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Examining Attitudinal Shifts Regarding STEM Education in Primary School Students With the Addition of Game Based Assignments

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EXAMINING ATTITUDINAL SHIFTS REGARDING STEM EDUCATION IN PRIMARY SCHOOL STUDENTS WITH THE ADDITION OF GAME BASED ASSIGNMENTS

A Master's Thesis

Presented to

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In Partial Fulfillment

Of the Requirements for the Degree

Master of Natural and Applied Sciences, Physics

By

Hayden R Stricklin

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Department of Physics, Astronomy, and Material Sciences

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Master of Natural and Applied Sciences

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ABSTRACT

There are an estimated 3 to 4 million open job positions in STEM fields (Ball, Huang, Cotten, & Rikard, 2018; Chen, 2013), lacking qualified individuals to fill them. Graduation rates for undergraduate degrees in STEM fields average just over 430,000 degrees per academic year (National Center for Education Statistics, 2023), leaving an approximate 2.5 million positions unfilled. This lack of workers and qualified individuals is a concern for the scientific community because a lack of degrees obtained results in a lack of scientists in the field and therefore less opportunity for advancement. To address this issue, the researcher proposes a form of early intervention through attitudinal intervention to impact students while still undergoing significant cognitive development. This study introduces a game-based, coding STEM intervention for fourth and fifth grade students wherein the students will code accurate simulations of magnetic and electromagnetic properties. The experimental group will receive an additional assignment where they will design a video game as a class, centering on the physics principle of electromagnetism, to assess resulting attitudinal changes and implications of this additional assignment. The researcher observed a significant shift in attitude of the experimental group, while the control group had only minor changes. This data demonstrates to the researcher that this is a viable form of intervention to increase student attitude towards STEM and STEM education.

KEYWORDS: cognitive reappraisal, computational thinking, constructivism, discovery-based learning, intervention, self-efficacy, STEM

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OVERVIEW OF THE STUDY

The aim of this study is to propose and test a creative solution to a fundamental problem facing STEM enrollment and graduation rates. Students often perceive science, technology, engineering, and mathematics, or STEM, as one of the most difficult fields of study (Bogusevschi, Bratu, Ghergulescu, C. Muntean, & G.M. Muntean, 2018; Saez-Lopez, Roman-Gonzalez, & Vazquez-Cano, 2016). This perceived barrier may dissuade students from even trying (Bogusevschi, Bratu, Ghergulescu, C. Muntean, & G.M. Muntean, 2018), leading to a lack of STEM students receiving degrees, entering the workforce, and contributing to advancing the field.

To address this issue, the researcher conducted a study with a target audience of students in the fourth and fifth grades. The researcher taught the students a few basic principles of magnetism and electromagnetism, while also teaching the basics of coding and computer science. The participants used a student-centered coding software called Scratch™ to create realistic simulations of pertinent physics principles. The experimental group received an additional coding assignment wherein they created a short video game, utilizing the principles of electromagnetism, utilizing the coding skills built throughout the intervention.

The goal of this additional, game-based coding assignment was to introduce an engaging activity to foster student interest and engagement, increase STEM self-efficacy, and motivate these students to continue within the STEM field through an early academic intervention.

A research proposal was presented to and approved by the Institutional Review Board (IRB-FY2022-354, date 12-03-21) at Missouri State University. See Appendix A for a copy of the IRB approval letter. Data was collected and analyzed in the form of surveys using multiple choice and Likert scale questions. The students were evaluated on content knowledge and perceived attitudes, with attitude being the primary focus. Analysis was done to quantify shifts in student attitude towards and interest in STEM as a result of the intervention by comparing initial attitude to post intervention attitude.

Statement of Problem and Rational

There are an estimated 3 to 4 million positions in the STEM workforce that need to be filled with qualified individuals (Ball, Huang, Cotten, & Rikard, 2018; Chen, 2013). The number of undergraduate degrees in STEM obtained in the United States during the 2020-2021 academic year was about 437,000, with an additional 146,000 master's degrees (National Center for Education Statistics, 2023). This disparity between graduation rates and open positions poses an issue because a lack of degrees obtained leads to a lack of educated and skilled workers, potentially resulting in a lack of progress.

There are numerous factors to investigate and address this problem while working on an individual level, with influences ranging from economic standing to personal academic development (Albrecht & Karabenick, 2017). A potential underlying issue may be academic interest. The researcher conducted this study with the intention of creating students with a personal interest in both STEM and academics. The reason for implementing a program at such an early stage in the students' academic career is to utilize the proven effectiveness of early intervention. The students are at an age where they are undergoing cognitive development and building executive function (Benzing et al., 2018), providing a promising opportunity for an intervention to aid such development. The researcher addressed this issue through the integration of a video game style coding assignment into the classroom to increase the students' interest, self-efficacy, and motivation in STEM.

A video game format was chosen because video games are a ubiquitous part of youth culture, with the generation of students currently progressing through primary school often being referred to as *digital natives*. This term was coined and published in a 2001 work (Prensky, 2001), and has since gained traction. The definition has varied, though, due to the rate at which technology advances and is utilized. The generally accepted definition, though, is that a *digital native* is someone who has grown up with long term exposure to technology and the internet, therefore being accustomed to and adept in the digital world (Anderson & Barnett, 2010; Ball, Huang, Cotten, & Rikard, 2018; Clark & Sheridan, 2010). Others argue that this term may be an overgeneralization, as it does not take factors such as socioeconomic status and access to technology into account (Ball, Huang, Cotten, & Rikard, 2018).

Many students regularly have access to technology outside of school, as well as much of the general population. In America, playing video games is a common pastime for both youth and adults, with 75% of households report having at least one resident who regularly plays video games. 21% of all gamers in America are under the age of 18, or about 51.1 million users (Jovanovic, 2023). The proliferation of this form of technology use provides a potential connecting ground for a large population of young people, regardless of academic interest. This could then act as a bridge between personal interest and academics, attracting a new audience that otherwise may not have interest in STEM.

There are video games that cater to every interest, from puzzle and strategy games to battle royale style multi-player online games. There are a variety of educational games and simulators as well, but a commonly cited reason for avoiding these games is a lack of entertainment value (Mayo, 2009). This lack of entertainment leads to a lack of interest and engagement, essentially removing the main attraction of playing a game.

Multiple commercial games, especially those available as a mobile application, function using scientific principles that the player may not notice. For example, games such as *Angry Birds*™ and *Cut the Rope*™ use the physics of projectile motion and pendulums to solve puzzles and complete challenges (Rodrigues & Carvalho, 2013). As users advance through the levels, their skills grow, and their conceptual understanding of these forms of motion increases even if the player is unable to articulate that it is happening (Sun, Ye, & Wang, 2015).

Educational editions of some popular games exist, such as *Minecraft*™ which released an educational version in 2016. The original *Minecraft*™ game is the second most purchased game of all time, with more than 100 million copies sold as of 2017 (Karsenti & Bugmann, 2017). Other non-educational games have potential in academic contexts as well. A study was performed using commercial, off the shelf games as a supplementary tool in an introductory undergraduate physics course to illustrate concepts such as dynamics, kinematics, and motion (Mohanty & Cantu, 2011), with promising results. This study successfully saw concept reinforcement through the use of these games, indicating that this would be an effective tool.

Though games are not directly part of STEM, the T stands for technology, which both video games and modern science rely on. This opens a wide range of potential materials available to students. Part of the technology aspect that can be seen as intimidating and difficult is coding (Saez-Lopez, Roman-Gonzalez, & Vazquez-Cano, 2016). Writing programs and simulations is often viewed as technically challenging and only attainable for the academically gifted, when it is a skill that can be built. Coding relies on computational and logical thinking, which students are actively building in primary education (Strawhacker & Bers, 2018), alongside the cognitive development that is already taking place (Benzing et al., 2018).

Introducing the technical skill of coding at this age may then help cement these logical processes as well as expand their abilities to multiple domains.

Another way to address trepidation around coding and STEM could be to demonstrate that the student would have interest in the subject. Students will be more invested, leading to a more thorough conceptual and technical understanding. Integrating the existing interest in video games into the technical skills of coding has the potential to greatly reduce the perceived barrier (Ball, Huang, Cotten, & Rikard, 2018).

Purpose Statement

The purpose of this study is to examine the attitudes and attitudinal shift of primary school students when given a game centered coding intervention. The main goal is increasing student self-efficacy, increasing interest in STEM as a field, and motivating them to continue studying STEM.

Research Questions

The questions driving this research are a) does coding a playable video game improve student attitude towards science, b) does it increase student motivation and interest in science, c) does it increase student STEM self-efficacy, and d) does this method reinforce concepts being taught? These questions will be answered through analysis of data collected in the form of surveys.

Hypothesis

The researcher hypothesized that introducing a game designing coding assignment would have a positive impact on student's attitude, interest, motivation, and self-efficacy in STEM and STEM curricula.

Design

Data is taken in the form of multiple choice and Likert scale questionnaires. This is a quantitative study taking numerical data from the groups both before and after the study.

Significance of the Study

The significance of this study is that it introduces and provides a proof-of-concept for a relatively new curricular method. A positive or negative result would be significant, either supporting this curricular method, or demonstrating weaknesses in the model to be corrected, such as age of participants or conceptual content.

This intervention is an integration of science and technology, or the S and T of STEM. The study aims to increase both technical skill and conceptual understanding. Technical improvement will come as a result of increased exposure to and use of computers and programming software (Clark & Sheridan, 2010), as well as underlying logical thinking skills that develop as coding abilities improve.

Additional benefits, outside of the technical and academic, include social development. Students are given a unique opportunity to help their peers troubleshoot and solve problems, using a collaborative learning environment to achieve their goals (Aris & Orcos, 2019; Clark & Sheridan, 2010; Khalili, Sheridan, Williams, Clark, & Stegman, 2011). It also allows the educator to interact with their students in a less traditional facet, that may not be possible during traditional lecture-based lessons.

The integration of personal interest provides a new avenue through which teachers can connect to their students. This can build a more personal learning environment, where students feel more supported and can effectively learn (Simon, Aulls, Dedic, Hubbard, & Hall, 2015).

Assumptions

The researcher assumes that the participants of the study have little to no previous coding experience. It is, however, assumed that said participants have basic computer literacy skills, allowing them to access the internet and effectively use the technology. It is assumed that students will have a basic understanding or familiarity with the concepts being taught, in that they know what a magnet is. The researcher also assumes that the demographic breakdowns of the participants in each group will be the same or similar, and that all students willingly and actively participate.

Limitations

Though the researcher assumes basic content knowledge, a thorough understanding is not expected. Previous understanding is not guaranteed, as this content is additional and outside of the typical curriculum. The coding conducted in the study is using a pre-existing programming language called Scratch™, placing limitations on what can be created.

Any previous experiences, positive or negative, cannot be mitigated by researchers, and therefore any strong opinions held by students may not be affected by this intervention. There is also no standardized test for measuring attitudes of primary school students for STEM or general academic self-efficacy, so the researcher compiled existing survey questions from previously a published study on student attitude in STEM (Brown, Cocannon, Marx, Donaldson,

& Black, 2016).

The data collected is self-reported, so the researcher must assume low reliability. Students of this age are still undergoing emotional development and may not be able to articulate their true attitudes as effectively as an older group of students. The researcher has taken these factors into account and are addressed in the discission section.

This study was also limited by time and classroom availability, allowing for a five-day intervention rather than over a semester or a full unit. The number of participants was also limited due to the researcher only having access to two groups of students at that time.

Definitions

- Autonomy – perception of level of control over a situation, or in an academic setting, what is being taught (Simon, Aulls, Dedic, Hubbard, & Hall, 2015).
- Cognitive load – amount of information being processed at one time (Zeng, Zhou, Hong, Li, & Xu, 2020).
- Cognitive reappraisal – reassessing a given situation and approaching it with a modified mindset (Spann, Shute, Rahimi, & D'Mello, 2019).
- Cognitive synthesis – the combining of previously attained knowledge to create a cohesive understanding (Sun, Ye, & Wang, 2015).
- Computational thinking – logically organizing and analyzing information through algorithmic thinking to achieve a goal (International Society for Technology in Education, 2023).
- Constructivism – a process of learning through which students build upon previous knowledge through the building of their own understandings through interaction (Piaget & Inhelder, 1967).
- Discovery-based learning – a process of learning through which students actively engage with the material to build their curiosity and knowledge (Svinicki, 1998).
- Intervention – additional instruction or supplementary material or action to improve academic performance (Mar, 2023).
  Physics engine – a computer software which reflects a physical system in real time, often used for simulations and video games (Newth, 2022).
- Self-efficacy – the belief or perceived ability or self-capability of success based on previous experiences (Simon, Aulls, Dedic, Hubbard, & Hall, 2015).

- STEM – an acronym for Science, Technology, Engineering, and Mathematics.

LITERATURE REVIEW

The continued demand for skilled workers in the STEM field is an issue that needs to be addressed, and there are numerous studies aiming to do so. Researchers have attempted to mediate this issue with numerous types of interventions, yielding varying results. As with any form of intervention, not all methods will be successful.

Introduction

There are innumerable reasons why a student will take the academic path that they do, and just as many reasons as to why they avoid taking a different path. One of the most cited reasons for not pursuing a STEM degree is a perceived difficulty (Bogusevschi, Bratu, Ghergulescu, C. Muntean, & G.M. Muntean, 2018; Saez-Lopez, Roman-Gonzalez, & Vazquez-Cano, 2016). Students may believe that STEM is only for the most skilled learners and that they cannot achieve these goals. This comes from their degree of self-efficacy, or belief in one's own ability to succeed at a given task (Simon, Aulls, Dedic, Hubbard, & Hall, 2015).

There are numerous contributors to student self-efficacy, from academic interaction to social interaction. There has been a persistent lack of representation in STEM fields for minority groups, which potentially prevents some students from seeing a person like themselves succeeding in this environment (Ball, Huang, Cotten, & Rikard, 2018). Social barriers such as socioeconomic status are still prevalent in education, exacerbating these issues and contributing to these disparities, with limited access to resources. Necessary technology, such as a laptop or home computer, often cost over $700 (Keerthana, 2020), which many people may be unable to pay.

A Need for Skilled Workers. The students entering a undergraduate programs for a STEM field represent about 28% of all incoming students in the United States. Of this 28%, only 52% of them attained a STEM degree (Chen, 2013; Simon, Aulls, Dedic, Hubbard, & Hall, 2015). According to a report published in early 2023, approximately 437,000 students obtained undergraduate degrees in STEM, and 146,000 obtained master's degrees (National Center for Education Statistics, 2023).

There are an estimated 3 to 4 million open job positions in STEM fields, lacking skilled workers to fill them (Ball, Huang, Cotten, & Rikard, 2018; Chen, 2013). In this context, a skilled worker is defined as someone who holds an undergraduate degree or higher in the respective field (Ball, Huang, Cotten, & Rikard, 2018; Chen, 2013). These open positions will, in theory, be filled by recent graduates entering the workforce. Assuming the numbers outlined above remain constant for both graduation rates and number of job openings, it will take an estimated 7 graduating classes to fill the current open positions.

Addressing a Deficit. To address this deficit, ideally one would increase enrollment while decreasing the rate of dropout at a university level. Realistically, a researcher could work to address one or the other. The study conducted by the researcher aims to address this issue through the increase of enrollment via early intervention to motivate students to pursue STEM, through the integration of personal interests such as video games.

Early intervention was conducted within a classroom setting, where students were encouraged to connect their experiences with additional material to increase their understanding (Benzing et al., 2018). The researcher's intention was to motivate students to continue pursuing STEM education. Many see career preparation as the primary purpose of education, where students are trained and taught marketable skills to produce capital and contribute to the economy, while others argue that education should be focused on the individual, aiming to create a well-rounded and well-informed member of society (Albrecht & Karabenick, 2017). These proposed citizens would then be able to create more well-rounded solutions to problems, with the ability to utilize skills from multiple disciplines and contexts rather than the technical skills acquired. These well-rounded citizens would be able to contribute to any field, not only STEM. The building of these cognitive tools and logical thinking skills can be translated to other disciplines as well.

How Can this be Addressed Conceptually?

When addressing an issue in education, one must first understand what it is that makes material resonate with students. The content needs to feel relevant to the student outside of the classroom, so the student can place more importance on the topic than just understanding for a test. Developing a sense of relevance will allow students to create meaningful connections between an academic setting and their everyday lives (Albrecht & Karabenick, 2017).

Relevance is not universal, and the student's needs must be kept in mind when evaluating what material to use (Albrecht & Karabenick, 2017). An art student would not need to understand calculus for their daily or professional lives, just as an accounting student would not need to know the works of famous artists to successfully do their job.

The generation currently progressing through the primary school system are what many would call *digital natives* (Prensky, 2001). This term was coined over twenty years ago and is still commonly used, though with updated definitions. A digital native is someone who has spent most of their life with access to and interaction with technology and the internet. Other characteristics often shown by these digital natives are a high level of visual literacy, a tendency to seek multiple resources for information and verification, and a high use of inductive reasoning (Anderson & Barnett, 2010).

One of the most popular digital content formats that American's use is video games. 75% of households in America have at least one resident who regularly plays video games. 21% of all gamers are under the age of 18, representing approximately 51.1 million users. The next age group, 18 to 34, represents approximately 81.4 million users (Jovanovic, 2023), indicating that this format appeals to a wide range of users, primary school students included. Some have referred to this proliferation of video games and their usage as becoming a cultural industry (Karsenti & Bugmann, 2017).

Many have raised the counterpoint that labeling this generation as digital natives is an overgeneralization and does not account for socioeconomic factors that may bar some students from this set of skills. There is a prevalent economic barrier that may be insurmountable to some when it comes to acquiring technology. The cost for a personal computer can range from $600 - $750 for the laptops often used in classrooms (Keerthana, 2020), to upwards of $1,200 for professional laptops (Keerthana, 2020). This cost does not include other expenses such as an internet subscription, protective items such as a case, or for any repairs that may need to be done throughout the lifespan of the technology.

The resulting consequence of lack of access to technology can have both academic and emotional impacts. When a student is faced with a situation in which their peers have seemingly more experience and proficiency, it can cause elevated emotional states such as frustration or embarrassment, hindering the cognitive process (Ball, Huang, Cotten, & Rikard, 2018). Continued, prolonged elevated emotional states, especially negative emotional states, can lead to poor academic performance (Spann, Shute, Rahimi, & D'Mello, 2019).

In Springfield, Missouri, 89% of all households report having a computer, and 75.6% of households having an internet subscription (United States Census Bureau, 2022). This indicates to the researcher that the rate of technology use in the area is comparable to a national average (United States Census Bureau, 2022), and therefore can be used as a generalizable representation of the population.

