THE IMPACTS OF A SCIENCE-BASED VIDEOGAME INTERVENTION ON INTEREST IN STEM FOR ADOLESCENT LEARNERS

BY

SHERRY YI

DISSERTATION

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Doctoral Committee:

Associate Professor H. Chad Lane, Chair
Professor, Jennifer Cromley
Associate Professor, Robb Lindgren
Professor Emerita Mary D. Ainley, University of Melbourne

ABSTRACT

Interest development is a topic that has fascinated and puzzled educators since the 20th century. Despite decades of research and important advances in the field, questions remain about interest and its relationship to learning. In particular, given the pervasiveness of technology in our daily lives, it is essential to understand how interest develops within these technology-enhanced environments. In this dissertation, I investigate the extent to which a digital sandbox game that allows for autonomy and peer-to-peer interaction can trigger interest in science, technology, engineering, and mathematics (STEM), as well as explore how prior game mastery impacts these changes. The sandbox game, Minecraft, is used as a platform to test whether interest in STEM can be triggered within a digital learning environment for adolescent learners. This study seeks to contribute to our foundational understanding of how interest functions within a digital learning environment.

From the educational psychology perspective, interest is both a psychological state and motivational variable. Interest is fluid and dynamic; what triggers interest in one individual may not work for another. For the purposes of this dissertation, interest triggering is defined to occur when a learner shows a willingness to reengage with content, express positive affect, attach value to a subject, reflect about the learning content, or connect content based on prior knowledge or experience.

Since 2016, our team has been developing a customized server in Minecraft that allows for participants to explore hypothetical scenarios of Earth (e.g., Earth on a tilted axis) supported by the National Science Foundation with the goal of designing an interest triggering experience for STEM topics. Participants in 2018 and 2020 were recruited at a local youth center in a Midwestern university town where we advertised our program as a five-day STEM-focused Minecraft summer camp. Selected case studies expressed the highest or lowest interest in STEM and Minecraft mastery in their respective groups on a 5-point Likert scale. Cases draw from a total of five sources: fieldnotes, STEM interest surveys, knowledge assessments, interviews, and self-reported levels of Minecraft mastery.

Fieldnotes provide the contextual information necessary for understanding interest triggering trends across the 2018 and 2020 camps. Surveys revealed the cases' overall interest in STEM as well as specific subtopics (science and technology). Content introduced during short lessons throughout the camp experience were assessed by astronomy knowledge scores and habitability definitions, which indicated change in knowledge. Lastly, interviews provided direct quotes for interest triggers that occurred. Instances of STEM-related interest triggering were first identified through the use of interviews and fieldnotes. Then, these episodes were quantified and categorized to unveil similarities and differences between each case, followed by specific examples of each type of interest triggering episode.

This research provides insights on how a sandbox videogame that enables freedom of choice and peer-to-peer interaction can act as a suitable context for triggering interest in STEM, even for those who expressed low interest in STEM prior to the intervention. Based on the four reviewed cases, a sandbox game that allows for peer-to-peer engagements and freedom of choice served as an effective context for triggering interest. Results showed an increase in interest for those with high Minecraft mastery prior to the intervention and mixed results for those with low Minecraft mastery. Outcomes from this study can be used to study interest triggering in other domains and out-of-school learning contexts and serve as foundation for those examining interest development within digital learning environments.

Results show positive effects of using a sandbox game to trigger interest in STEM for learners with varying degrees of incoming interest in STEM and Minecraft mastery. In three out of four cases, interest in technology improved regardless of changes in interest in STEM or level of Minecraft mastery. In cases of low Minecraft mastery, one-on-one technical support was needed to sustain engagement with content and STEM interest triggers seemed to rely on the unique preferences of learners. For those with high incoming interest in STEM, they exhibited majority explicit/prompted interest triggering episodes, whereas those with low incoming interest in STEM exhibited majority implicit/prompted interest triggering episodes. Future studies on interest triggering should continue to utilize a variety of measures to track changes in interest rather than rely on one type (e.g., using only surveys) and further explore how videogame technologies can be used to study interest development.

