Study Escape Room or the confusing interface design for selecting the number of sub-atomic particles in Space Repair. These and other usability issues led to a lot of unneeded frustration with the games. It would be beneficial to have a deeper analysis of the usability of the games to get a better understanding of what factors in educational video games provide a more positive experience for students.

To address the differences in the study setting with that of a regular classroom it would be beneficial for future research to apply a similar design to a classroom setting. Having a chance to see how engagement and interest might be impacted when students are in a classroom setting
under the direction of a teacher guiding a lesson. This would give a lot more insight and feedback about how well the educational video games can work in the classroom and how the impact to interest and engagement may change when in a more normal environment. The main change that would be needed from this study’s design is that a think aloud method would not work in a classroom setting, so other methods of data collection would be needed.

**Recommendations for Practice**

This study has several important implications for the use of educational video games in a science classroom. Participants in the study expressed that educational video games made the lesson more engaging and, in some instances, made the topic more interesting. Many participants saw science as having too much notetaking and lecture and expressed how adding lessons with video games decreased some of that monotony, making the lesson more enjoyable. Implementing video games in science class may be easier because science lessons often inquiry. Educational video games provide another avenue for inquiry.

**Designer Recommendations**

The findings in this study suggest several ways that designers can improve their games to better reach female students to provide a more engaging lesson and better capture student interest. Many of the problems were due to design features that impacted how easily the participants could navigate each level. One way to improve this would be the inclusion of a more detailed tutorials that walk less experienced gamers or those who may not have enough familiarity with the content through exactly what they will be required to do. One of the participants' significant complaints was the lack of tutorials that integrated the game mechanics and science content. They needed something to guide them through exactly how to accomplish their goals. Those with more video game experience had an easier time with this, but many
students may not have a strong background in video games and needed more handholding to understand how to play.

It is also essential to ensure that the games properly increase the difficulty. The increase needs to either be slower for those struggling to allow them time to incorporate the material, or the games need to provide options to allow students to set their difficulty based on their level of understanding. This would help maintain student engagement by not being too easy so that it feels more like a lesson or being so complex that they lose engagement too quickly. Game designers need to ensure that the proper tools are in place so that their content can reach learners with different educational needs, even among the same grade level. The inclusion of additional games to help those who are struggling with the content, like those seen in Space Repair, would also provide a way to help those students build the foundation they need to succeed.

Designers also need to avoid content that focuses on low-level recall. Content should be structured in a way that has students apply what they are learning. The Study Escape Room only used low-level multiple choice recall questions as their barriers for passing from one question to the next. How the student uses what they are learning needs to be the primary method of making progress to ensure that they are better developing their understanding of the content.

When designing games, it is also important for the developers to clearly communicate the purpose of the game to educators so the game is properly used. Mechanics found in Guiding Lights work far better as an introduction to new content and a chance for students to explore, while Space Repair worked well for review and remediation. Having a clear goal for the game's use and communicating this to teachers will help to ensure that the game is being used in the best way for student success.
**Teacher Recommendations**

When teachers are considering using an educational video game as part of a lesson it is important to have a clear vision of what the game will be used for and its purpose in a unit of instruction. Educational video games need to be vetted properly to ensure that the content is correctly integrated within the game itself. Teachers need to explore the games to ensure they will work as they intend for the planned broader lesson. For example, Guiding Lights focused less on giving specific lessons and more on student exploration, along with trial and error in figuring out how to use lenses to direct the movement of light. Understanding how the game is designed will help to understand during which part of the learning process the game should be used. If used as an introduction to the topic, it is easier to allow the student to explore and see their understanding of the content after completing the game and what they may have picked up before the main lesson even begins. However, if this were being used to help support learning content specifically, then some form of assessment would be needed to ensure they could learn the material. While it would not be advised to have the game as the sole teaching method, it would work well for reinforcement or reteaching of content that the class is covering. Ensuring the game's design matches what the teachers want it to do is essential and will require exploring the game and seeing how it will fit into the overall lesson.

As mentioned earlier, teacher-created assessments may need to be incorporated depending on the intended use of the educational video game. The platform used in this study did not ensure that in-game assessments aligned with the game content; instead, questions were only aligned with the standard tied to the game. The game did not address all topics within the standard, so the game did nothing to prepare students for those assessment items. For example, in Space Repair, the focus was on building atoms and learning about the different sub-atomic
particles. However, at the end of the game, one of the post questions was on specific information about the periodic table, which was not part of this game but did tie into the overarching standard.

Depending on what part of the learning process the game is being used, how the teacher wishes to assess student learning may be very different, but a program like this will most likely need to be something based in the classroom setting. If the game is more exploratory, then some general review or class discussion should suffice in seeing what students may have picked up from their experience. Suppose the teacher intends to use the game to reinforce or remediate the lesson. In that case, they will need to be prepared with questions related to the topic, such as an exit ticket or potentially some in-class dialogue among the students to see where they are and what additional support might be needed.