Within the generalized population, technology in the form of video games report a significant rate of user interaction. Popular games such as *Minecraft*™ and *World of Warcraft*™ have each reported over 100 million users. *Minecraft*™ is currently the second most sold game in history, with over 100 million copies sold (Karsenti & Bugmann, 2017). *World of Warcraft*™ reached 10 million users more than a decade ago in 2009 (Mayo, 2009) and over 120 million users today (MMO Populations, 2022), demonstrating that the cultural impact of video games is not a new phenomenon, and that video games themselves can hold the interest of the players for extended periods of time.

The makers of *Minecraft*™ published an educational edition of the game in 2016 with the intention of classroom integration. This version utilizes the open-world nature of the game while restricting outside interaction such as public-online play (Karsenti & Bugmann, 2017). This created a unique scenario where students interact with a virtual world that they may already be familiar with, while then applying content knowledge that they are currently obtaining to create a more cohesive understanding.

Educational video games, not just educational editions of commercial games, are also widely available to students and educators. However, educational games tend to have a mixed reception by students. Many cite an aversion to them due to their poor user interface, the repetitive content, or the lack of entertainment value (Mayo, 2009). If these games do not have the ability to hold the student's attention and interest, they will be ineffective as a learning tool (Karsenti & Bugmann, 2017).

Another issue often facing educational games is that they are the result of projects or initiatives that are funded by grants. These games can be the result of a study, where the game is a tool being used by the researchers, or as a result. Even if the game in question is incredibly high quality and has a positive reception, it may not be a sustainable tool. Grants do not pay for promotion or distribution, so any resultant games would potentially live and die by that study (Mayo, 2009).

Why Video Games?

Video games of all varieties are readily accessible to consumers. Video games range in content from cooking to puzzles to first-person combat games. As mentioned above, educational games are an option, but often do not have the accessibility and marketability that a commercial game has (Karsenti & Bugmann, 2017; Mayo, 2009). Commercial games can have educational applications with less traditional content. For example, the game *The Sims*™ is a 3D representation of a virtual world, wherein the player builds and designs a house. Instructors have used this software for students studying interior design and city planning (Yang, 2019), due to its high level of interactivity and customizability.

Other games, such as flight simulators, provide realistic scenarios which the student may encounter in their post-academic lives. There are industrial flight simulators that are used to train commercial and military pilots which include life sized controls and motion generators, but this is not an option for those not enrolled in that specific course. The video game format of such a simulator is accessible to any consumer who wishes to use it on a traditional computer, and it can therefore be used as an educational aid when such resources are limited.

Another popular commercial game, *Assassins Creed*™, has numerous editions with varying themes. These games are built around a historical period and event, using real historical settings and characters (Karsenti & Bugmann, 2017). This game can serve as an interactive and realistic look back into history for students studying such events (Yang, 2019). This game is so historically accurate that news sources reported that many fans, architects, and historians suggested using *Assassins Creed: Unity*™ as a guide when rebuilding the façade Notre Dame after it was damaged by a fire in 2019 (Jackson, 2019).

Video games often reflect real-world mechanics with accurate representations of physical concepts such as projectile motion. A researcher conducted a study with undergraduate, introductory level physics students, teaching them certain foundational concepts using video games. These games included *Shaun White Skateboarding*™*, Little Big Planet*™*, Uncharted 2*™*,* and *Guardians of the Light*™. These games represented kinematics, dynamics, a realistic physics engine, and an environment for collaborative exploration (Mohanty & Cantu, 2011). These games also present a unique opportunity of observing inaccurate representations of physics. For example, if a character steps off a ledge but does not immediately fall, gravity is not being accurately represented in that instant. These moments provide an opportunity for students to notice and discuss such impossibilities and explain what the correct reaction should be.

The popular mobile game *Angry Birds*™ functions using the physical concepts of projectile motion and kinematics, with elements such as speed, velocity, trajectory, and force being implemented in the gameplay (Rodrigues & Carvalho, 2013). Since its release in 2009, the game has had over 4 billion downloads, and currently reports 66.8 million active users (Smith, 2023). This does not beat *Minecraft*™ for the second most popular game, however, because it is a free-to-download mobile application rather than game that must be purchased. Multiple editions of *Angry Birds*™ have been released, such as *Angry Birds Space*™, which adds the element of circular motion and gravity (Sun, Ye, & Wang, 2015). These editions are not marketed as educational games but have been successfully integrated into primary and secondary school classrooms to demonstrate and reinforce these concepts (Rodrigues & Carvalho, 2013).

There are existing educational games which are shown to be effective, such as virtual reality simulations that demonstrate abstract processes that may be difficult to visualize (Anderson & Barnett, 2010). One such example is a simulation of the water cycle, where students were presented the content in a multimodal fashion in the form of audio, video, graphics, and closed captions, as well as interacting with the cycle itself (Bogusevschi, Bratu, Ghergulescu, C. Muntean, & G.M. Muntean, 2018). The online game *Crayon Physics*, has players draw simple machines such as levers and inclined planes to solve puzzles, giving them a change to interact with practical applications of these tools (Sun, Ye, & Wang, 2015).

Benefits of Video Games. Video games themselves have numerous benefits outside of content knowledge. A successful game must engage and interest the player, maintain motivation for the player to continue (Khalili, Sheridan, Williams, Clark, & Stegman, 2011), provide relevance in context of the goals (Sun, Ye, & Wang, 2015), and provide players a sense of autonomy (Ball, Huang, Cotten, & Rikard, 2018). These concepts are incredibly relevant in education as well to keep students invested in the content.

When a player is engaged in a video game, they develop a sense of presence (Yang, 2019). They are so deeply involved in the scenario in front of them that they feel immersed in the content. This has been shown to increase time spent with that content, which in turn can reinforce the concepts being used (Clark & Sheridan, 2010).

Video games are an existing format that has been shown to be present in many students' lives, with 21% of teens between the ages of 13 and 15 reporting that they regularly play games. 9.8% of teens report using video games 20 or more hours per week (Jovanovic, 2023). This prolonged usage reinforces the idea that a game will in fact hold attention and maintain engagement. The age group surveyed is above the age group that the researcher studied, but no national data could be found for users under the age of 13.

In a study conducted with the intention to serve underrepresented groups and minorities, 92% of responding students reported owning a gaming console, and many of them disclosed that they regularly play games for 3 to 6 hours a day (Ball, Huang, Cotten, & Rikard, 2018). These respondents were fourth and fifth grade students, representing the same age group that the researcher studied. This statistic reflects a higher percentage than the national averages and demonstrates a community in a specific area, which therefore may not be a perfect generalization.

Popular games have maintained long term engagement, both in the form of multiple hours spent with the game as well as longevity of the game. This shows that the game itself is what holds the players rather than the novelty of a new game being released. *World of Warcraft*™ was released 14 years ago and reached over 10 million players in the first year (Mayo, 2009). This game currently reports approximately 120 million players (MMO Populations, 2022).

Prolonged use of these games and advancement through a storyline will motivate players to persist and work to solve the challenges that they face (Simon, Aulls, Dedic, Hubbard, & Hall, 2015). As is the case with many skills, there is a correlation between time spent with technology and proficiency with that skill (Aris & Orcos, 2019). In a game setting, players strive to accomplish goals in creative ways and are not dissuaded by setbacks (Spann, Shute, Rahimi, & D'Mello, 2019). Games include a reward system of some kind, whether it is the accumulation of points, the collection of items, or a celebratory animation. These rewards are a tangible goal for the player and act as another source of motivation (Yang, 2019). These rewards, especially in the form of achieving medals or stars, encourage the player to repeat levels until they reach the highest reward. Repetition reinforces both mechanical and conceptual understanding of the game (Sun, Ye, & Wang, 2015).

Successful video games often elicit an emotional response. Players become invested in the story or characters in the game and have emotional reactions to their own failures or successes (Spann, Shute, Rahimi, & D'Mello, 2019). This elevation of emotions can also be seen in academic settings, when a student encounters a challenge that they feel inadequately prepared to face. Elevated emotions can disrupt cognitive processes (Spann, Shute, Rahimi, & D'Mello, 2019), further elevating emotional responses, creating a feedback loop that is difficult to break out of.

When facing this elevation of emotion in the context of a video game, often the player can remove themselves from the situation and remind themselves that "it's just a game". This regulation is a process called cognitive reappraisal (Spann, Shute, Rahimi, & D'Mello, 2019), where the person reassesses their methods and then approaches said problem with a new mindset. Self-regulation and emotional modification have been correlated with success both in gaming and in academics (Spann, Shute, Rahimi, & D'Mello, 2019).

Benefits of Games in Academics. Video games provide numerous benefits to an academic setting by reinforcing concepts (Mohanty & Cantu, 2011; Rodrigues & Carvalho, 2013), building technical skills (Aris & Orcos, 2019; Spann, Shute, Rahimi, & D'Mello, 2019;

Sun, Ye, & Wang, 2015), and allowing students to learn through various methods. Simulated reality provides a safe space for students to experiment without repercussion. For example, a medical student can use a surgical simulator and not have to worry about losing a real patient (Yang, 2019). It also provides context to a player. These medical simulators often include audio files to mimic the real sounds of machinery that would be present in an operating room. Other such simulators, like a sports or leisure activity, create an immersive environment where the player can place themselves in the situation (Zeng, Zhou, Hong, Li, & Xu, 2020). This safe space for trial-and-error creates a situation in which participants can practice and fail in order to learn (Clark & Sheridan, 2010; Spann, Shute, Rahimi, & D'Mello, 2019; Sun, Ye, & Wang, 2015).

The worlds created within video games and the subsequent learning comes as a result of a constructivist approach. Constructivism is a theory first put forth by Piaget, suggesting that knowledge cannot simply be given to a student, but the student must build their own personal understanding (Piaget & Inhelder, 1967). Knowledge is built and gained through interaction with material rather than from simply hearing the information.

Piaget also stated that knowledge must be based on the student's current needs. There needs to be contextual relevance for what is being learned, otherwise there is not a concept upon which to build (Piaget & Inhelder, 1967). This is reflected in video games, where the player must have a foundational understanding before they can try to achieve their goal. The player must complete a tutorial or progress through a series of simple challenges to learn the mechanics of the game before advancing (Sun, Ye, & Wang, 2015).

Discovery based learning is another method often seen in academic settings and is utilized in video games as well. Discovery based learning includes an element of exploration and experimentation on the part of the student, where they then incorporate new discoveries into their existing knowledge (Svinicki, 1998). This builds on constructivism in the sense that the acquisition of knowledge is created by the learner rather than through instruction alone (Piaget & Inhelder, 1967; Svinicki, 1998).

Part of discovery-based learning and constructivism is active engagement. Active engagement is as important in a classroom as it is in a video game, as is interactivity. Video games have the unique ability to provide immediate feedback to the player as they progress (Aris & Orcos, 2019). If they do something incorrectly, it will let them know or require them to correct the mistake before advancing. There are often hint features where the player can access additional help if needed (Clark & Sheridan, 2010). In a traditional lecture style class, the ability to ask questions is significantly lower, averaging 0.11 question asked per hour (Mayo, 2009).

This level of student engagement in traditional settings is lower than desired, and there are educational initiatives taken by some major companies with the intention of increasing student engagement and interactivity. One such example is LEGO Mindstorm™ and the LEGO™ FIRST League. FIRST is an acronym standing for “Fostering Interest in Robotics, Science, and Technology” (Aris & Orcos, 2019). This program is implemented in schools, asking students to design, assemble, program, and compete with a robot based on that year’s nationwide challenge (Aris & Orcos, 2019). This competition sees students from across the country being united by a mutual interest in STEM as well as personal interest in commercial products such as LEGO™.

Commercial products, such as video games, contain other interactive features that would be difficult to replicate in an educational setting. Commercial games utilize what is referred to as a physics engine, which simulates reactions in a way that mimics real world interactions (Newth, 2022). This interactivity gives the student the ability to observe as well as test their own hypotheses to confirm or correct their conceptual understanding in real time (Mohanty & Cantu, 2011).

Computers, games, and other technology all require a specific skill set to efficiently utilize them as tools (Ball, Huang, Cotten, & Rikard, 2018). This is true in an academic setting as well. These technical and computer skills are transferable to other forms of technology. It has been shown that those with confidence in their ability to play video games have a higher level of confidence when using computers (Ball, Huang, Cotten, & Rikard, 2018). When students approach technology with confidence, there is a corresponding translation of that confidence into their content knowledge (Ball, Huang, Cotten, & Rikard, 2018; Saez-Lopez, Roman-Gonzalez, & Vazquez-Cano, 2016). The frequent interaction with video games creates a domain specific skill of efficiently interacting with technology (Ball, Huang, Cotten, & Rikard, 2018; Clark & Sheridan, 2010; Saez-Lopez, Roman-Gonzalez, & Vazquez-Cano, 2016).

Games also encourage critical and logical thinking. Critical thinking is essential to academics and leads to a deeper understanding of the content matter as well as the students' ability to use that information (Khalili, Sheridan, Williams, Clark, & Stegman, 2011). In a video game, this can be seen in multiple ways. Many games have limited resources, forcing the player to ration supplies and think critically about when that resource is most needed (Ball, Huang, Cotten, & Rikard, 2018).

Players must examine the world around them to come up with creative solutions while remaining within the logical and physical bounds of the game (Zeng, Zhou, Hong, Li, & Xu, 2020). Players also have a great deal of autonomy in the decisions they make and the actions they perform (Ball, Huang, Cotten, & Rikard, 2018; Simon, Aulls, Dedic, Hubbard, & Hall, 2015; Sun, Ye, & Wang, 2015), while remaining within the bounds of the game. For example, a realistic farming simulator would not let you drive a tractor on top of a house. This critical and logical thinking can be seen translated into a classroom setting when students must analyze the information to then come to a logical conclusion (Saez-Lopez, Roman-Gonzalez, & Vazquez-Cano, 2016).

In initiatives such as LEGO FIRST, the students are responsible for designing, coding, debugging, and presenting a functional robot that completes an assigned task (Aris & Orcos, 2019). Critical thinking comes into play for all steps of this process, by creating the most efficient design, thinking computationally to write code, critical thinking when debugging the code to fix mistakes, and logical thinking when creating a presentation to display the final work (Aris & Orcos, 2019).

The building of the robots involved with LEGO™ FIRST begins with a brainstorming activity, where students lay the foundation for what they want to build. This bottom-up thinking (Spann, Shute, Rahimi, & D'Mello, 2019) is also seen in video games, which typically begin with a tutorial level, that introduces players to the controls, rules, and objective of the game. The players then build upon this knowledge, with new skills gained as the levels progress (Zeng, Zhou, Hong, Li, & Xu, 2020). This building of and combination of skills is an example of cognitive synthesis (Sun, Ye, & Wang, 2015). The same format is used in educational settings, when the student must learn the basic principles before they can delve into more complex details.

Building these foundational skills created by the player, or student, sets up an opportunity for success. Successes in both academic and game settings create a boost of confidence for the participant, leading to a higher level of self-efficacy (Karsenti & Bugmann, 2017). These increases in self-efficacy are correlated with an increase in achievement (Simon, Aulls, Dedic, Hubbard, & Hall, 2015). Self-efficacy can be increased through various processes, such as vicarious and enactive experience or social and emotional influences.

When a student displays high self-efficacy, there is a correlation with a higher rate of engagement, effort, and persistence. Increasing the amount of time spent engaging with content will increase the content understanding and the learner's confidence in their understanding. This increase in self-efficacy can then be tied back to an increase in achievement in the classroom (Ball, Huang, Cotten, & Rikard, 2018).

Applicability to Intervention

Technical and computational skills have become intertwined with education, with the initial integration beginning more than two decades ago (Prensky, 2001). Despite being part of modern culture, not all students can innately utilize technology (Ball, Huang, Cotten, & Rikard, 2018) and may see this as a barrier to entering STEM and other technical fields.

The demand for technically skilled workers to enter the workforce is already existent and will likely continue to grow (Ball, Huang, Cotten, & Rikard, 2018; Chen, 2013). Educators have adapted curriculum to include some of these skills, such as coding, in many schools (Saez-Lopez, Roman-Gonzalez, & Vazquez-Cano, 2016). That does not, however, mean that all students are able to acquire these skills effectively and efficiently. Just as in any other academic subject, students of varying skills can be assisted with an academic intervention (Mar, 2023).

The intention behind such an intervention is to increase the necessary skills to equip the learner with tools that they can use again in the future when faced with such a situation (Mar, 2023). Interventions are intended to aid this process by introducing a new perspective to the problem. Introducing an intervention that is received as a fun activity is shown to be an effective way to impart enthusiasm as well as teaching skills (Saez-Lopez, Roman-Gonzalez, & Vazquez-Cano, 2016).

Early intervention has been shown to be very effective (Benzing et al., 2018; Saez-Lopez, Roman-Gonzalez, & Vazquez-Cano, 2016), though typically, the classification of "early" is with subjects aged between 5 and 8 years old. Studies have been conducted with older subjects, aged 10 to 12, and yielded results which suggested that this age group is still receptive to early intervention (Benzing et al., 2018), indicating to the researcher that an intervention with fourth and fifth grades students will still be impactful.

Previous Studies. When approaching a topic within STEM, or any topic that is perceived as difficult by the students, it can be valuable to look for a solution from a creative perspective. Previous studies and programs have shown promising results when investigating the viability of using games as an intervention (Anderson & Barnett, 2010; Clark & Sheridan, 2010; Karsenti & Bugmann, 2017; Khalili, Sheridan, Williams, Clark, & Stegman, 2011; Mohanty & Cantu, 2011; Sun, Ye, & Wang, 2015).

An introductory level physics course was taught with the aid of commercial, off-the-shelf video games to test the validity of using such a tool. Games such as *Shaun White Skateboarding*™ were used to demonstrate physical concepts, such as kinematics, by the students being able to observe motion using the virtual character and their interaction with the environment (Mohanty & Cantu, 2011). Other games, such as *Uncharted 2*™*,* were used because of their realistic physics engines, meaning that the reactions in the game mimic real world consequences. For example, if a bottle is hit from different angles it will result in different rotation patterns, or how far an item will travel depending on the angle it is thrown from (Mohanty & Cantu, 2011). The conclusion put forth by the researchers was that the use of commercial video games did have a positive effect on conceptual understanding.

Games such as *Angry Birds™* are strategy-based games where the player has a limited amount of tries to complete the level. The success of the player depends on utilizing the concepts of trajectory and speed (Sun, Ye, & Wang, 2015). Another popular mobile game, *Cut the Rope™*, functions using pendulums. The player completes the level by delivering a piece of candy to the stationary character by cutting a series of ropes to swing the candy to a new position. The player must act quickly, though, because gravity is a factor in this game and, as in the real world, the pendular motion slows down with every swing (Sun, Ye, & Wang, 2015).