Keywords: interest development, sandbox games, videogames, videogame design, STEM learning, informal learning

To my parents

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CHAPTER 1: INTRODUCTION

> *If we can discover a child's urgent needs and powers, and if we can supply an environment of materials, appliances, and resources–physical, social, and intellectual–to direct their adequate operation, we shall not have to think about interest. It will take care of itself* (Dewey, 1913, p. 95).

In the turn of the 20^{th} century, Dewey hypothesized in *Interest and Effort in Education* (1913) that genuine interest was indicated by the captivation and power in an occupation or pursuit. He hypothesized different types of educative interests, mainly those that involve the growth of power, physical activity, constructive activity, social activity, and intellectual activity. Dewey believed in the power that stemmed from realization of meanings from consciously *doing*. He gathered that there was intellectual value in physical activity that had to be learned and in the use of tools that distinguished games and work from play through complex tasks. Social interests had influence over one's overall interests. Intellectual interests, he believed, could be subordinate to the accomplishment of a process, or develop and become a dominant and direct interest. The latter type of intellectual interest was driven by "the sake of finding out something" instead of "thinking things out and discovering them for the sake of the successful achievement of an activity" (Dewey, 1913, p. 82).

We have discovered much about cognitive and affective processes involved with interest development since Dewey's contributions. Interest was largely unrecognized as its own construct by the research community until the 1980's. Since then, there have been numerous empirical studies of interest conducted in classrooms, afterschool workshops, museums, and more over the last century. Many studies have now demonstrated that interest has been shown to serve as an important motivational variable. Interest had been linked to improvements in attitudes and willingness to learn (Potvin & Hasni, 2014), achievement and performance in school (Harackiewicz & Hulleman, 2010), and meaningful engagement with content (Renninger, Ren, & Kern, 2018). A well-developed interest can lead to higher levels of self-efficacy and a decrease in negative self-perceptions (Lipstein & Renninger, 2006) and support development of a deep conceptual understanding than those who lack interest in the subject (Andre & Windschitl, 2003; Renninger et al., 2014). On the other hand, a lack of interest may impede a learner's persistence and willingness to reengage in a subject (Nieswandt, 2007; Sansone, Fraughton, Zachary, Butner, & Heiner, 2011).

With additional scrutiny, it is clear that Dewey's initial thoughts on interest involved motivational variables that differ from interest. For instance, researchers have converged on the distinction between *intrinsic motivation*, or doing something for internal rewards (e.g., satisfaction), from *extrinsic motivation* in which action is taken in pursuit of a reward (e.g., grades, salary). Most recently, scholars have argued that repeated experiences of *curiosity* are vital to the maintaining and deepening of interest (Arnone et al., 2011; Ainley, 2019). Refined technological tools such as fMRI scans show how areas of the brain associated with anticipation of reward are activated during states of high curiosity (Kang et al., 2009).

However, despite these advances, the study of interest and its processes have yet to be explored extensively in digital learning contexts. This is a much-needed research area if we are to utilize modern technology for learning and to consider the ways young learners frequently engage with content in the 21st century. New media technological advances have provided new potential sources of interest, such as instant access to a vast amount of information on the Internet (Arnone et al., 2011) and emotionally evocative experiences (Graesser et al., 2009; Rigby & Przybylski, 2009; Yannakakis & Paiva, 2014). More broadly, scholars have called for the need of innovative approaches for learner engagement in topics such as STEM (Subotnik et al., 2009).

Given the remarkable popularity of videogames, it is worthwhile to investigate whether videogames are capable of triggering interest in STEM. One endeavor in the interest literature is furthering our understanding of how to cultivate the momentary, fleeting presence of interest (situational) to develop into the more stable and enduring form of interest (individual). The primary goal of this dissertation is to unpack the extent to which a science-focused game intervention can impact STEM interest in adolescents. More formally, the research questions posed are:

RQ1: To what extent does a digital sandbox game intervention that enables freedom of choice and peer-to-peer interactions trigger interest in STEM?

RQ2: What is the influence of prior gameplay experience on changes in STEM interest when using a game-based science learning intervention?