Conclusion

This study aimed to describe how the assumptions about student learning are embedded in the designs of educational video games that are used to teach physical science and how these games influence how middle school girls engage with the content and develop their interest in the subject. What has been shown is that many different designs can both support or discourage engagement with an educational video game and interest in the science content being taught through the game. Using CHAT, this study was able to show a deeper analysis of the interactions between the girls and the games to understand better how the implemented designs impacted their experience in learning the various science lessons. Overall, each participant expressed how the educational video game felt different from what they saw as a typical science lesson and that it improved engagement and interest in using it. While this may not be a permanent solution to issues with interest in science declining for girls in middle school, it shows that more tools are
needed to enhance the students’ experiences in class further and try new things that may make the lesson more engaging and fun.
APPENDIX A: IRB PERMISSION LETTER
July 12, 2023

Dear Stephen Petit:

On 7/12/2023, the IRB reviewed the following submission:

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<th>Type of Review</th>
<th>Modification / Update</th>
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<td>Title</td>
<td>Using CHAT to examine how assumptions of student learning are built within a serious video game and its influences on engagement for middle school girls.</td>
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<td>Investigator</td>
<td>Stephen Petit</td>
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<td>Funding</td>
<td>None</td>
</tr>
<tr>
<td>Grant ID</td>
<td>None</td>
</tr>
<tr>
<td>IND, IDE, or HDE</td>
<td>None</td>
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</table>
| Documents Reviewed | · Campus Map, Category: Other;  
                     · E-Signature Instructions and Alternatives, Category: Other;  
                     · MOD 4340 Petit IRB - HRP-503 - Protocol update 7-6  
                       (1) IRB edits.docx, Category: IRB Protocol;  
                     · Parent Consent Letter 7-6.pdf, Category: Consent Form;  
                     · Recruitment Flyer, Category: Other; |

The IRB approved this modification on 7/12/2023.

In conducting this protocol, you are required to follow the requirements listed in the Investigator Manual (HRP-103), which can be found by navigating to the IRB Library within the IRB system. Guidance on submitting Modifications and a Continuing Review or Administrative Check-in is detailed in the manual. If continuing review is required and approval is not granted before the expiration date, approval of this protocol expires on that date.

Use of the stamped version of the consent form is required.

When you have completed your research, please submit a Study Closure request so that IRB records will be accurate.
If you have any questions, please contact the UCF IRB at 407-823-2901 or irb@ucf.edu. Please include your project title and IRB number in all correspondence with this office.

Sincerely,

[Signature]

Harry Wingfield
Designated Reviewer
learning as measured by various achievement tests as opposed to achievement that includes an evaluation of the consistency and quality of classwork as in a course grade. The latter seems to be more strongly correlated to attitude.

**Appendix: Attitude toward Science in School Assessment**

Please use this scale to answer the following questions:

<p>| | | | | | |</p>
<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>SA</td>
<td>A</td>
<td>N</td>
<td>D</td>
<td>SD</td>
<td></td>
</tr>
<tr>
<td>Strongly agree</td>
<td>Agree</td>
<td>Neither agree nor disagree</td>
<td>Disagree</td>
<td>Strongly disagree</td>
<td></td>
</tr>
</tbody>
</table>

(Circle one choice.)

(1) SA A N D SD Science is fun.
(2) SA A N D SD I do not like science and it bothers me to have to study it.
(3) SA A N D SD During science class, I usually am interested.
(4) SA A N D SD I would like to learn more about science.
(5) SA A N D SD If I knew I would never go to science class again, I would feel sad.
(6) SA A N D SD Science is interesting to me and I enjoy it.
(7) SA A N D SD Science makes me feel uncomfortable, restless, irritable, and impatient.
(8) SA A N D SD Science is fascinating and fun.
(9) SA A N D SD The feeling that I have towards science is a good feeling.
(10) SA A N D SD When I hear the word science, I have a feeling of dislike.
(11) SA A N D SD Science is a topic which I enjoy studying.
(12) SA A N D SD I feel at ease with science and I like it very much.
(13) SA A N D SD I feel a definite positive reaction to science.
(14) SA A N D SD Science is boring.

**References**


Bloaser, Patricia E. (1984). Attitude research in science education. ERIC Clearinghouse of Science, Mathematics and Environmental Education Information Bulletin, No. 1, Ohio State University, Columbus, OH.
APPENDIX C: CONSENT TO USE LEGENDS OF LEARNING ASSETS
Hi Stephen,

Thank you for reaching out! We appreciate your interest in Legends of Learning for your research study. Feel free to use screenshots from our games and/or platform as part of your study. Thank you for checking and please let me know if I can assist you with anything else.