These commercial games demonstrate physical principles and have succeeded in being valued as entertaining and engaging (Karsenti & Bugmann, 2017). This method provides an opportunity to integrate computational thinking and computational skills while utilizing the benefits of playing a game. Other studies have examined the use of tailor-made, or participant made, games and their impact.

A game called *Supercharged!* was designed and implemented in an introductory physics course to act as an aid for the concept of electromagnetism (Anderson & Barnett, 2010). This concept does not have an interactable counterpart in real life where students can physically see what is happening. The level of abstraction can be a barrier to students who have poor visualization skills, but the integration of a game style representation can help clarify the concept.

Supercharged! is a first-person game where the player acts as an electron navigating a maze, being propelled by attraction and repulsion of other charges (Anderson & Barnett, 2010). students have the opportunity to visualize this concept, as well as place themselves in the situation, creating an opportunity for discovery-based learning, as well as constructing a more thorough understanding.

Studies Utilizing Game Creation. Other programs have succeeded using these custom games but going the other direction, having students design and build the game to match the content. A program in Washington, D.C. divided a set of students into groups, had each of these groups design a game for their peers to play while accurately demonstrating a physical concept. Through this program, researchers saw the students gain confidence and content knowledge, and observed students seeking help from peers. This collaborative learning led to students producing games that articulated the content knowledge while still being considered fun by other students (Clark & Sheridan, 2010).

Introducing a fun, game-like aspect in an otherwise difficult setting motivates students to continue looking for answers outside of the classroom (Khalili, Sheridan, Williams, Clark, & Stegman, 2011). Another study done using the concept of domain specific games had students create a game based on a concept in immunology, which none of the participants had prior knowledge of. By the end of the program, all groups of students successfully created a game that accurately depicted their given topic (Khalili, Sheridan, Williams, Clark, & Stegman, 2011). Researchers also reported that students would conduct their own research outside of class time to then use the next day, displaying a personal investment in creating an accurate and entertaining game. This resulted in engagement with and gained conceptual understanding of a previously unstudied topic (Khalili, Sheridan, Williams, Clark, & Stegman, 2011).

This leads the researcher to believe that using the creation of a video game as a curricular intervention is possible regardless of students' previous knowledge or content understanding. It also suggests that these gains of technological skill are not bound by topic and widely usable.

METHODOLOGY

The purpose of the researcher's study is observing attitudinal shift in primary school students with the addition of a game-based coding assignment. Presented in this chapter will be a) research design, b) site of study, c) participants, d) data collection procedures and instrumentation, and e) data analysis methods.

Research Design

The researcher performed an intervention with students transitioning from their fourth to fifth grade years, with an average age of 10. This age group has been previously studied and it has been determined that early intervention is still effective (Benzing et al., 2018). The control and experimental group were both taught a few basic principles of magnetism and electromagnetism, and then coded realistic simulations of these concepts using the programming language Scratch™.

Scratch™ is a block-style, online programming language launched by MIT, intended for young students to introduce coding in a less complex manner. Rather than having the user type out and physically write code, the basic commands are provided as colorful, categorized blocks that fit together. See Figure 1 for an example of Scratch™ coding blocks. This prevents several common coding issues with new users, such as typos, syntax errors, and combining commands that are not compatible (Saez-Lopez, Roman-Gonzalez, & Vazquez-Cano, 2016). The block formatting also prevents users from coupling these incompatible commands and uses shapes in addition to color to indicate where these blocks can be placed. The researcher selected this software both for the introductory level compatibility, and the proven effectiveness of Scratch™

in classroom settings (Saez-Lopez, Roman-Gonzalez, & Vazquez-Cano, 2016).

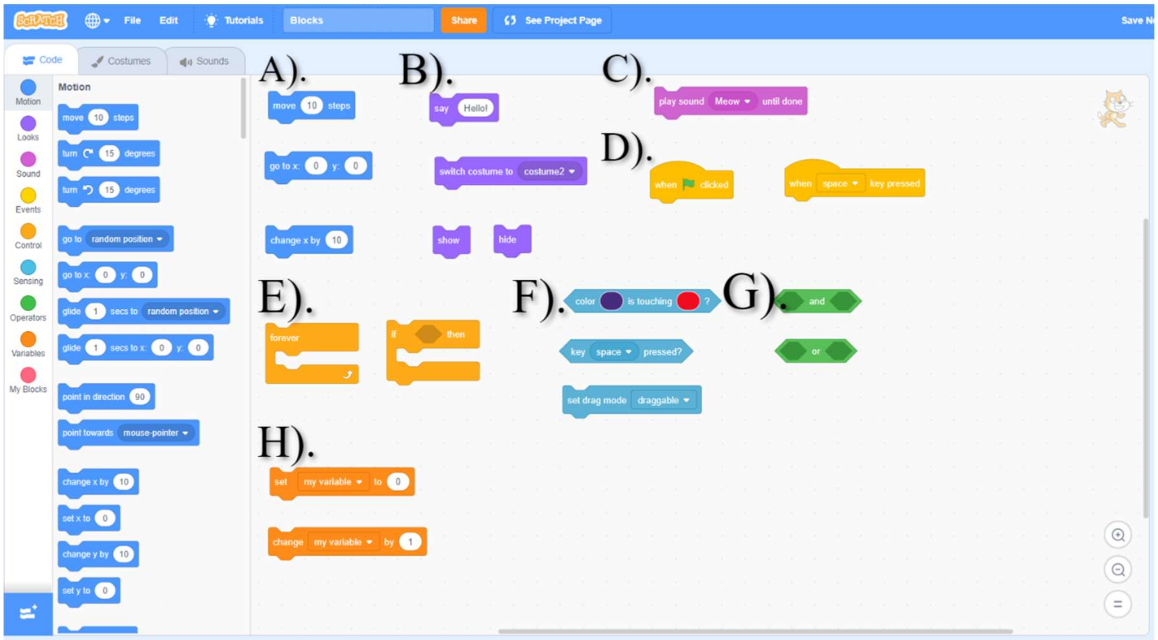

Figure 1: Demonstration of block coding elements used in Scratch™.

In Figure 1, The letters correspond with the following categories, A). Motion, B). Looks, C). Sound, D). Events, E). Control, F). Sensing, G). Operators, and H). Variables. The final category, My Blocks, was not included because it was not relevant to the study.

A research proposal was presented to and approved by the Institutional Review Board, prior to the start of the study, (IRB-FY2022-354, date 12-03-21) at Missouri State University. See Appendix A for a copy of the IRB approval letter. Data for the researcher’s study was collected in the form of a pre and post survey, observing how attitude surrounding STEM may have shifted throughout the intervention. This study was a descriptive design, using structured questions asked in the form of multiple choice and Likert scale questions. This was a longitudinal trend survey, following the same group of subjects from beginning to end (Mills & Gay, 2019).

Implementation. This study was done over the course of five, one hour class periods for each class, or over one school week. See Table 1 for the full intervention schedule. The experimental and control groups received the content over the same period of time, but each group moved at a different pace. It was necessary for the researcher to accelerate the pace of content for the experimental group to allow time for the game based intervention.

Table 1: Intervention Schedule for the Control and Experimental Groups

Intervention Day	Control Group	Experimental Group
Day 1	1. Complete Attitudinal and Content Pre-Survey	1. Complete Attitudinal and Content Pre-Survey
	2. Create student Scratch™ accounts	2. Create student Scratch™ accounts
	3. Introduce upcoming content through class discussion on previous knowledge	3. Introduce upcoming content through class discussion on previous knowledge
		4. Demonstrate physical interactions of permanent magnets with each other as well as other objects. Ask students to make connections and find out where they have interacted with magnets before
Day 2	1. Demonstrate physical interactions of permanent magnets with each other as well as other objects. Ask students to make connections and find out where they have interacted with magnets before	1. Discuss interactions seen in the physical demonstrations, with concepts such as magnetic field, poles of a magnet, and attraction and repulsion.
	2. Explicitly discuss the	2. Direct students back to their

Table 1. continued

Intervention Day	Control Group	Experimental Group
Day 2 (continued)	interactions being seen; the presence of a magnetic field, poles of a magnet, and attraction and repulsion	Scratch™ accounts and guide them to the pre- completed bar magnet simulation and ask them to interact with it and discuss similarities
	3. Introduce students to the Scratch™ website by guiding them to a pre-completed simulation representing bar magnets	3. Direct the group to a prefabricated bar magnet simulation that is non-functional and discuss the coding steps that are missing
	4. Encourage students to play with the simulation, and ask them what they notice in the simulation that they saw with the physical magnets	4. Have the students (individually or as a class) work through the scaffolding to complete the code to work as a real-life simulation
	5. Allow students to look at the coding of the simulation by selecting "Remix" or "See Inside"	5. Have students open a new project by selecting "Create
		6. Challenge the students to make the character, or Sprite, move with arrow commands. This will build off a skill built in the bar magnet simulation, preparing students with the first step of coding their game.
Day 3	1. Demonstrate and discuss the mechanics of block coding through the use of the completed bar magnet program as an example	1. Introduce electromagnets by first breaking down the word (electro – magnet) and having students hypothesize a meaning. Ask students if they know any "electro" words

Table 1. continued

Intervention Day	Control Group	Experimental Group
Day 3 (continued)	2. Navigate to the program that the students viewed and manipulated on Day 2 and have students look at the coding itself.	2. Present the electromagnet WITHOUT a power source. Ask the students to predict what will happen, and if they believe it will be the same as the bar magnet they had seen before.
	3. Discuss the major coding elements, such as the If Then statement and a Forever Loop, and how they would be related to the magnets we have observed	3. Demonstrate that the electromagnet cannot function without a source of power and ask students how they may solve this problem.
	4. Direct students to the scaffolded program and ask them to fill in the commands to the best of their ability	4. Probe student knowledge, asking if they have ever encountered an electromagnet outside of school, and if so, how was it used
	5. Troubleshoot and debug with the students and encourage them to ask their classmates for help if needed	5. Provide real-world applications of electromagnets, such as a crane at a junk yard to help sort metal by type
	6. Encourage the students to play with their completed simulation and compare their program to the physical demonstration given previously	6. Direct students to pre-made games made by the researcher which function using electromagnetism. These games use the basic principle that there is only a magnetic field when there is a source of power connected
		7. Introduce the final, game aspect and goal to the group. Inform the students that they will be working together with the coding skills they have built along with their new knowledge of electromagnets

Table 1. continued

Intervention Day	Control Group	Experimental Group
Day 3 (continued)		to design a game.
		8. The only stipulation is that the game MUST be won using electromagnetism
Day 4	1. Introduce electromagnets by first breaking down the word (electro – magnet) and having students hypothesize what that could mean	1. Direct students to a scaffolded electromagnet program and ask them to look for familiar commands (such as If Then's and Forever Loops).
	2. Present the electromagnet WITHOUT a power source. Ask the students to predict what will happen, and if they believe it will be the same as	2. Ask the students to fill in the missing lines of code to the best of their ability and ask them to help their peers troubleshoot and debug programs
	3. Demonstrate that the electromagnet cannot function without a source of power and ask students how they may solve this problem.	3. Allow students to once again play with the pre-made electromagnet games and ask them to brainstorm what they would like their game to look like
	4. Probe student knowledge, asking if they have ever encountered an electromagnet outside of school, and if so, how was it used.	4. Gather the students back together and have them decide on game elements as a class.
	5. Provide real-world applications of electromagnets, such as a crane at a junk yard to help sort metal by type	5. Have students pick a theme, a main character, an objective, and a solution. The only requirement is that it MUST use an electromagnet to win. Allow them to work together

Table 1. continued

Intervention Day	Control Group	Experimental Group
Day 4 (continued)		to find a common interest within the group
	6. Direct students to a scaffolded electromagnet program and ask them to look for familiar commands (such as If Then’s and Forever Loops).	6. Work with the students’ ideas and help them scaffold their ideas into a game format.
	7. Ask the students to fill in the missing lines of code to the best of their ability and help troubleshoot and debug student programs .	7. Compile the ideas once the class has come to a decision, and the researcher will then create a scaffolded program like the ones previously used
Day 5	1. Lead a final discussion about electromagnets, asking students to tell you what they have learned	1. Present the game specific sprite pack to the students and ask them to complete it on their own without any assistance from the researcher
	2. Compare the bar magnet to the electromagnet and ask for similarities and differences between the two	2. Encourage students to seek help from peers.
	3. Distribute and collect the post attitudinal and content surveys	3. Ask students to show you their completed program and demonstrate by playing it.you their completed program and demonstrate by playing it.
		4. Distribute and collect the post attitudinal and content surveys

The pre surveys, both attitudinal and content, were distributed on the first day of intervention before any instruction had begun. Both groups then created Scratch™ student accounts, where their work was automatically saved into a studio that the researcher had access to. Once this was completed, both groups then introduced to the upcoming concepts that they would be interacting with throughout the intervention. The experimental group observed physical demonstrations about the structure of bar magnets as presented by the researcher.

The control group received physical demonstrations at the beginning of the second day and both groups were asked about the interactions they observed. The concepts involved included magnetic fields, poles, and attraction and repulsion. Both groups were then introduced to the Scratch™ website and were directed to a simulation of the bar magnet that they had just interacted with.

The experimental group then began learning to write code in Scratch™ to simulate the bar magnet that they just interacted with, with the assistance of pre-structured programs created by the researcher, called Sprite Packs. See Figure 2 and Figure 3 for examples of a Sprite Pack.

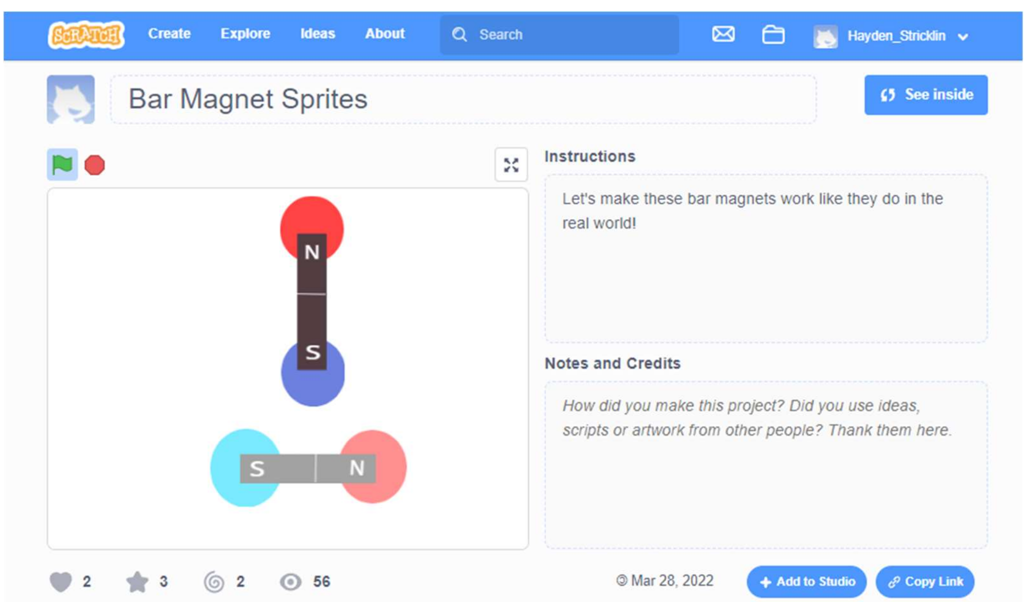

Figure 2: Exterior of a Sprite Pack.

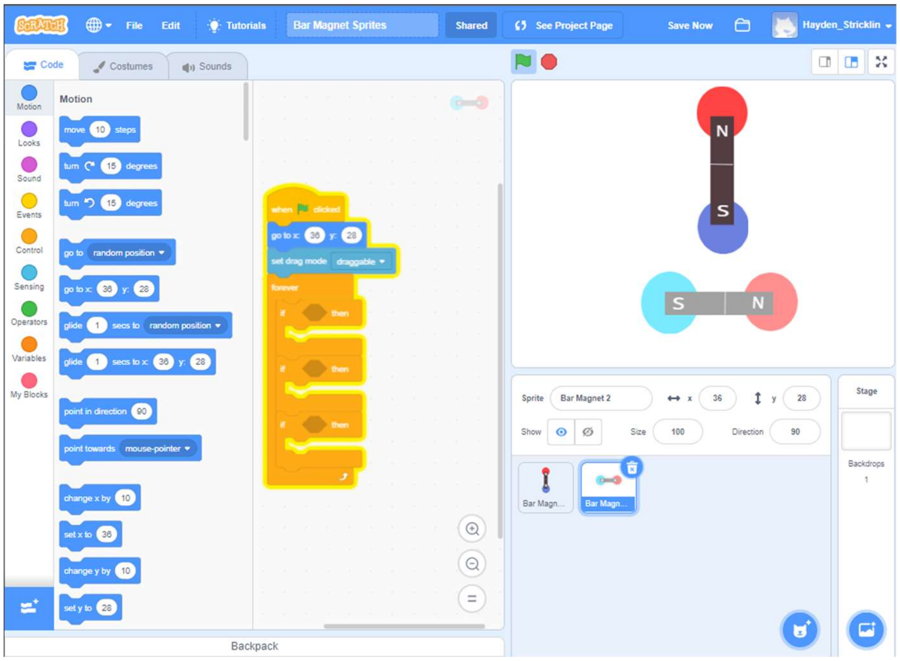

Figure 3: Interior Structure of a Sprite Pack.

These programs include conditionals such as if-then statements and forever loops. These concepts were discussed in depth by the researcher, and the students were able to articulate their meanings. An appropriate number of if-then statements were provided as a guide to allow the students to focus on the content and concepts rather than structure. The experimental group had an additional activity where they wrote a program allowing them to create a character that was controlled by the arrow keys. See Figure 4 for the interior of the Sprite Pack. This was the first game element being introduced, and students were informed that by the end of the week they would have created a game together. They were then told to start brainstorming what they wanted their class-wide game to be.

The third day had the experimental group coding the scaffolded bar magnet simulation, again discussing the conditionals such as If-Then statements and Forever Loops. The students were encouraged to work on their own to complete the program, but if they needed help, they were instructed to ask peers first. Once students completed their simulation, they were encouraged to play with it and compare their program to the bar magnet they observed.

The elements that were included in the simulation were north and south poles and their respective field interactions. If two ends with the same field are near each other they would repel, and opposite fields would attract. The experimental group was then introduced to electromagnets through a series of physical demonstrations and video demonstrations. There were class-wide discussions about the similarities and differences between the bar magnet and the electromagnet. The experimental group was also directed to existing games on Scratch™ that functioned using electromagnetism. See Figure 5 for an example of such a game. To complete the game and find the key, the player must assemble an electromagnet. The key cannot be found with just the battery or the magnet, it must be connected. See Figure 6 for an interior view of the electromagnet component of the game's code.