In this dissertation, I analyze data collected from 2018 and 2020[1] science-focused summer camps and selected four case studies. These four cases—the top and lowest performers within their groups—were chosen based on their incoming interest in STEM and prior level of Minecraft play experience. This research seeks to serve as a foundation for understanding game features that may be beneficial to learning and to what extent a digital sandbox game that allows for peer-to-peer interactions and freedom from preset goals can help trigger interest in STEM.

The case study methodology suited my investigation as interest triggering phenomena occurs in real-life contexts and multiple factors were taken into account for these four selected cases (Yazan, 2015; Yin, 2002). The evidence used to triangulate interest triggering within these

[1] I chose the datasets I was most familiar with. In 2018 and 2020, I was actively involved in interacting with participants, taking fieldnotes, and collecting survey and interview data, whereas in 2019 I was not on-site or involved in the process of data collection.

cases are as follows: pre- and post-test STEM interest surveys, interviews, scored astronomy scores, definitions for habitability, and self-reported prior experience with playing Minecraft. Following the implementation of these instruments was a delayed follow-up survey that tracked changes in knowledge. The purpose of utilizing a variety of instruments was to capture the authentic experience of participants and to allow readers to make their own generalizations and interpretations (Stake, 1995) while considering the perspective and arguments from the researcher.

Findings from this dissertation serve as a concrete example of the extent in which a carefully designed sandbox videogame intervention can trigger interest in STEM and is the first study of its kind. The cases presented illustrate how the learners' previous experience with a game impacts their STEM learning, which holds practical implications on the future implementations of educational technologies. For example, an instructor interested in making their content more relevant to their students may leverage a customizable computer game. How should the game be customized? What are the features of the game to evaluate for interest and how will they know which features to emphasize?

The early days of stereotyping a videogame player as a 20-something-year-old Caucasian, unmarried male living in his mother's basement have been dispelled by the great shift in demographics of videogame players in the last decade (Dale and Green, 2017). This narrative can be found in the statistics reported by the Entertainment Software Association, a conglomerate of major players in the videogame industry—such as Warner Brothers Entertainment, Microsoft, EA Games, and Bandai—working together to promote games' positive impact on society. In America, 46% of videogame players in 2019 are female (M = 34-years-old) compared to 41% of female players (M = 37-years-old) in 2017 (Entertainment

Software Association, 2019; Entertainment Software Association, 2017). Within the same report and considering this year's pandemic forcing many to socially isolate themselves, 70% of men ages 18-34 reported that games helped them stay connected with friends and family while 55% of women ages 18-34 played videogames for the same reason.

The videogame industry had a record-breaking revenue exceeding $43.4 billion dollars in 2018 (Entertainment Software Association, 2019), demonstrating the reach of the industry not only in America but across the globe. The United States alone had a total of 214.4 million videogame players with 51.1 million (70%) videogame players who are under 18-years-old. The majority of Americans (70%) have had at least one child who plays videogames in their household, and along with the demographic shift, the role of videogames is also changing in American society: nearly three-quarters (74%) of parents believe videogames can be educational for their children and more than half (57%) enjoy playing games with their child at least weekly (Entertainment Software Association, 2019). Based on reports from the Entertainment Software Association from 2017 to 2020, parents in America consistently paid attention to videogames their child plays (90% and above per year).

While researchers in recent years have studied both the positive and negative effects of playing videogames, the overall climate towards videogames for learning has been increasingly positive and speaks to the need for educational technology research for the public. Educators, researchers, and practitioners can all benefit from a deeper understanding of how best to use digital learning tools and environments to promote specific learning outcomes, such as increased interest in a topic. It is my hope that my work contributes to this area and that the sharing of my results and their practical implications will influence the interest triggering design of such educational technologies.

CHAPTER 2: LITERATURE REVIEW

In this literature review, I explore three key areas relevant to my research: the relationship of interest and related motivational variables, trends found across interest triggering literature, and how the STEM field benefits from interest triggering research. First, I define interest and related variables, followed by trends in interest triggers within digital learning contexts. Second, I argue for the beneficial role interest research in particular can play in the STEM field. Third, I make the case for using Minecraft, a sandbox videogame, for STEM interest triggering. Then, I justify the use of a constructivist framework in relation to the nature of sandbox videogames. At the end of the chapter, I discuss what next steps should be taken to further our understanding of interest triggering within digital learning contests.