Have a great day!
Allison

Allison
Legends of Learning
Title of Study: Using CHAT to examine how cultural assumptions within a serious video game influences engagement for middle school girls.

Principal Investigator: Stephen Petit

How to Return this Consent Form:
You are being provided with two copies of this consent form. If you are consenting for your child to participate in the research please sign one copy and return it to your child’s science teacher. Keep the other copy for your records.

Key Information: The following is a short summary of this study to help you decide whether or not you wish for your child to be part of this study. More detailed information is listed later on in this form.

Why is my child being invited to take part in a research study?
Your child is being invited take part in a research study because she is a girl in middle school taking a class in science.

Why is this research being done?
This research is being done to examine the designs of educational video games and how they influence middle school girls’ interest in science related content. This study hopes to build a deeper understanding of educational video games as a learning tool.

How long will the research last and what will my child need to do?
We expect that your child will be in this research study for 60 minutes of observed gameplay with an interview afterwards that could take 30 minutes for a total time of 2 hours.

Your child will be asked to play at least 3 pre-selected educational video games on the Legends of Learning platform. Each participant will be playing the same three games. This is an online educational platform the school district has asked teachers to evaluate this year. Your child will be asked to think out loud while playing and navigating the games. They will also be asked questions about the games they played once they are done.

More detailed information about the study procedures can be found under “What happens if I say yes, I want my child to be in this research?”

Is there any way being in this study could be bad for my child?
The risks to participants are minimal and do not exceed the risks associated with activities found in daily life.

Will being in this study help my child in any way?
There are no guaranteed benefits for taking part in this research study. However, your child may learn something about science by playing the game.

What happens if I do not want my child to be in this research?
Participation in research is completely voluntary. You can decide to have your child participate or not to participate. Not participating will not hurt your child in any way.
Your alternative to participating in this research study is to not participate.

Detailed Information: The following is more detailed information about this study in addition to the information listed above.

What should I know about a research study?
Someone will explain this research study to you and your child.
Whether or not you allow your child to take part is up to you.
You can choose not to allow your child to take part.
You can agree to allow your child to take part and later change your mind.
Your decision will not be held against you or your child.
You can ask all the questions you want before you decide.

Who can I talk to?
If you have questions, concerns, or complaints, or think the research has hurt your child, talk to the research team:
Principal Investigator: Stephen Petit
petit.stephen@knights.ucf.edu
Faculty Advisor: Dr. David Boote
david.boote@ucf.edu
This research has been reviewed and approved by an Institutional Review Board ("IRB"). You may talk to them at 407-823-2901 or irb@ucf.edu if:
Your questions, concerns, or complaints are not being answered by the research team.
You cannot reach the research team.
You want to talk to someone besides the research team.
You have questions about your child’s rights as a research subject.
You want to get information or provide input about this research.

How many people will be studied?
We expect 10 students in grades 6-8 will be in this research study with a minimum of two students participating per grade level.
**What happens if I say yes, I want my child to be in this research?**

Your child will complete the Attitudes Toward Science in School Assessment. Once this is complete the researcher will contact you to schedule a day and time that your child can stay after school to participate in the study. On the day of their participation, your child will access the educational program *Legends of Learning* on a provided laptop. They will be instructed to play several games from the platform while talking out loud about their decision and thought processes as they play the game. During game play, they will be audio recorded and screen grabbing software will be used to record the game footage. Once your child has completed the games, they will complete an interview with the researcher to go over some of the data collected and clarify some of what was observed. The estimated time is between 1 to 2 hours. The participant will only interact with the researcher. This will be done in one of the science classrooms at Tuskawilla Middle School.

You child will be audio recorded during this study. If you do not want your child to be recorded, he or she will not be able to be in the study. Discuss this with the researcher or a research team member. If your child is recorded as part of this study, the recording will be kept in a locked, secure place. The recording will be erased or destroyed 5 years after study closure per Florida law.

**What happens if I say yes, but I change my mind later?**

You can choose to have your child leave the research at any time it will not be held against you or your child. When deciding to withdraw from the study, currently gathered data will still be used unless you request that they not be used. In that case, all data will be stored in a separate location for 5 years after study closure, per Florida law.

**What happens to the information collected for the research?**

Efforts will be made to limit the use and disclosure of your child’s personal information to people who have a need to review this information. We cannot promise complete secrecy. Organizations that may inspect and copy your information include the IRB and other representatives of this organization.
Signature Block for Parent of Child

Your signature documents your permission for the named child to take part in this research.