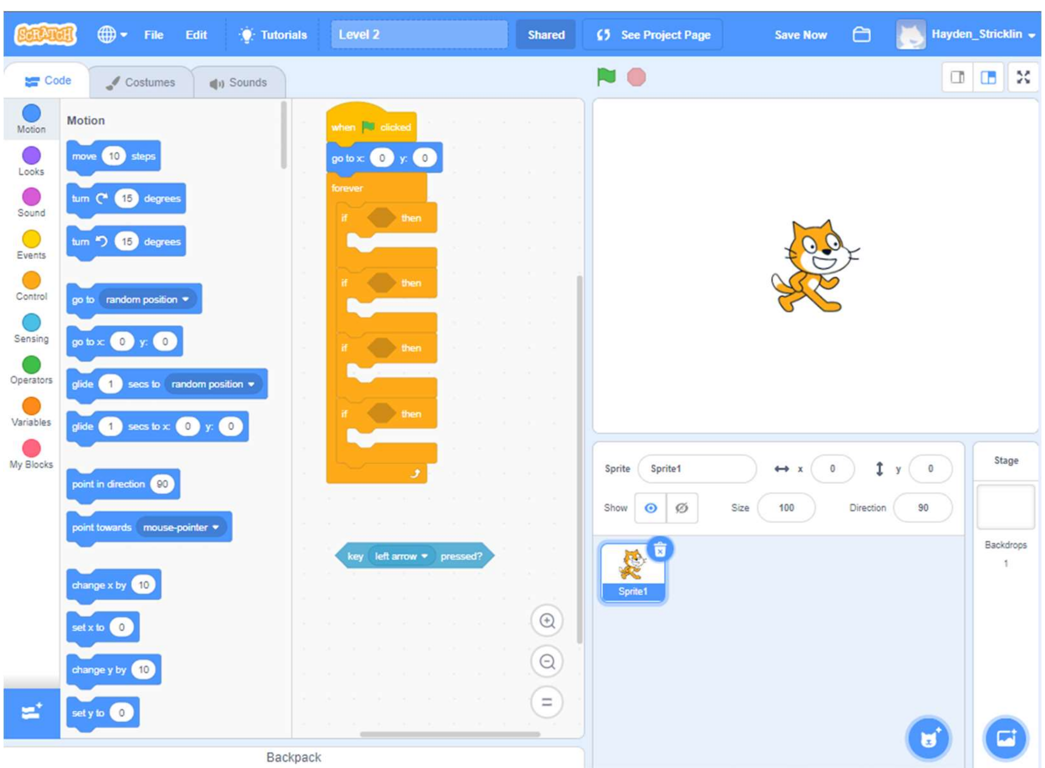

Figure 4: Structure of a Sprite Pack Used by the Experimental Group.

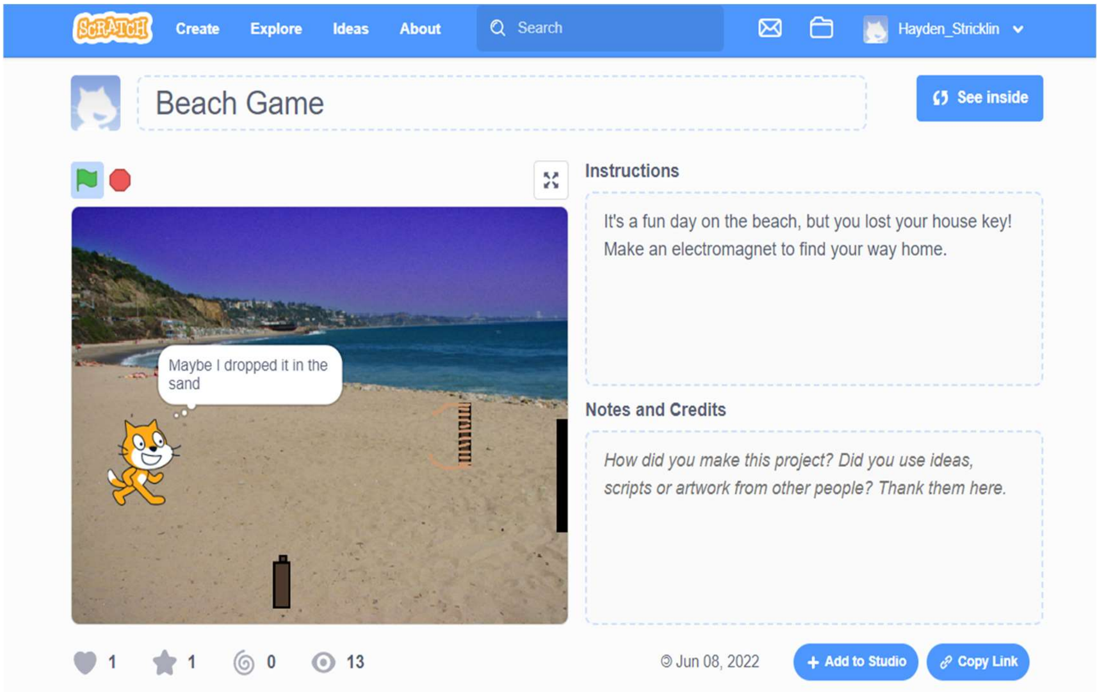

Figure 5: Example of an Electromagnet Game.

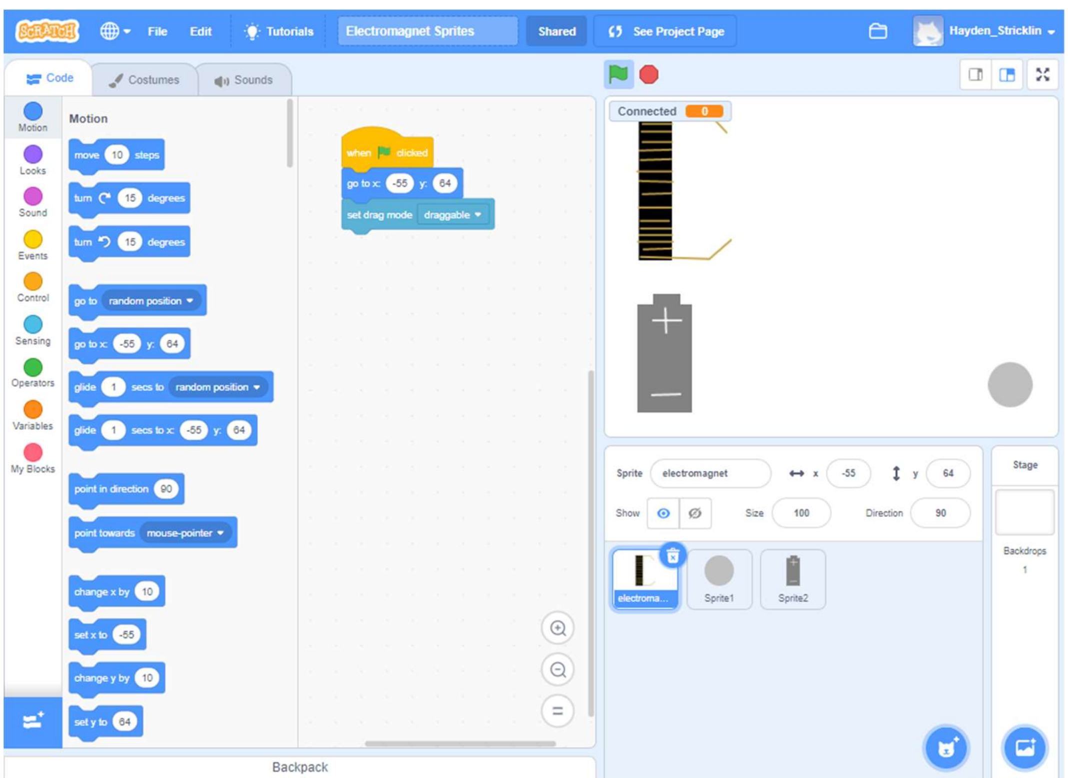

Figure 6: Electromagnet Component of the Electromagnet Sprite Pack.

See Figure 7, where the variable function is introduced. This correlated with the operator function. See Figure 8 for a demonstration of this function. Notice that the round ball, sprite 1, is set to “not draggable”. This is so that the only way to move the ball is through connecting the electromagnet. This ensures a realistic representation of the electromagnet observed in class and reinforces the concept that the electromagnets must be connected to a power source to produce a magnetic field and attract an object.

The experimental group had time dedicated to designing their game as a class. The researcher prompted the students for elements such as a character, a problem to be solved, and a potential solution. The only parameter the experimental group was given was that it must use an electromagnet to complete the game. Due to time limitations, the researcher took the elements that the class decided on and created an outlined structure to help students successfully code the game with the remaining class period.

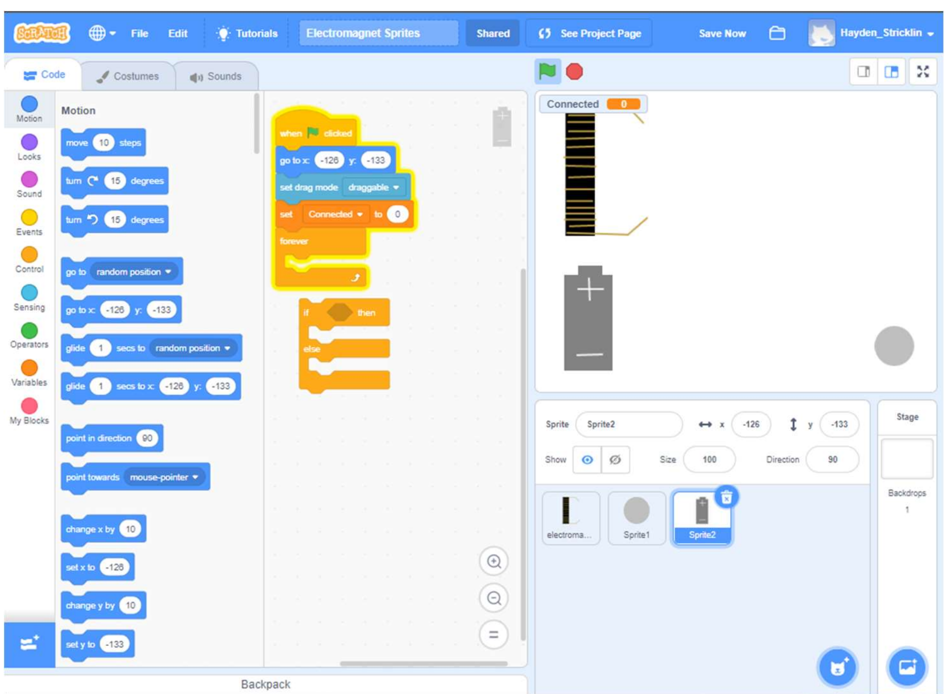

Figure 7: Battery Component of the Electromagnet Sprite Pack.

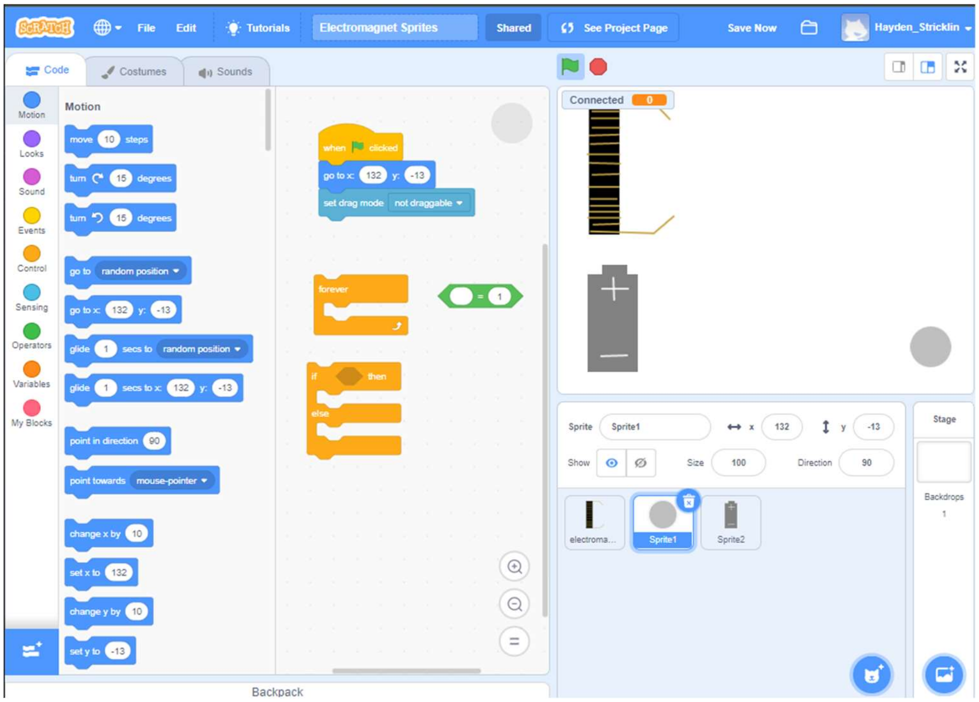

Figure 8: Steel Ball Component of the Electromagnet Sprite Pack.

Game Creation. The final day of intervention entailed the control group continuing to discuss and interact with electromagnets and electromagnetism. The experimental group worked together as a class to program the game that they pitched the previous day with the help of the researcher. Once the programming was complete, the students played and shared their games. See Figure 9 as a demonstration of the exterior of the game designed by the class, with the backgrounds, character, and Sprites already uploaded. This Sprite Pack allows the students to focus on the coding aspect of the game rather than the aesthetics.

See Figure 10 for the interior structure of the character sprite's control page. The if – then statements are structured inside a forever loop, but do not have commands included. The first if – then statement includes a sensing block to remind students of previous programs to prompt them to use previously gained knowledge. The students will rely on their experience from previous activities, with their skill and knowledge being applied in a new context.

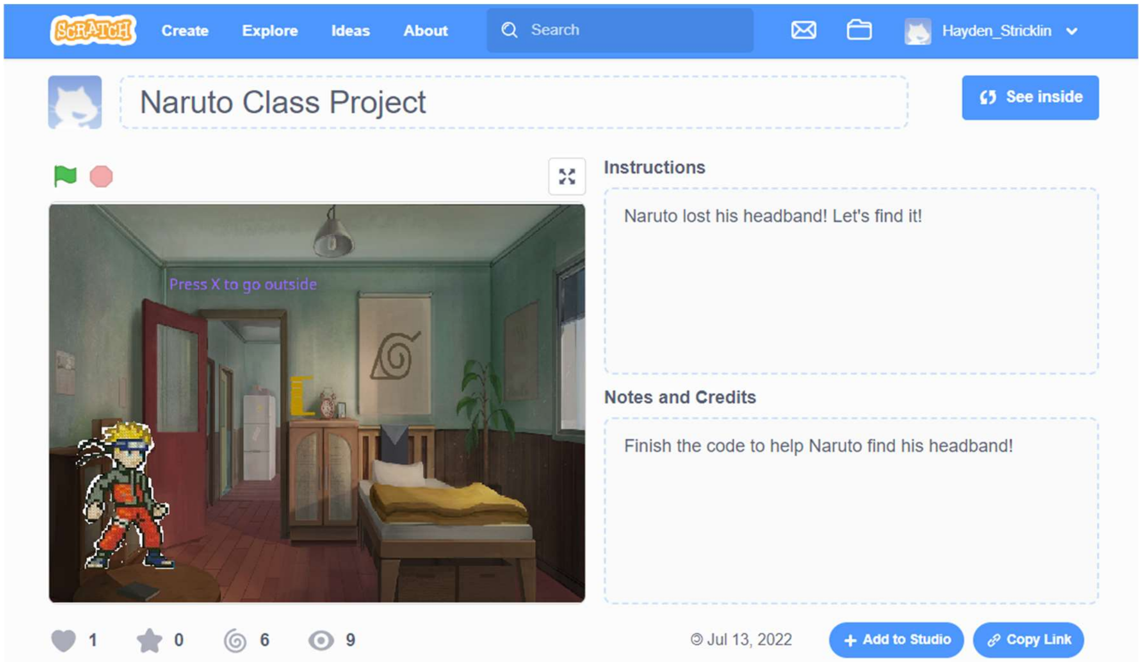

Figure 9: Exterior of the Class Project Sprite Pack.

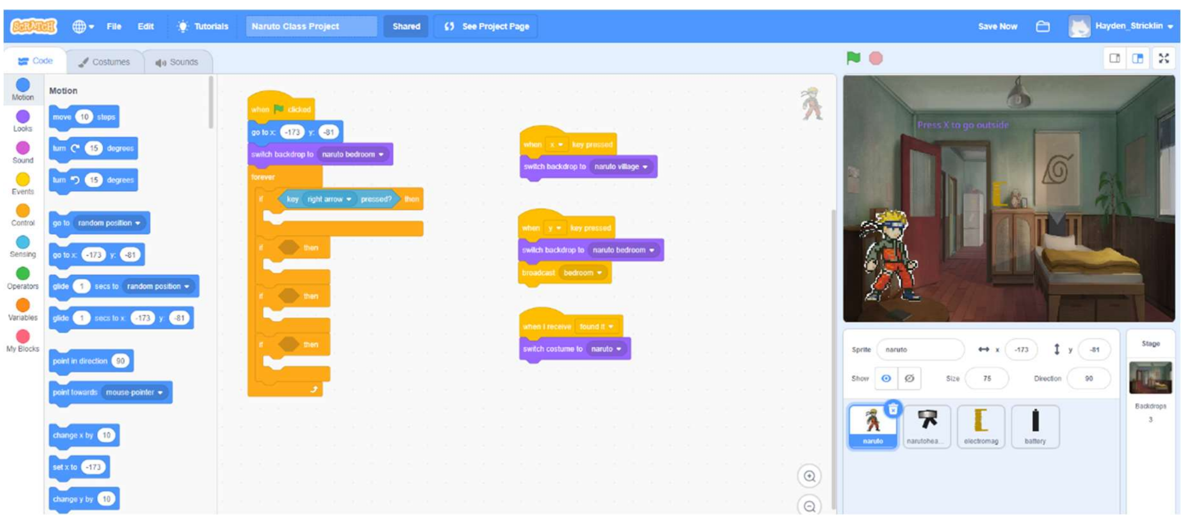

Figure 10: Character Control Page.

The internal structure of the battery sprite, See Figure 11, and the structure of the electromagnet, See Figure 12, include the initial conditions of using a variable. In the case of Figure 11, the variable is the battery.