2.1 Defining Interest

The term ‘interest’ can be interpreted a number of ways. Imagine walking through a modern art exhibit and overhearing the conversations of its attendants—what one may describe as ‘interesting,’ others may label ‘exciting,’ ‘weird,’ or ‘different’ with the same level of enthusiasm. Interest has been defined as a psychological state and a tendency to reengage with particular content over time that develop through the interaction of an individual and their environment (Hidi, 2006; Krapp, 1999, 2007) with strong influence on an individual’s cognitive and affective functioning (Ainley et al., 2002; Krapp, 1999; Renninger & Hidi, 2011; Schiefele, 1991). Studies have shown that curiosity/interest activates the reward circuitry in the brain, in particular the caudate in the striatum, an area that was previously associated with anticipated rewards (Kang et al., 2009; Gruber et al., 2014). The literature on interest commonly distinguished between two types of interest: individual and situational.

Individual interest has been defined as an individual's predisposition to attend to certain stimuli, events, and objects (Ainley et al., 2002; Hidi, 1990; Schiefele, 1991) and as something that develops slowly over time (Hidi, 1990). *Situational interest* has been described as a response to the environment (Ainley et al., 2002) or situation (Krapp, 1999), and an interaction between an individual and his or her environment could lead to the development of a personal interest (Hidi, 1990). The field of educational psychology has traditionally defined situational interest as an affective reaction to stimuli within an environment, which can increase levels of learning (Harackiewicz, et al., 2008; Hidi, 1990; Hidi & Renninger, 2006; Rotgans & Schmidt, 2014, 2017).

Situational interest has potential to develop into an individual interest, a long-term interest that is sustained throughout one's life, as a learner continues to re-engage with a subject in multiple ways (Hidi & Renninger, 2006). For example, someone who is interested in photography might submit their photo into a contest, read online reviews of various camera models, scope out other photographers' portfolios, and ask for feedback on their own work within a photography-focused community. Repeated and consistent exposure to content that triggers situational interest is necessary for the development of individual interest (Rotgans & Schmidt, 2017) as well as for the development of a support network (Renninger et al., 2018).

While the progression of situational interest to individual interest may seem linear and straightforward, the nature of interest triggering is ever-changing and complex. An individual may gain or lose interest based on factors out of their control. In the photography example, perhaps the photographer received their first camera from a family member as a gift, which led to initial interest triggers. Perhaps this individual never considered photography as a hobby, but *merely owning a digital camera* provides substantial opportunities for interest development that did not exist prior to owning a camera.

The factors that influence interest development may sometimes be outside an individual's control. As the hypothetical individual's interest in photography develops, obstacles present themselves. Perhaps the photographer does not have sufficient dues to enter the photography contest, needs to work shifts that overlap with photography club meetings, or receives harsh criticism without a network of support. While those in advanced phases of interest may not be as easily deterred as those in early phases of interest by these obstacles, this example speaks to the complexities and reliance on uncontrollable dynamics involved in interest triggers. Interest development should be understood as an indirect process because the pathway to advanced phases of interest is unclear and varies from one person to the next. In other words, there is no 'one size fits all' approach for interest development.

The presence of situational interest in learning can significantly impact a learner's intrinsic motivation (Chen et al., 2001). In practice, situational interest can be used to accurately predict academic performance in an introductory college level and has shown promise in affecting long-term interest in content for both learners with prior content interest and those with little content interest (Harackiewicz, et al., 2008). A lack of situational interest can be counteracted by well-structured support (Glowinski & Bayrhuber, 2011). More specifically, when a student experiences a loss of interest, the use of tasks, interesting specific content, and establishing relevancy of the content to students' experience and knowledge can help regenerate interest (Tin, 2009). The repeated arousal of situational interest has shown to directly influence the development of individual interest (Rotgans & Schmidt, 2017).