____________________________________________________________________________
Printed name of child

____________________________________________________________________________
Signature of parent or individual legally authorized to consent to the child’s general medical care

____________________________________________________________________________
Printed name of parent or individual legally authorized to consent to the child’s general medical care

Date

☐ Parent
☐ Individual legally authorized to consent to the child’s general medical care (See note below)

Note: Investigators are to ensure that individuals who are not parents can demonstrate their legal authority to consent to the child’s general medical care. Contact legal counsel if any questions arise.
APPENDIX E: RESEARCH FLYER
Research Participants needed to play educational video games.

A local research study needs middle school girls (grades 6 – 8) to participate in a study on educational video games.

Educational Video Games and their Influence on the Engagement of Middle School Girls.

The purpose of this study is to examine the design of an educational digital game called Legends of Learning, which is used to teach science content. This study will examine how this game affects how middle school girls engage with the science content.

Volunteers will be expected to take the Attitudes Towards School Science Assessment, engage with three educational video games on physical science related topics, and participate in a post-interview to discuss their experience.

Location
- The study will take place in-person at either the UCF John C. Hitt Library located at 12701 Pegasus Drive, Building 2 Orlando, FL 32816, or at another library located closer to where you live.
- Each participant is expected to participate in the study for around 1 hour and 30 minutes.

Are you eligible?
- Current Middle Schooler (8th – 8th grade)
- Female

If you’re unsure if you meet the requirements, call or email a member of the study team:
Stephen Petit
Primary Investigator
St255225@ucf.edu
305-338-5452

University of Central Florida
4000 Central Florida Blvd, Orlando, FL 32816
Hi my name is Mr. Petit. If you have any questions about what I am telling you, you can ask me at any time.

I want to tell you about a research study I am doing. I want to find out more about how the design of educational video games influence your attitude and engagement with them. I am asking you to participate because you are a girl in 6th – 8th grade. If it is okay with you, I will ask you to play a series of educational video games that teach different science lessons. I would like you to talk out loud about what you are thinking as you play the game and your thoughts when making a decision. After you have played two or three games, I may ask you some questions about what happened.

Some of the tasks in the game may be hard to do. If you reach a point that the game that is too hard to complete, let me know and you can move on to the next. If you want to stop at any time, just tell me and we will stop.

You do not have to be in this research study. It is up to you. You can say yes now and still change your mind later. All you have to do is tell me. No one will be mad at you if you change your mind.

Your parents say it is okay for you to be in this study. If you have questions for me or for your parents you can ask them now or later.

Do you have any questions? Are you willing to participate?
Field Notes

During observation of the participant, information about different events will be noted during their gameplay. Examples of noteworthy events include expressions of joy or frustration at game design element or the game play itself, decisions they make during game play (when they are given a choice) periods of extended silence, or comments such as wanting to quit or whether they are enjoying the game or are dissatisfied with it. These events will help give insight about how different game elements are impacting the participants engagement and learning of the material as well as providing for possible discussion questions after game play is complete.

Interview guide

<table>
<thead>
<tr>
<th>Data</th>
<th>Question</th>
<th>Prompts &amp; elicitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial thoughts</td>
<td>Please tell me what you think about the games.</td>
<td>Pointing out different expressions they may have given or different comments they made while playing.</td>
</tr>
<tr>
<td></td>
<td>What did you like most about them?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>What did you like the least?</td>
<td></td>
</tr>
<tr>
<td>Explaining different choices they made during game play</td>
<td>Can you explain why you decided to........?</td>
<td></td>
</tr>
<tr>
<td>Describing their thoughts on the different features of the games</td>
<td>What was the easiest feature to figure out while playing the games?</td>
<td>-Asking about specific game mechanics or changes in gameplay (mini games)</td>
</tr>
<tr>
<td></td>
<td>Were there any features of the games that were difficult to understand?</td>
<td>-Specific features (ex. Reading vs being read to)</td>
</tr>
<tr>
<td>Describing how gameplay influenced their interest in the science topic</td>
<td>How did playing this game influence your interest in (topic) if at all?</td>
<td></td>
</tr>
<tr>
<td>Describing their experiences in science classes.</td>
<td>What has been your overall experience in science class like?</td>
<td>Looking for more information on influences from teachers, peers, and family.</td>
</tr>
</tbody>
</table>
LIST OF REFERENCES


https://doi.org/10.1080/09500690701344966


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Hunt, P. K., Dong, M., & Miller, C. M. (2021). A multi-year science research or engineering experience in high school gives women confidence to continue in the STEM pipeline or seek advancement in other fields: A 20-year longitudinal study. *PLos One, 16*(11), 1-20. https://doi.org/10.1371/journal.pone.0258717


https://doi.org/10.1007/s11165-017-9670-y


https://doi.org/10.1145/3432727