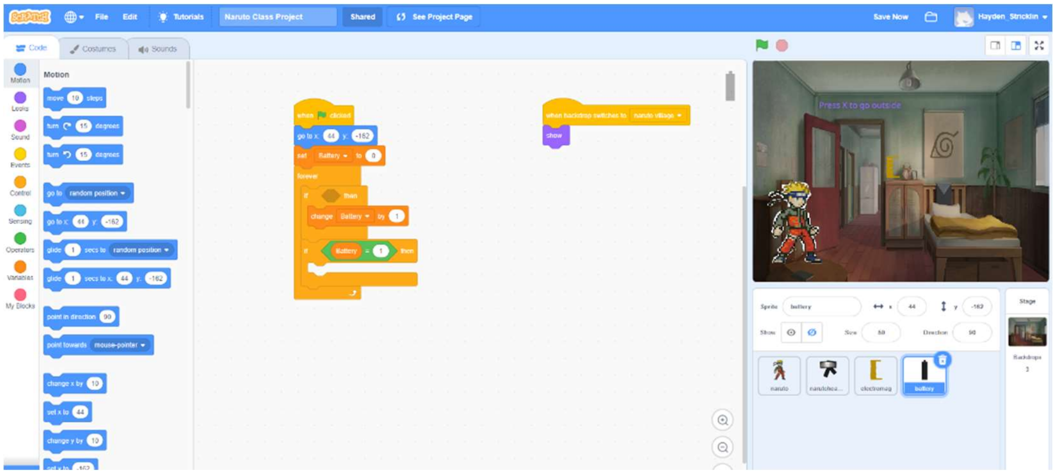

Figure 11: Battery Structure.

This command structure was discussed in previous lessons when building the electromagnet simulation and is presented to students in this format to avoid confusion and save time to allow more focus on conceptual understanding. The internal structure of the headband, See Figure 13, which is the chosen goal of the game, is the magnetic item that the electromagnet attracts and can only be found after the assembly of the magnet. See Figure 12, which has the variable set to be the coil, or the electromagnet without power connected.

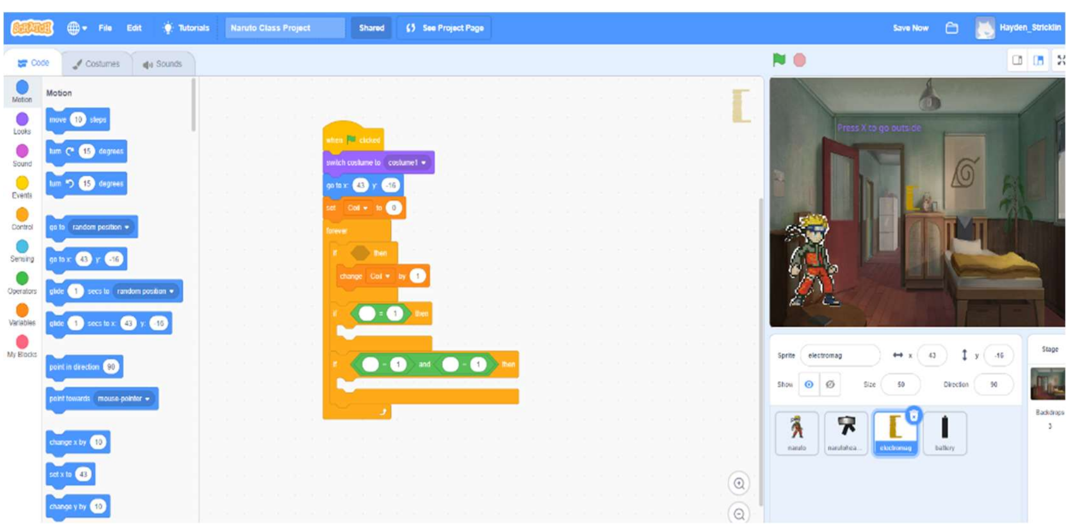

Figure 12: Electromagnet Structure.

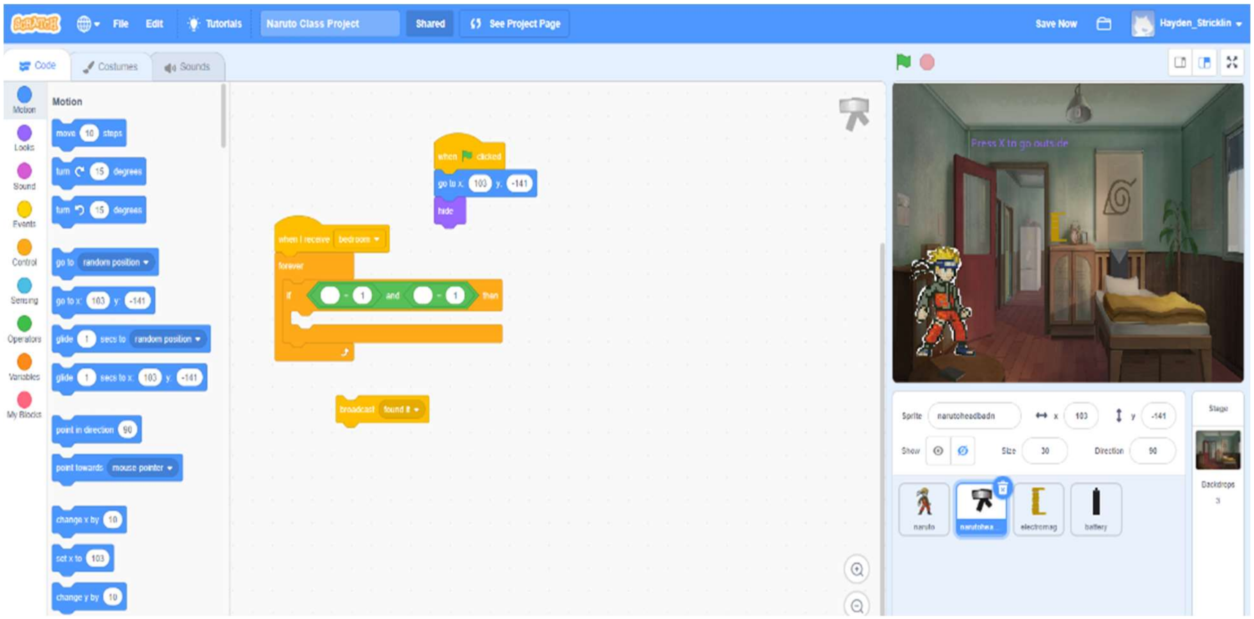

Figure 13: Structure of the Headband and Final Prize.

Site of Study

This study took place at Delaware Elementary School in Springfield, Missouri. This school had a population of 233 students and ranked in the bottom 50% of Missouri schools (Missouri Department of Elementary and Secondary Education, 2021). The math proficiency score was 25-29%, which is significantly lower than the Missouri average of 37% (Public School Review, 2021) This suggests that STEM intervention may be a valuable tool for these students.

The demographic breakdown of the school was 76% white or Caucasian, 10% Hispanic, 5% black or African American, and 7% identifying as two or more races. This closely reflected the average breakdown of Missouri schools (Public School Review, 2021), so the researcher asserts that this location can act as a generalized representation.

55% of students at Delaware Elementary received free lunches, compared to the state average of 43%, and 8% received reduced price lunches (Public School Review, 2021). This suggests that this area was less affluent than average. Despite this, 89% of households reported owning computers, and 75.6% of households had regular access to the internet. This again reflects the average statistics for Missouri (United States Census Bureau, 2022).

Participants. The participants of this study averaged an age of 10 years old and were participating during a summer session of school, between their fourth and fifth grade years. This was not a required school semester, so the state mandated curriculum was not required or enforced. This was also not a summer camp, so there were still assignments and an educational structure as there would be during an academic year.

The number of participants were 10 in the control group, and 7 in the experimental group. This small sample size can lead to issues when analyzing the data, leading to a large margin of error. This was taken into account when analyzing data. Groups were blindly decided by the researcher prior to the beginning of the intervention, with the groups selected as experimental or control before the researcher had any interaction with participants.

Authorization for Working with Students. The participants were minors, so informed consent was obtained from legal guardians. A copy of the form was included in Appendix B. The researcher was also in contact with the principal of the school prior to, during, and after the intervention to ensure all necessary steps were taken to protect the participants and all school policies were followed.

Instrumentation

The instruments used were multiple choice or Likert scale questionnaires. There is no standardized tool for measuring the attitude of elementary students (Ball, Huang, Cotten, & Rikard, 2018), so surveys were constructed based on an existing survey that was used in a previously published study (Brown, Cocannon, Marx, Donaldson, & Black, 2016). The content survey was 10 questions, and the attitudinal survey was 25 questions. See Appendix C and Appendix D for the full surveys.

Data Collection Procedures

Data was collected in the form of written surveys. A pre and a post survey were distributed to measure initial attitudes to compare to attitudes after the intervention. The subjects in both the control and the experimental group were given the pre attitudinal survey and the content survey on the first day, before any of the intervention began. The post surveys were given again on the final day of the intervention, after all activities had concluded. Informed consent forms were distributed to students and their guardians the week before the intervention began and were all securely collected and stored according to procedures.

Data Analysis Procedures. The content survey was analyzed like a traditional test or quiz, with answers marked correct or incorrect. Pre and post scores were compared to look for an increase of conceptual understanding. The Likert scale questionnaire was analyzed individually for each class, and for pre and post scores. These questions were to gauge attitude, so the data was compared in a total of four groupings: control pre, control post, experimental pre, and experimental post. Cronbach's alpha was calculated to verify internal consistency. A Welch's t-test was performed to verify the comparability of the two groups with unequal sample sizes.

The attitudinal surveys were analyzed to find the average opinion of the group, so the mean score was recorded for each question. This was done for each of the four data sets. Standard error was then calculated to determine statistical significance.

Analyzing Groups. The control and experimental pre survey data were compared to each other, to see if there is a difference in opinion of each group to start with. The post survey scores were then compared to their corresponding pre survey, to look for changes in attitude resulting from the intervention. The magnitude of change from pre to post test was also noted for each group and then compared.

Ethical Considerations

Because the participants were minors, informed consent had to be obtained from parents or legal guardians. The collected data was then anonymized through the use of ID numbers, with the name encryption key stored in a separate location. All physical data was stored in a secure office that requires a key to access, and all electronic data was stored on a secure server that only the researcher can access. All procedures are in accordance with IRB guidelines, and a research proposal was presented to and approved by the IRB (IRB-FY2022-354, date 12-03-21) at Missouri State University. Paper and electronic data will be kept in accordance with federal regulation (45 CFR 46) and will be shredded, or otherwise destroyed, and electronic data will be deleted from all servers at 3 years after the study concludes.

FINDINGS

The following charts, graphs, and explanations describe the findings and analysis of the data collected during the study. All calculations are done in accordance with the methodology detailed in the previous chapter. Cronbach's alpha was performed for each group, and a Welch's T-test was performed to ensure validity of comparisons between groups with unequal sample sizes, with an acceptable calculated value of ($t = 0.002$).

Content Survey

The content survey contained 10 multiple choice questions focusing on the structure and function of magnets. Data collected was analyzed to determine if this intervention had a measurable effect on the student's content understanding, and if this is therefore a valuable conceptual intervention for primary school students.

Pre Survey. The survey was distributed to both the control and experimental groups on the first day of intervention before any instruction had begun. The average score for the control group survey was 57%, and the experimental average score of 67.143%.

The experimental group scored slightly higher than the control group suggesting that the experimental group had a higher level of baseline content knowledge. This is not a concern for the researcher, because shift in attitude and understanding are being measured rather than level of content knowledge. The acquisition of content knowledge will be assessed by comparing the pre and post content surveys for each group individually, and then the control and experimental groups will be compared to determine the effectiveness of the intervention. See Figure 14 for a comparison of the pre intervention content survey between control and experimental groups.

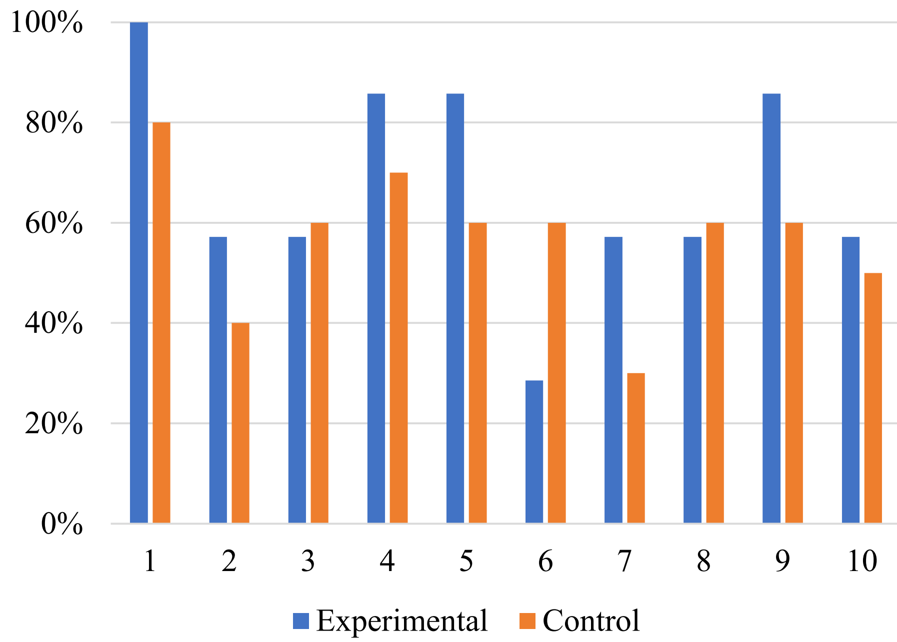

Figure 14: Content Survey Score Comparison, Pre Intervention.

Post Survey. The post test was distributed to both groups on the final day of intervention after all activities had concluded. The average score for the control group was 64%, and the experimental group averaged 78.571%. This represents an increase of 7% for the control group, and an increase of 11.429% for the experimental.

The experimental group scored higher on numerous questions, See Figure 15, suggesting that at the end of the intervention the experimental group had a higher level of knowledge.

Magnitude of Change. Because the experimental and the control group had differences between baseline scores on the content survey, the researcher was unable to draw conclusions from these figures alone. The magnitudes of change from pre to posttest average scores, See Figure 16, displays content acquisition.

The experimental group had a higher magnitude of change, indicating that their content knowledge acquisition was higher than the control groups, through their use of intervention. The researcher compared the magnitude of change for each question, and then compared the magnitudes of change for each group.

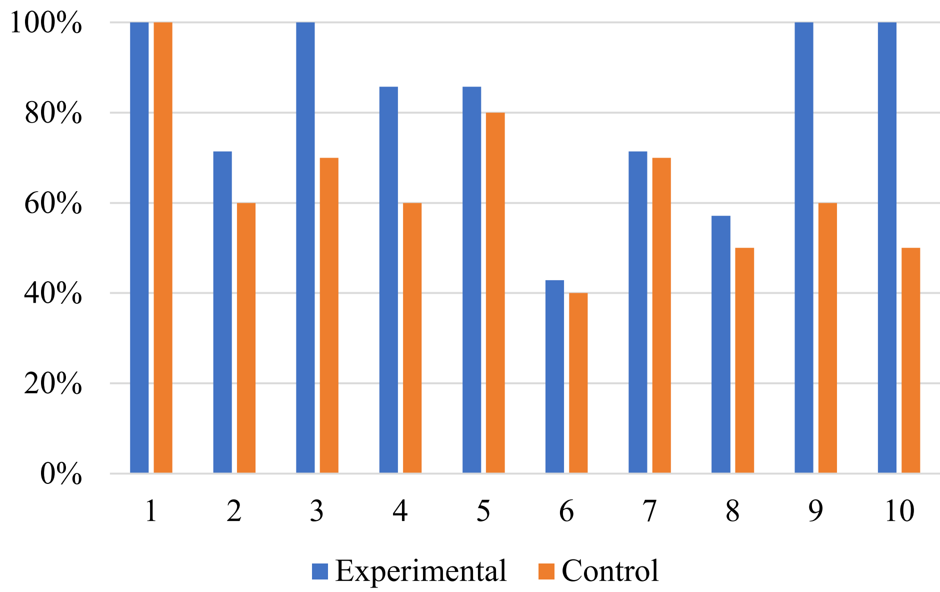

Figure 15: Content Survey Score Comparison, Post Intervention.

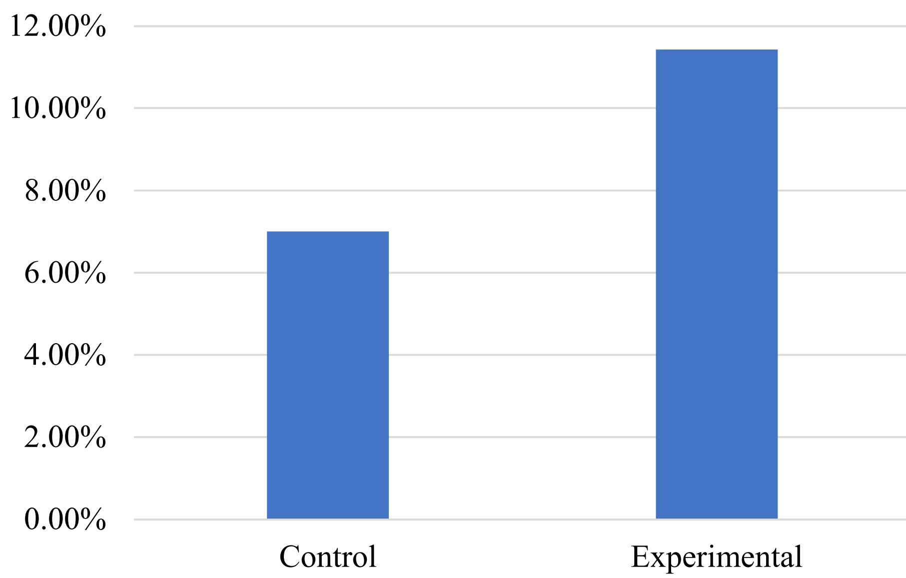

Figure 16: Magnitude of Content Knowledge Change from Pre to Post Intervention.

The magnitudes of change, See Figure 17, displayed varying results. Notice that the experimental group only displayed positive changes between the pre and post assessments. The control group also displayed positive changes, but also displayed a negative result for a few questions.

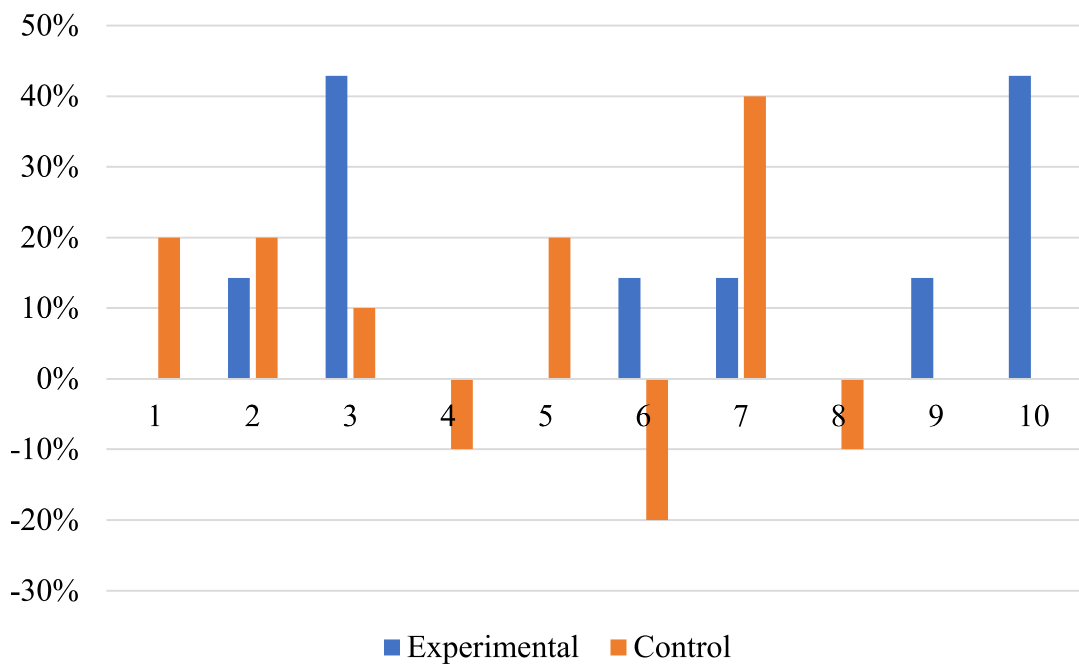

Figure 17: Magnitude of Change, Broken Down by Question.

Questions 2, 3, and 7 showed a positive change for both the control and the experimental group. These questions are "If two north poles are near each other…", "If a north and a south pole are near each other…", and "What items are needed to create an electromagnet?". These results indicate that the study increased conceptual knowledge of the structure and function of electromagnets and magnetic fields.

The experimental group saw an increase on questions 6, 9, and 10 as well, while the control either decreased or remained constant. These questions were "What's the difference between an electromagnet and a permanent magnet?", "If a magnet gets more power, what happens to the strength of the magnet?", and "If magnet A can hold 3 steel paperclips and magnet B can hold 5 paperclips, which one is stronger?" The researcher believes that the wording of question 6 may have caused confusion, as the term "permanent magnet" was not frequently used throughout the week. Despite the potential miscommunication, the experimental group saw an increase in correct answers while the control did not.

The control group saw positive changes for 5 of the questions, no change on 2 questions, and negative change on 3 questions. This suggests to the researcher that there was an increase, but it is not significant due to the negative or no change results. The experimental group, however, saw a positive change in 6 questions, and no change in 4 questions. The researcher argues that this suggests an overall positive effect, and that the intervention reinforced the concepts being taught.

Due to both positive and negative nature of the control group's magnitude of change, the researcher asserts that this can be accepted baseline result. This suggests to the researcher that there was in fact a difference in effect between the control and the experimental groups, with the group receiving the intervention demonstrating a greater gain in content knowledge.

Attitudinal questions were divided into categories, such as interest, perception, self-efficacy, and confidence, as shown in Table 2 and Table 3. Table 2 contains the first set of questions, asked on a scale of 1 to 5.

Table 2: Questions Categorized

Category	Number	Question
Interest	1.	I enjoy learning about STEM
	7.	I would like to know more about jobs using STEM

Table 2. continued

Category	Number	Question
Interest (continued)	9.	If I could choose, I would not take any more STEM classes
	10.	Science is one of the most interesting school subjects
Perception	2.	STEM is useful in solving everyday problems
	8.	We live in a better world because of STEM
	11.	Coding is not relevant to science
	17.	Coding is fun
Self-Efficacy	3.	I am good at problem solving
	4.	My peers can help me troubleshoot and solve problems
	5.	Coding and computer science are hard
	6.	I usually give up when I don't understand a STEM concept
	12.	I cannot understand STEM even if I try hard
	13.	I am sure I can do well on science tests
	16.	If my code doesn't work, I will give up

Table 3 contains the second set of questions, ranked on a scale of 1 to 10, assessing student confidence in STEM and their own abilities. These questions were separated into a second set of data for a clearer visualization of results.

Table 3: Questions Categorized, Second Section

Category	Number	Question
Confidence	18.	I am good at coding
	19.	I am good at science
	20.	I am good at solving problems
	21.	I am good at helping friends solve problems
	22.	I can figure out hard things
	23.	I can write programs on my own
	24.	I know a lot about magnets
	25.	I did well on the content survey

Attitudinal Pre-Surveys

Questions 1 through 17 were ranked on a 5-point Likert scale, ranging from strongly disagree to strongly agree. Questions 18 through 25 were ranked on a 10-point scale, ranging from "Not so much" to "Expert". These questions have a wider range to gain more in-depth insight into the student's personal confidence and attitudes about themselves as learners, whereas the first section of questions is more aimed at self-efficacy around STEM activities.

Comparison of the responses from both control and experimental groups for initial attitude surrounding STEM before the intervention are displayed in two sections. Questions 1 through 17, See Figure 18, and questions 18 through 25 are represented separately in for clarity and consistency. Cronbach's alpha was calculated for each group, with pre-survey values of (Experimental = 0.439) and (Control = 0.742). Values of at least 0.600 are considered acceptable, so the initial Cronbach's alpha of the experimental group is lower than acceptable, but the value of the control group is acceptable at over 0.700. This indicates that the control group had a more consistent, class-wide attitude, while the experimental group saw little to no correlation between students. This does not mean that the experimental group's data is inaccurate, but rather that there was not a clear trend within the dataset.

Figure 18 illustrates numerous differences between the group's answers, with varying degrees of significance. Questions 1, 3, 4, 5, 7, 9, 12, and 16 have visibly different results which the researcher found to be illustrative of the initial differences between the groups.

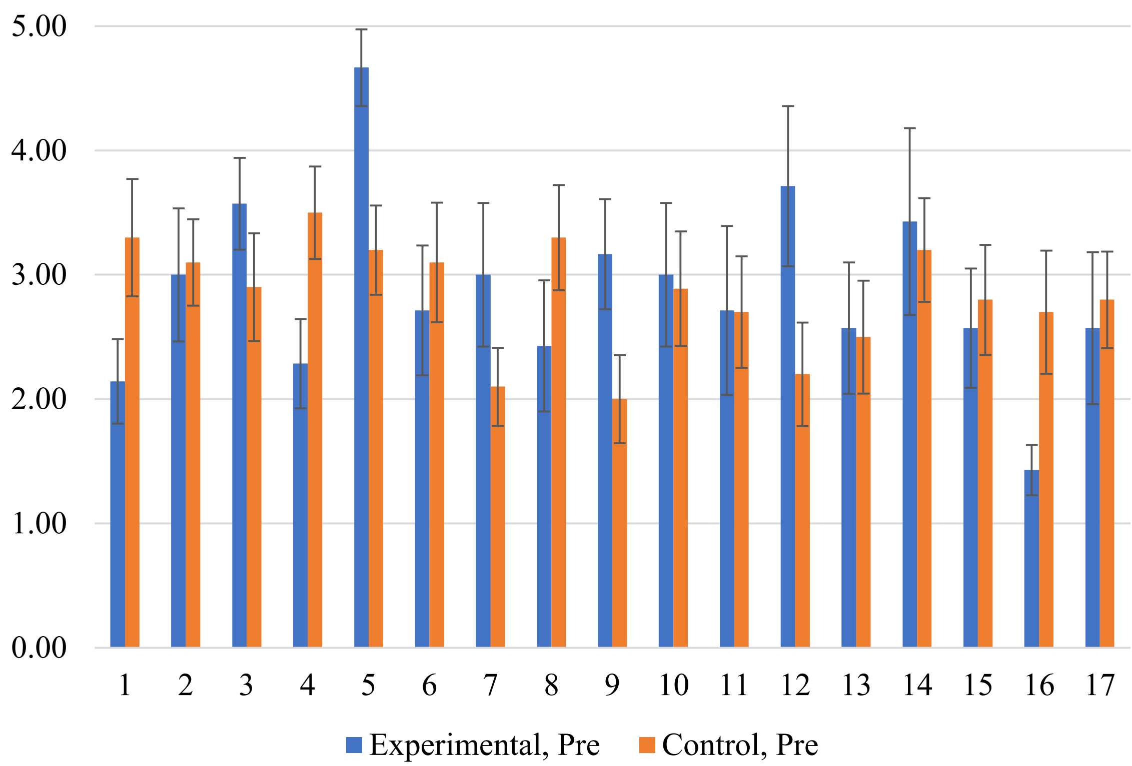

Figure 18: Comparing Attitudinal Survey Results, Pre Survey.

A significant result is determined by the calculation of a p-test, with a p-test in the acceptable range (<0.050) considered statistically significant. If the two data points' error margins do not overlap it may still be discussed, but do not necessarily qualify as statistically significant data points.

Interest and Perception. Of the observably variant results, questions 1, 7, and 9 looked for student interest in STEM education as well as interest in science outside of the classroom. Questions 1 and 7 were asked in the positive, meaning the higher the numerical score the more positive the response.

Question 1 was an overarching statement, "I enjoy learning about STEM". The control group scored noticeably higher, indicating that the experimental group did not begin the intervention with a high level of interest in learning the subject. This provided the researcher a promising opportunity to perform an intervention which directly tied to interest, with the potential to affect a group of students without prior enthusiasm.

Questions 7 stated "I would like to know more about jobs using STEM", probing student interest in pursuing the field. The experimental group reported a higher average score, indicating interest in STEM outside of a purely academic and educational setting.

Question 9 was asked in the negative, stating "If I could, I would NOT take any more STEM classes in school". A higher numerical response indicated agreement, or a wish to discontinue studying STEM. Interestingly, the experimental group reported a higher average, or a wish to stop taking STEM classes.

The experimental group expressed a disinterest in taking STEM courses in school, with negative responses to questions 1 and 9, but indicated an interest in STEM as a potential career path. The researcher suggests that this is due to the presentation, or lack thereof, of STEM material in an academic setting, and that this intervention has the potential to be a valuable tool to influence student opinion and attitude toward STEM education.

Self-Efficacy. Questions 3, 5, 12, and 16 were probing student self-efficacy. Question 3 was an example of a question being asked in the positive, stating “I am good at problem solving”. Questions 5, 12, and 16 are all questions being asked in the negative with statements such as “I cannot...” or “computer science is hard”. In this situation, the higher the numerical value, the more negative the response. A low number indicated contradictive thinking, meaning that they had a higher level of self-efficacy or a more positive response.

The experimental had a higher numerical response for questions 3, 5, and 12, and a lower response for question 16, See Figure 18. Of these questions, only question 3 is asked in the positive. In this case, the higher response denotes a higher self-efficacy. For questions 5, 12, and 16, a lower numerical response would correspond with high self-efficacy.

Questions 5 and 12 stated “Coding and computer science are hard”, and “I cannot understand STEM even if I try hard”. The experimental group averaged a higher numerical response, indicating that they believed that they could not understand this difficult content and a low self-efficacy. The control group’s average remained close to a value of 3, indicating a neutral response.

The experimental group reported a lower numerical score for question 16, which was asked in the negative stating “If my code doesn’t work, I will give up”. The lower the numerical value, the less likely they were to give up. This indicated to the researcher that the experimental group would likely utilize the tools imparted during the intervention to continue solving their own problems. This lasting effect is a goal of early intervention, suggesting that the researcher’s experimental group received the benefits of early intervention.

The experimental group also reported a lower score on question number 4, stating “my peers can help me troubleshoot and solve problems”. This indicates a lower level of confidence in peers and suggests that the students would not likely seek guidance from each other.

Of the results obtained regarding self-efficacy in the pre survey that yielded a statistically significant result was question 5, with an acceptable p-test value of (0.0185), falling within the (<0.050) requirement. Questions 3, 12, and 16 had calculated values greater than (0.050) and are therefore not considered statistically significant, though they did have visual difference when the data is presented as a graph.

This tells the researcher that before the intervention, the two groups had varying levels of self-efficacy in regard to coding. The experimental group reported a more negative score, indicating that they did not believe in their ability to successfully write code. This suggests to the researcher that the experimental group could potentially benefit from the introduction of a STEM intervention centered around coding.

Confidence. Questions 18 through 25 focused on student confidence, See Figure 19, with statements starting with “I am good...” or “I can...”. These questions differ from self-efficacy because self-efficacy revolves around the ability to complete a specific task, whereas these questions are asking more about the student’s attitudes about themselves as learners.

The average responses of the experimental and control group with standard error were calculated and graphed. These questions were graphed separately from questions 1 through 17 due to their ranking being on a 10-point scale instead of a 5-point scale.

From this figure, the only visible result was in question 23, stating “I can write programs on my own”. This question probed initial confidence in an ability that they may not have tested before. The experimental group reported a lower average than the control group, but it should be noted that both scores are less than 5, indicating slightly negative responses from both groups.

Despite the visual representation of data, See Figure 19, the second set of questions yielded significant results for every question. When calculating p-test values for questions 18 through 25, all data points returned an acceptable value of (<0.050). The researcher suggests that the graph above does not visually reflect this due to the change in scale from 5-point to 10-point.

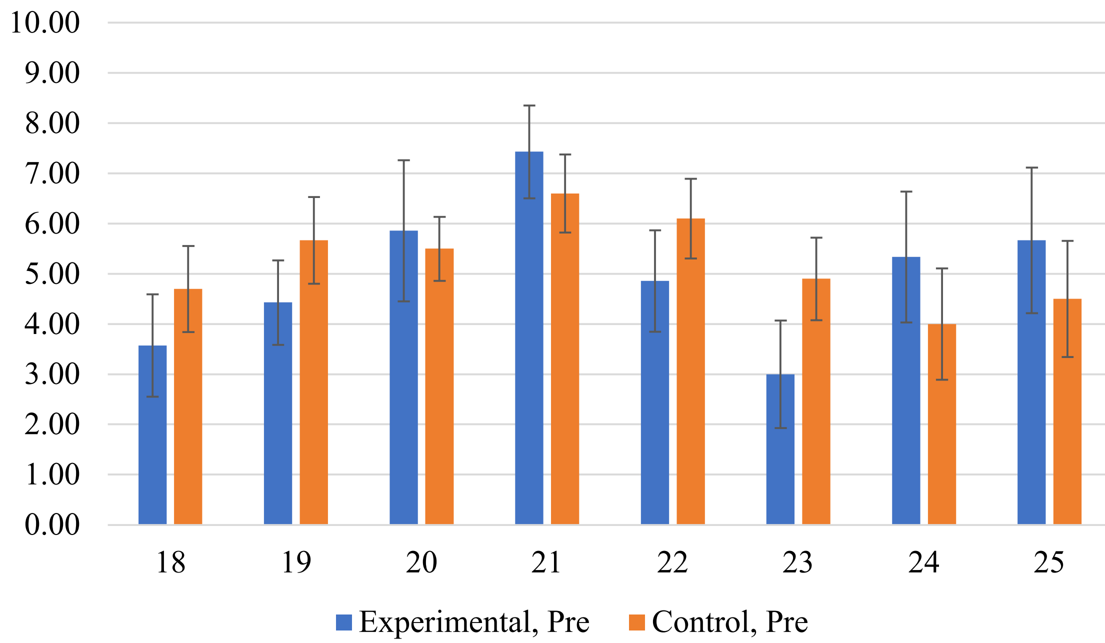

Figure 19: Comparing Attitudinal Survey Results, Second Section, Pre Survey.

All questions, 18 through 25, were asked in the positive, indicating that a higher numerical value representing a more positive response. The control group gave a more positive response for questions 18,19, 22, and 23. The experimental group gave more positive responses for questions 20, 21, 24, and 25. With the data points varying, roughly half of the responses are more positive for each group. The researcher suggests that while these data points are significant, they represent an equal split between the groups. These datapoints indicate a relatively low confidence score from both groups. This suggested to the researcher that the groups were starting with a comparable set of attitudes, with a confirmed reliability through Welch's t-test with an acceptable value of (t = 0.002).

Attitudinal Post-Surveys

The same survey was distributed to both the control and experimental groups at the end of the 5-day intervention. The same analysis procedure was performed for this data set. Cronbach's alpha was calculated for each group, with pre-survey values of (Experimental = 0.773) and (Control = 0.883). Values of at least 0.600 are considered acceptable, and a value of 0.800 or higher is considered very good. The experimental group shows a significantly higher value for Cronbach's alpha in the post test than in the pre test. See Figure 20, illustrating the average response for questions 1 through 17 with standard error calculated and graphed as well.

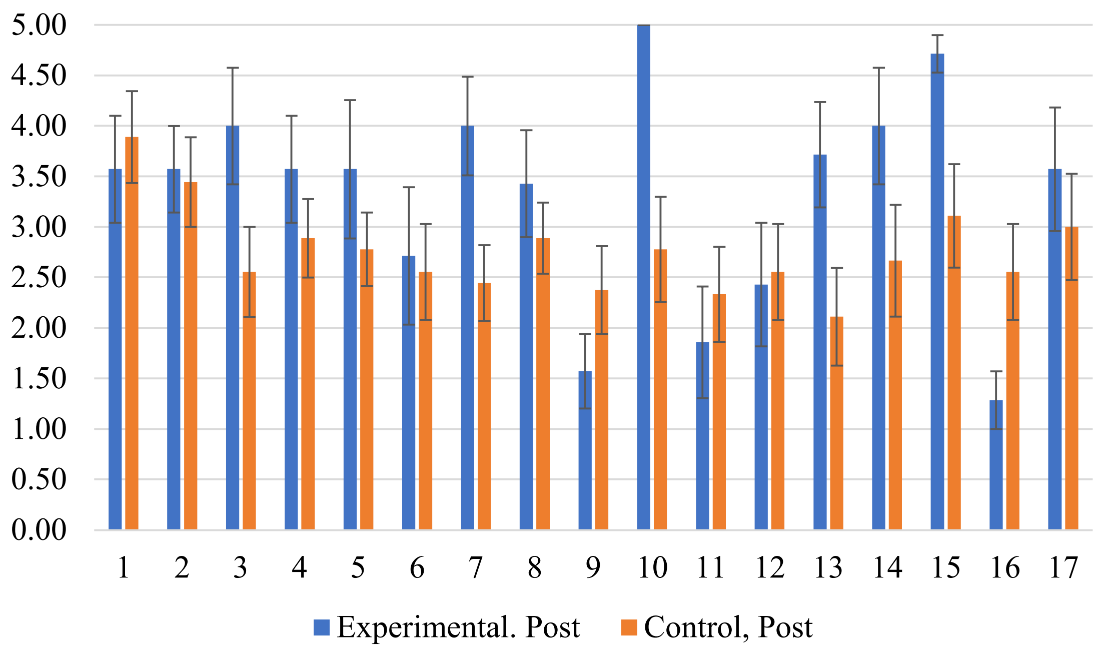

Figure 20: Comparing Attitudinal Survey Results, Post Survey.

This suggests to the researcher that there was an element of confusion or a lack of clarity in the minds of the experimental group before the intervention, leading to less reliable results, that had been corrected through the course of the intervention.

Interest and Perception. Questions 10, 14, and 15 ask about interest in STEM. These questions are, “Science is one of the most interesting school subjects”, “I like to watch STEM based TV shows”, and “We do a lot of interesting activities in science class” respectively.

The experimental group reported an observably higher average score, indicating a positive response or agreement with the statements. This suggests that the intervention positively affected the experimental group’s interest in STEM. Questions 10 and 15 directly ask about science classes, to which the experimental group had a statistically and significantly higher numerical response, indicating that the experimental group concluded the intervention with a strong interest in STEM classes.

In the post survey scores, the experimental gave a higher, or more positive response to question 7 than the control, and on question 9 gave a lower response. For question 9, this lower numerical response reflects a more positive result, indicating a desire to continue studying STEM. Both data points indicate a higher level of interest in the experimental group than in the control. These results are not considered statistically significant, though, because the calculated p-test value for both questions are greater than the acceptable (0.050).

Self-Efficacy. Questions 3, 13, and 16 yielded results about student self-efficacy. Questions 3 and 16 displayed differences in results in the pre survey as well, though they are not statistically significant in either survey. The experimental group appeared to express more positive attitudes regarding their self-efficacy but did not meet the threshold of p-test (<0.050) to be considered significant.

Question 13 states "I am sure I can do well on science tests". In the pre survey, there was no statistical difference between the control and experimental groups, indicating a similar belief being held by all students. In the post survey, the experimental group averaged a higher response, potentially indicating a higher level of self-efficacy than the control group, though it does not have a calculated statistical significance.

Confidence. Questions 18 through 25 focus on student confidence, with statements starting with "I am good..." or "I can...". The post survey yielded statistically significant differences for questions 18 through 25, See Figure 21.

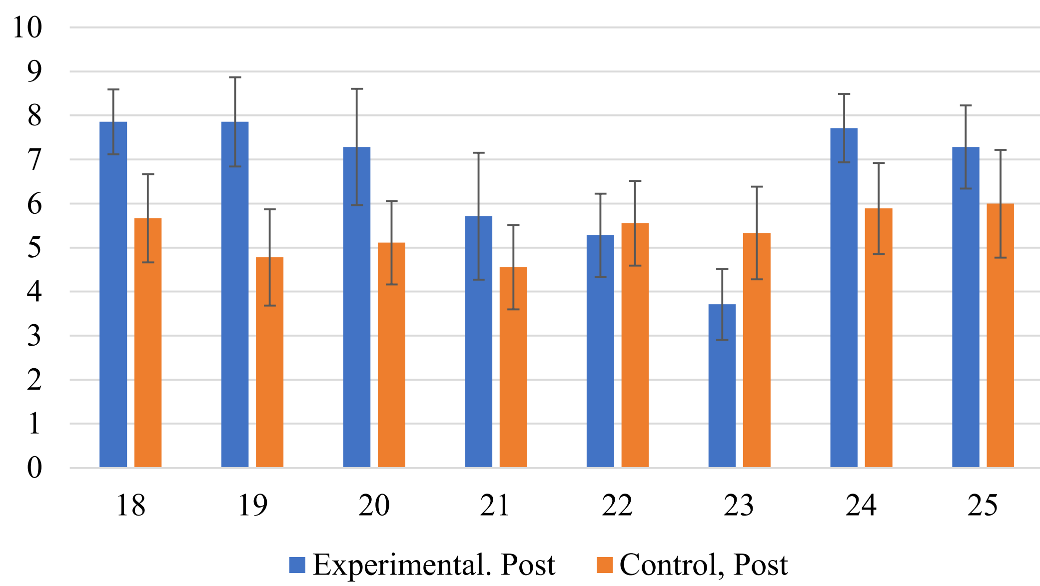

Figure 21: Comparing Attitudinal Survey Results, Second Section, Post Survey.

In this figure we see more positive responses for the experimental group which are significant in comparison to the control group, with the exception of questions 21 and 22. This indicates to the researcher that the intervention did have an overall positive effect on the experimental group's confidence. The pre survey displayed an even split between the control group's answers, but the post survey displays the majority of the positive responses coming from the experimental group. This indicates to the researcher that there was an increase in confidence from the experimental group, causing an increase in numerical responses due to the intervention.

Pre to Post Comparison and Analysis

To determine the magnitude of the effect of this intervention, the initial data needs to be compared to the final data to determine if there was a difference in change in interest, perception, and self-efficacy within the groups.

The average results of the pre survey for questions 1 through 17 were compared to the post survey results for the control group, See Figure 22.

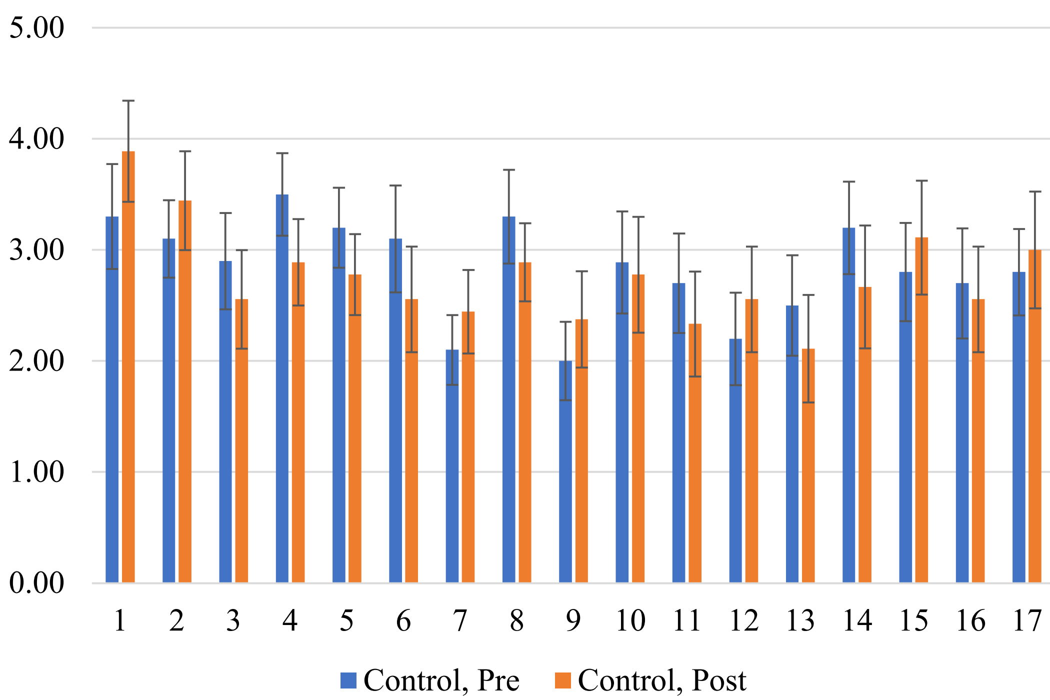

Figure 22: Control Group Pre and Post Survey Comparison.

Looking at the graph, there are no visible differences from beginning to end. When calculating the p-test values to determine the statistical significance, only question 1 returned an acceptable value of (<0.050).

The control group's pre survey to the post survey for questions 18 through 25 were then compared, See Figure 23. There are observable differences in questions 21 and 24, with minor overlap of error on 24. These questions are "I am good at helping friends solve problems" and "I know a lot about magnets".

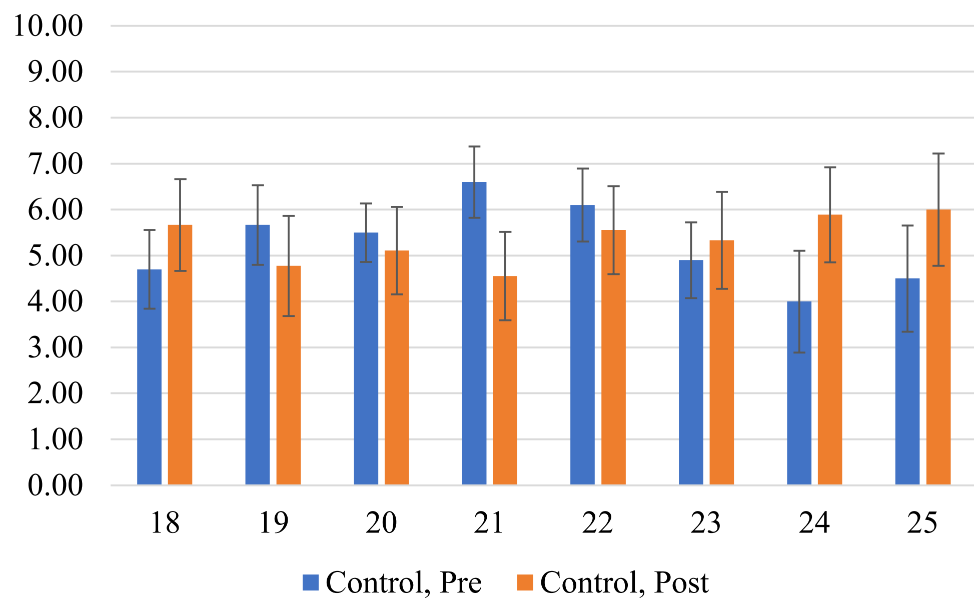

Figure 23: Control Group Pre and Post Survey Comparison, Second Section.

All questions, 18 through 25, returned an acceptable p-test value of (<0.050), indicating statistically significant results. Interestingly, not all results were positive or in the researcher's favor. Questions 19 through 22 saw a numerical increase in responses, indicating an increase in student confidence, but questions 18 and 23 through 25 saw a numerical decrease. The mixture of both positive and negative results suggests to the researcher that there was no clear indication that their presence increased the control group's confidence.

The pre and post survey results of the experimental group, See Figure 24, were graphed with standard error included. There are numerous observable differences in results, including questions 1, 4, 5, 7, 8, 9, 10, 13, 15, and 17.

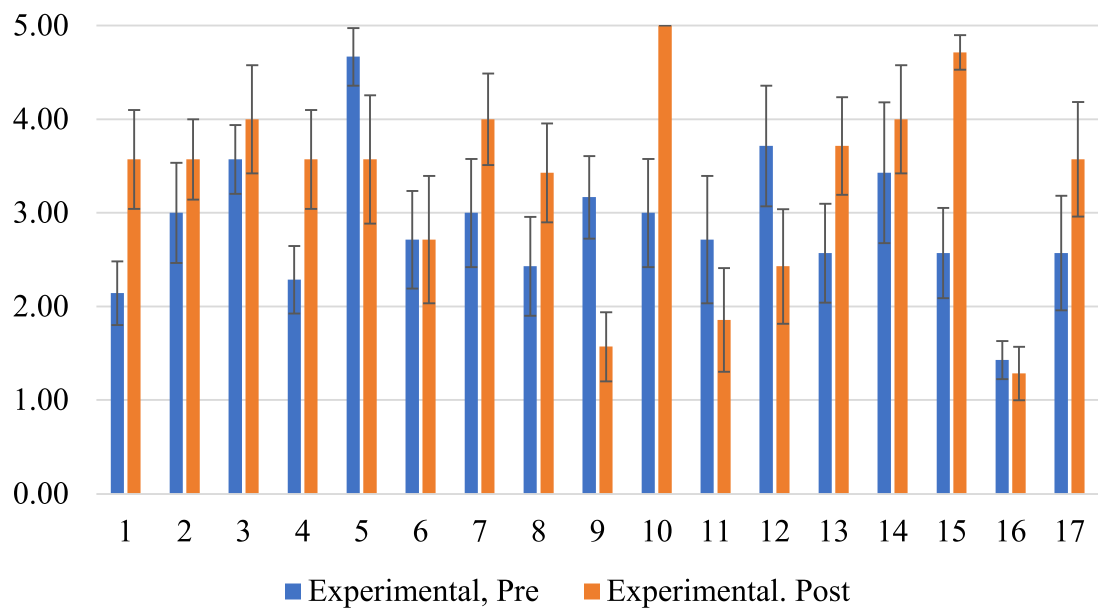

Figure 24: Experimental Group Pre and Post Survey Comparison.

Questions 1, 4, 7, 8, 10, 13, 15, and 17 all saw increases in value indicating an increase in attitude and efficacy. Questions 5 and 9 saw a numerical decrease, which indicates a positive change due to the questions being asked in the negative.

Of these results, questions 5, 7, and 10 were calculated to be statistically significant. Though there was not a visible difference in the graph above, questions 3 and 14 were also found to be statistically significant. These results all represented an increase in attitude and efficacy, or a positive effect. Due to the consistency of increase, the researcher asserts that the intervention had a positive effect on student attitude.

The experimental student responses from the pre and post surveys are illustrated with standard error included, See Figure 25. There are statistical differences between all questions except for number 23.

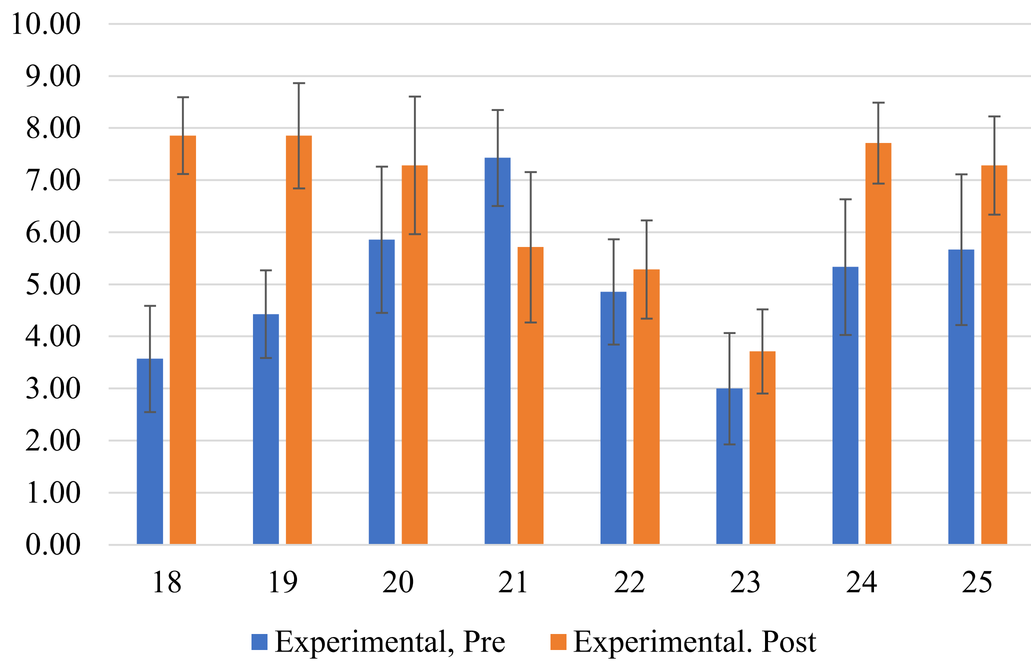

Figure 25: Experimental Group Pre and Post Survey Comparison, Second Section.

Questions 18, 19, and 24 all hold results displaying an increase in value, indicating a positive change. These questions are, "I am good at coding", "I am good at science", and "I know a lot about magnets". These three questions highlight the acquisition of content knowledge as well as an increase in confidence with coding and science abilities. The other questions also displayed a statistical increase in value, or a positive effect on the experimental group's attitude.

This result is in accordance with the researcher's hypothesis, and it can be argued that this intervention did in fact have a significant, positive effect on the experimental group.

Magnitude of Change. The data illustrated in the figures above display a difference within the groups, and a difference from pre to post surveys, but to determine how strong of an effect was felt between the groups, the researcher must compare the magnitudes of change of the control and experimental groups.

Magnitude of change was calculated by subtracting the numerical responses of the pre test from the responses of the post test. These are not the absolute values of the magnitude, so the direction of the data point indicates a positive or negative change. The results are illustrated graphically, See Figure 26.

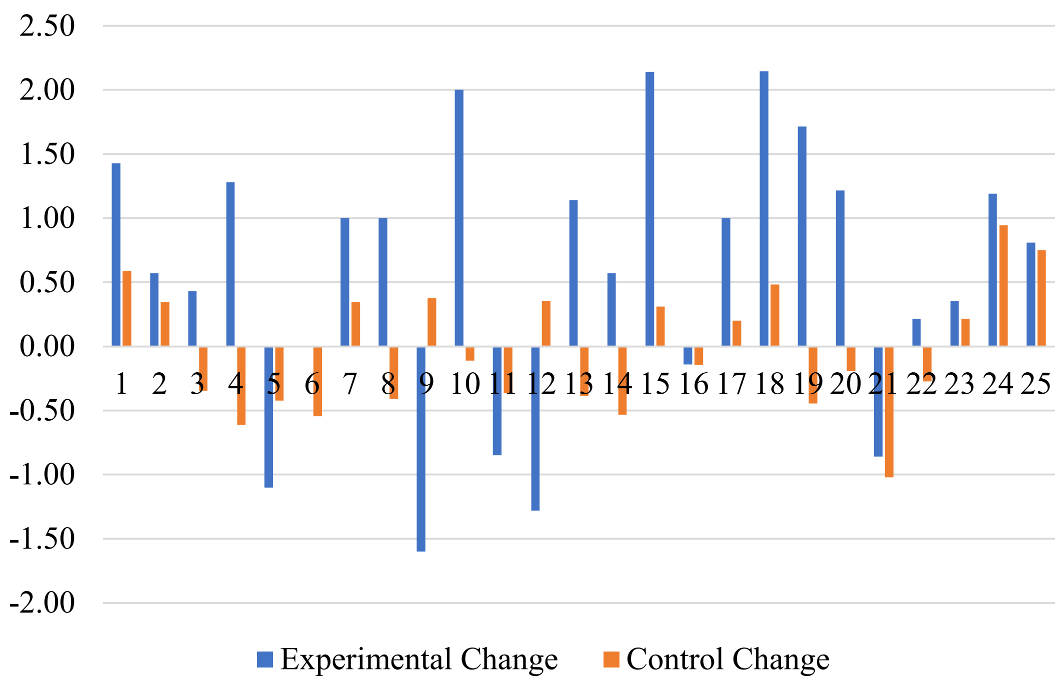

Figure 26: Magnitude of Change with Attitudinal Reflection.

It is important to note that questions 5, 6, 9, 11, 12, and 16 were asked in the negative, so a data point with a negative result indicates a positive change in attitude. It is also important to note that questions 1 through 25 are all included in the same Figure. To allow the scale to remain within the bounds of ± 5, the scores for questions 18 through 25 were divided by 2.

Comparing Magnitudes. This graph demonstrates the magnitude of change as well as illustrating the fact that not all changes were in the researcher's favor. It also illustrates that the experimental and control groups did not have the same results and in fact saw opposite effects in some respects. See Figure 27 as a display of the absolute value of magnitude of change for all survey questions.

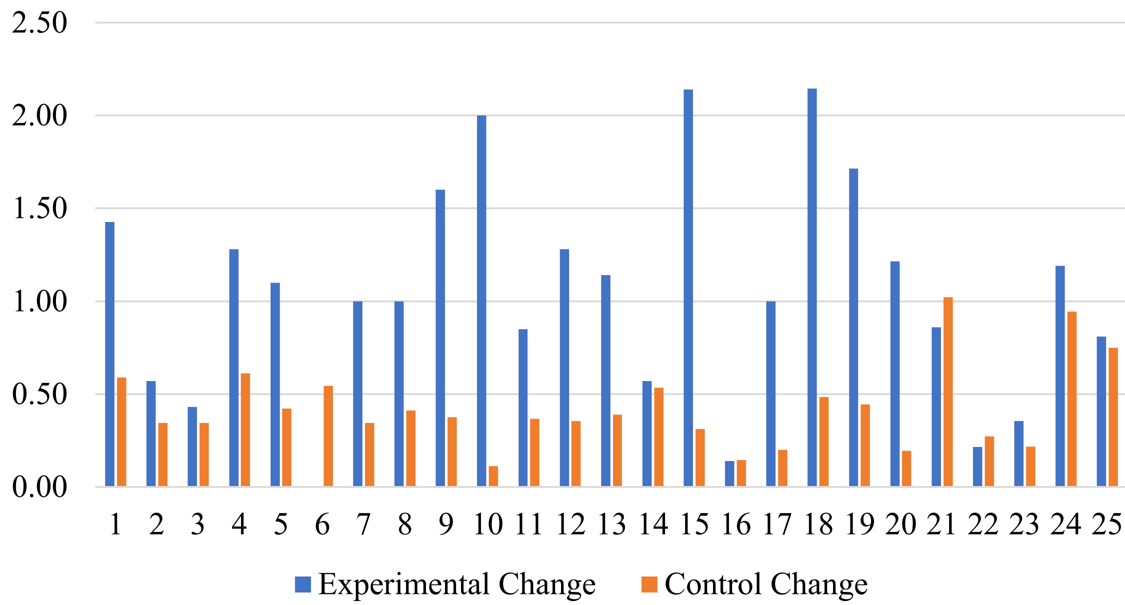

Figure 27: Absolute Value of Magnitude of Change.

Questions 3, 4, 8, 9, 10, 13, 14, 19, 20, and 22 had results with opposite signs between the experimental and the control. These instances demonstrate that the experimental group increased in interest, perception, and self-efficacy, while the control group slightly decreased in these same categories.

As shown in the figure above, there is a greater magnitude of change for the experimental group than there is for the control group in almost every question. The most noticeable differences can be seen in questions 10, 15, and 18. A reliable p-test could not be performed due to the size of the magnitudes of change. The values of change for the control group averaged less than 1, which are too small to use to calculate significance. For the purposes of the researcher's comparison, these questions will still be discussed with the understanding that they are not considered statistically significant.

Question 10 assesses interest, stating "Science is one of the most interesting school subjects". The experimental group saw a numerical change of 2 points on a 5-point scale, indicating a distinct increase in attitude. In comparison, the magnitude of change for the control group was 0.11 points. There is a remarkable difference, 18.18x the effect, between the experimental and control groups, with the intervention increasing interest when comparing the groups. This suggests to the researcher that the intervention had a measurable, positive effect on student interest.

Question 15 states, "We do a lot of interesting activities in science class". Again, the experimental group saw a large numerical increase of 2.140 points, while the control group saw an increase of 0.311 points. The experimental group saw 6.90x more effect than the control group. This question is probing interest and perception of STEM as an academic field.
The increase seen by the experimental group suggests to the researcher that this intervention was successful in increasing student interest in STEM within academics. Question 18 is in the Second section of questions which is ranked on a 10-point scale as opposed to the 5-point scale used in questions 1 through 17. To account for this difference, the values of the second section, the values of questions 18 through 25 were divided by 2 to be reflected on the 5-point scale.

Question 18 states, "I am good at coding". This statement investigates the overall effect of the intervention on the student. The method of intervention was centered on coding and self-efficacy, which are both addressed in this question. The experimental group saw an increase of

2.145 points, while the control group saw an increase of 0.483 points. The magnitude of change for the experimental group was 4.440x greater than the change of the control group.

This demonstrates that both the control and experimental group saw fluctuations in attitude, but the group was more affected by the intervention than the control group. This indicates to the researcher that the increased students' self-efficacy and confidence was correlated with the introduction of a game-based intervention.

Summary

The Figures above help illustrate data collected from the experimental and the control group's pre and post surveys. There is a demonstrated, significant difference in effect between the experimental and the control group, indicating that the intervention did have a significant impact. The effect of the intervention was hypothesized to be positive, and is corroborated with the data, demonstrating an increase in interest, perception, self-efficacy, and confidence.

Question 10 directly assessed interest, stating "Science is one of the most interesting school subjects". The post survey demonstrated a statistically significant difference between the control and the experimental group's responses, with the experimental group reporting a more positive response. When observing magnitude of change, the experimental group saw an increase of 2 points on a 5-point scale, indicating an increase in attitude. In comparison, the magnitude of change for the control group was 0.111 points. When comparing the magnitudes of change between the control and experimental, the experimental experienced 18.018x more of an effect on interest in science classes.

Question 15 states, "We do a lot of interesting activities in science class". Again, this question looks at interest in science in school, and again displayed a statistically significant difference. The experimental group reported a statistically significantly higher numerical score on the post survey, suggesting that the intervention demonstrated an interesting activity that could potentially be integrated into academic curriculum. The experimental group also saw a numerical increase of 2.140 points when looking at magnitude of change, while the control group only saw an increase of 0.311 points. The experimental group saw 6.90x more effect, suggesting that the intervention had an effect on the group.

The final section of the surveys focused on the confidence that the student has regarding themselves as learners. These questions began with statements such as “I am good...”, “I know I can...”, and “I know...”. Question 18, stating “I am good at coding”, saw a statistically significant difference between the experimental and control groups, with the experimental group reporting a more positive response. The experimental group saw a numerical increase of 2.145 points, while the control group saw an increase of 0.483 points. The magnitude of change for the experimental group was 4.440x greater than the change of the control group, suggesting that the intervention had an effect on the experimental group’s attitude.

The rest of the questions, 19 through 25 with the exception of 23, all yielded significant results with the experimental reporting more positive responses. Due to this, the researcher argues that the introduction of the intervention to the experimental group did in fact have a significant, positive effect on student interest and confidence.

For future research, the researcher recommends exploring a tool for measuring student attitude. A primary struggle that the researcher faced was to find an existing and reliable tool to measure student attitude. There is no standardized tool for this, as mentioned previously, so the researcher constructed their own. Creating such a tool, and testing it on primary school students, would be an impactful way to benefit educational researchers in the future.

Due to the age of the students, the researcher would recommend implementing this intervention over the course of two school weeks if possible. The complexity of the subject and the technical details require in-depth explanations, and due to time constraints, the researcher created scaffoldings for the students to fill in rather than having them start from a blank page. Another viable option would be to conduct this study with an older age group of students.

CONCLUSION

Integration of video games and game-based assignments is a topic that has been studied in the past, but not as thoroughly as many other forms of intervention. There are proven cognitive benefits for the use of video games, and there are academic benefits as well. This is a common form of technology that the average person interacts with, providing a familiar and comfortable transitional space into an academic context.

The researcher took this idea and applied it to a fourth and fifth grade class, integrating coding and magnetism, hypothesizing that a game designing assignment would have a positive impact on student's attitude, interest, motivation, and self-efficacy surrounding STEM and STEM curricula. One group received an intervention in the form of designing a playable video game using the coding skills they learned and their conceptual understanding of magnetism, while the control group completed the lessons and coding activities in a traditional format.

The questions driving this research were a) does coding a playable video game increase student attitude towards science, b) does it increase student motivation and interest in science, c) does it increase student self-efficacy, and d) does this method reinforce concepts being taught?

Based on the findings and data outlined above, the researcher has concluded that this intervention was successful in accomplishing its goals of increasing student attitude towards STEM, motivating students to continue studying STEM, increasing self-efficacy, and reinforcing concepts.

The experimental group, with an additional assignment wherein they coded a video game together as a class, showed significant increases over the course of the intervention in regards attitudinal scores on interest and self-efficacy. Questions 10 and 15 illustrate this fact with statistically significant results when comparing the experimental group to the control group using a p-test with acceptable values at (<0.050). See Appendix E for a hyperlink to a completed copy of the experimental group's final game.

The second section of the attitudinal survey, questions 18 through 25, also yielded statistically significant differences between the experimental and control groups. The experimental group showed a greater increase in numerical response, corresponding with a more positive attitude, than the control. This again suggests that the intervention had a positive effect on student confidence.

The content survey also demonstrated an acquisition of knowledge, indicating that the intervention was successful as a conceptual tool as well as attitudinal. The experimental group demonstrated an increase in content knowledge, as shown in Figure 16. The control group, who did not receive a game-based assignment, demonstrated an increase in content knowledge as well, though not statistically significant.

The researcher's initial hypotheses of a game designing assignment having a positive impact on student's attitude, interest, motivation, and self-efficacy surrounding STEM and STEM curriculum has been confirmed by the data as outlined above. Students in the experimental group who received the intervention showed statistically significant increases in attitude that were not seen in the control group, as seen in questions 5, 10, 15, and 18 through 25. This reflects the researcher's initial hypothesis, confirming that the introduction of a game designing assignment would have a positive effect on student attitude regarding STEM and STEM curriculum.

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APPENDICIES

Appendix A: IRB Approval

Date: 4-28-2023

IRB #: IRB-FY2022-354
Title: Examining Attitudinal Shifts Towards STEM Education in Primary School Students with the Addition of Game Based Assignments
Creation Date: 12-3-2021
End Date:
Status: Closed
Principal Investigator: David Cornelison
Review Board: MSU
Sponsor:

Study History

Submission Type	Initial	Review Type	Expedited	Decision	Approved
Submission Type	Modification	Review Type	Expedited	Decision	Approved
Submission Type	Closure	Review Type	Unassigned	Decision	

Key Study Contacts

Member	David Cornelison	Role	Principal Investigator	Contact davidcornelison@missouristate.edu
Member	Hayden Stricklin	Role	Primary Contact	Contact stricklin9817@live.missouristate.edu

Appendix B: Informed Parental Consent Form

INFORMED PARENTAL CONSENT FORM

Your child's classroom/group has been asked to participate in a research study being conducted by Hayden R Stricklin who is a graduate student at Missouri State University, as part of their thesis project titled EXAMINING ATTITUDINAL SHIFTS TOWARDS STEM EDUCATION IN PRIMARY SCHOOL STUDENTS WITH THE ADDITION OF GAME BASED ASSIGNMENTS. The study, as well as your and your child's rights as a participant, are described below.

Description: The purpose of this study will be to observe attitudinal shifts surrounding STEM and STEM education of third and eighth grade students when presented with an assignment where they are responsible for designing a short, playable video game, or receiving a game to play. Your student will be instructed to use a free programming language called Scratch to use drag-and-drop coding to design their own video game, centered on the STEM concept of electromagnetism.

Confidentiality: Student's answers will not be associated with their names, but a confidential ID number that will be assigned by the researcher. The resulting games will be sent to the researcher for analysis and will also be assigned an ID number. Students will have the option to make their games public, and playable by anyone who has access to the Scratch™ website.

I agree to have my participant's program made public

____

Signature

Risks & Benefits: There will be no risk to your child's safety. The content and activity will increase student's critical thinking and reasoning skills, as well as introduce them to the basics of coding, which may be beneficial for future education as well as career opportunities.

Freedom to Withdraw or Refuse Participation: I understand that my student has the right to refuse to answer survey or content questions that will be collected for research purposes, without prejudice from the investigator.

Grievance Procedure: If I have any concerns or am dissatisfied with any aspect of the study, I may report my grievances anonymously if desired through the Institutional Review Board for the College of Natural and Applied Sciences (CNAS) at Missouri State University.

Questions? Feel free to contact the investigator for any questions or concerns at hs36654@live.missouristate.edu at any time before or during the study.

Informed Consent Statement

I, ______________, give permission for my child/student, _______________ to participate in the research project entitled, "EXAMINING ATTITUDINAL SHIFTS TOWARDS STEM EDUCATION IN PRIMARY SCHOOL STUDENTS WITH THE ADDITION OF GAME BASED ASSIGNMENTS". The study has been explained to me and my questions answered to my satisfaction. I understand that my participant's right to withdraw from participating or refuse to participate will be respected and that their responses and identity will be kept confidential. I give this consent voluntarily.

Parent/Guardian Signature:

____________________________________ ________________________

Signature *Date*

This may be returned to the investigator in physical form by the student, OR parents may return an email with written confirmation, or verbal consent verified by BOTH researcher and the student's teacher that they understand the information outlined above. An example format would be:

My name is ________, I am parent/guardian of ________. I have read the attached document and am giving consent for participation.

Appendix C: Content Survey

Name: ___________________

How old are you?

5 6 7 8 9 10 11 12 13

These questions are to see what you understand so far.

1. What are the two ends of a magnet called?
    a. North and South poles
    b. East and West poles
    c. Up and down
    d. Left and right
2. If two north poles are near each other …
    a. Nothing will happen
    b. They will attract
    c. They will be demagnetized
    d. They will repel
3. If a north and a south pole are near each other …
    a. Nothing will happen
    b. They will attract
    c. They will be demagnetized
    d. They will repel
4. A magnetized piece of steel can be used to make …
    a. A compass
    b. A computer mouse
    c. A remote control
    d. A watch
5. Which object would not be attracted to a magnet?
    a. Scissors
    b. Water
    c. A screw
    d. A nail
6. What's the difference between an electromagnet and a permanent magnet?
    a. Electromagnets are stronger
    b. Electromagnets can be turned on and off
    c. Permanent magnets are stronger
    d. Permanent magnets can be tuned on and off
7. What items are needed to create an electromagnet

    a. A battery, a coil of wire, a metal core
    b. A magnet and a copper wire
    c. A magnet, a plastic core, and a power source
    d. A power source, a plastic wire, and a metal core
8. Does moving the magnet further away make the magnet stronger or weaker?
    a. Stronger
    b. Weaker
9. If a magnet gets more power, what happens to the strength of the magnet?
    a. It decreases
    b. It increases
    c. It stops the magnetic field
    d. There is no change
10. If magnet A can hold 3 steel paperclips and magnet B can hold 5 paperclips, which one is stronger?
    a. Magnet A
    b. Magnet B
    c. They are equally strong
    d. Magnets would not attract steel paperclips

Appendix D: Attitudinal Survey

Name: ____________________

How old are you?

5 6 7 8 9 10 11 12 13

For the following questions, rate your answers from 1 to 5, with 1 being strongly disagree and 5 being strongly agree

1. I enjoy learning about STEM

Strongly Disagree 1 2 3 4 5 Strongly Agree

2. STEM is useful in solving everyday problems

Strongly Disagree 1 2 3 4 5 Strongly Agree

3. I am good at problem solving

Strongly Disagree 1 2 3 4 5 Strongly Agree

4. My peers can help me trouble shoot and solve problems

Strongly Disagree 1 2 3 4 5 Strongly Agree

5. Coding and computer science are hard

Strongly Disagree 1 2 3 4 5 Strongly Agree

6. I usually give up when I don't understand a STEM concept

Strongly Disagree 1 2 3 4 5 Strongly Agree

7. I would like to know more about jobs using STEM

Strongly Disagree 1 2 3 4 5 Strongly Agree

8. We live in a better world because of STEM

Strongly Disagree 1 2 3 4 5 Strongly Agree

9. If I could choose, I would **not** take any more STEM classes in school

Strongly Disagree 1 2 3 4 5 Strongly Agree

10. Science is one of the most interesting school subjects

Strongly Disagree 1 2 3 4 5 Strongly Agree

11. Coding is not relevant to science

Strongly Disagree 1 2 3 4 5 Strongly Agree

12. I cannot understand STEM even if I try hard

Strongly Disagree 1 2 3 4 5 Strongly Agree

13. I am sure I can do well on science tests

Strongly Disagree 1 2 3 4 5 Strongly Agree

14. I like to watch STEM based TV shows or videos (MythBusters, Bill Nye, the Magic School Bus etc.)

Strongly Disagree 1 2 3 4 5 Strongly Agree

15. We do a lot of interesting activities in science class

Strongly Disagree 1 2 3 4 5 Strongly Agree

16. If my code doesn't work, I will give up

Strongly Disagree 1 2 3 4 5 Strongly Agree

17. Coding is fun

Strongly Disagree 1 2 3 4 5 Strongly Agree

For the next questions, rank your confidence from 1 to 10

18. I am good at coding

Not so much 1 2 3 4 5 6 7 8 9 10 Expert

19. I am good at science

Not so much 1 2 3 4 5 6 7 8 9 10 Expert

20. I am good at solving problems

Not so much 1 2 3 4 5 6 7 8 9 10 Expert

21. I am good at helping friends solve problems

Not so much 1 2 3 4 5 6 7 8 9 10 Expert

22. I can figure out hard things

Not so much 1 2 3 4 5 6 7 8 9 10 Expert

23. I can write programs on my own

Not so much 1 2 3 4 5 6 7 8 9 10 Expert

24. I know a lot about magnets

Not so much 1 2 3 4 5 6 7 8 9 10 Expert

25. I did well on the content survey

Not so much 1 2 3 4 5 6 7 8 9 10 Aced it!

Appendix E: Link to Completed Student Games

These students' parents gave permission to have their project saved publicly. For anonymity, the students created a username that did not contain any personal information, and therefore cannot be traced back to that student without the researcher's secured data.

https://scratch.mit.edu/projects/714220905

https://scratch.mit.edu/projects/714220868