For interest to be established, it is necessary to have the learner's interest *triggered*. Renninger & Bachrach (2015) defined interest triggering as the activation of interest such that engagement is established. They posited, alongside other interest scholars, that interest triggers can be fleeting but provide opportunities for interest to develop into a more advanced and persistent form. Notably, interest triggering differs from piquing a student's curiosity in that interest builds on existing knowledge and develops over time, whereas curiosity is driven by the need to explore the unknown (Renninger & Hidi, 2019). Interest triggering is relevant across situational to individual interest phases, and its continuous occurrence over time is needed to maintain and promote interest. Triggers that work for an individual on the first day may fail to trigger interest in the next; there is a range of ways to trigger learner interest and both the activity and learner characteristics seem to impact the ways that triggering (Renninger & Bachrach, 2015).

The role of interest triggering is crucial to advancing the development of interest. In an attempt to synthesize research on interest development, Hidi & Renninger (2006) proposed a four-phase model: 1) triggered situational interest, 2) maintained situational interest, 3) emerging individual interest, and 4) well-developed individual interest. The model posits that interest can develop from one phase to another with the possibility of interest regressing or disappearing altogether if the interest is unsupported. Scholars have found that the state of interest requires continued interaction with content and can be further developed through a network of support such as teachers, friends, and family (Krapp, 1999; Schiefele, 1991), which supports the phases of interest proposed by Hidi and Renninger.

2.1.1 Differentiating Between Motivation, Engagement, and Interest

Motivation, engagement, and interest influence each other to facilitate learning. While it may seem intuitive to use motivation, engagement, and interest as interchangeable terms, there are several distinctions between these variables. In this dissertation, *motivation* is defined as an individual's response to their social and cultural circumstances, specifically the will to engage, which in turn influences the individual's goal settings and working to accomplish those goals (Renninger et al., 2018; Hidi & Harackiewicz, 2000; Wigfield et al., 2006). *Engagement* refers to an individual's behavioral, cognitive, and/or affective responses in the context of participation (Christenson et al., 2012; Fredricks et al., 2004; Renninger et al., 2018; Shernoff, 2013).

Lastly, *interest* describes the individual's relationship with specific content (e.g., computer science), including the individual's psychological states during engagement with that content and the likelihood of reengagement with that content over time (Hidi & Renninger, 2006; Renninger & HIdi, 2016; Renninger et al., 2018). Renninger and Bachrach (2015) observed that there has been little cross-referencing between the research of interest development and engagement. It is my hope that this dissertation can serve as a guide for those curious about the distinctions and relationships between motivation, engagement, and interest, ultimately leading to empirical studies that enrich the literature and add a variety of disciplines that focus on interest as its own unique construct.

Motivation and Engagement

The relationship between motivation and engagement seems reciprocal in nature (Buil et al.. 2019; Renninger & Bachrach, 2015; Singh et al., 2002) and develops from the interaction between an individual and the environment (Barron, 2006; Reschly & Christensen, 2012; Hidi & Renninger, 2006). Research has shown that throughout the ages of 5- to 15-years-olds, extrinsic motivational reasons (e.g., “I want to please my parents”) replace intrinsic motivational reasons (e.g., “I want to study hard to get into a good school”) for task engagement in school (Chandler & Connell, 1987). Similar findings have been found through the progression of third through eighth or ninth grade (Lepper et al., 2005; Cordova & Lepper, 1996; Newman, 1990; Tzuriel, 1989; Harter, 1980, 1981). It appears that the more time children spend in schools in the United States, the less interest they have in learning for its own sake (Lepper & Henderlong, 2000). Thankfully, increasing motivation can lead to engagement in academic tasks, which is related to achievement (Banks et al., 1978; Dweck, 1986) and stresses the importance of motivational variables such as goal setting, self-efficacy, and self-regulation (Renninger & Bachrach, 2015) in classrooms.

Digital games have been found to foster intrinsic motivation (Birk et al., 2016; Buil et al., 2019; Dickey, 2007). In fact, a study by Tuzun et al. (2009) discovered that the use of a geography-focused game for elementary schoolers resulted in statistically significant higher intrinsic motivations and statistically significant lower extrinsic motivations for those enrolled in the game-based environment as opposed to regular classrooms. At the collegiate level, Buil et al. (2019) found that both intrinsic motivation and engagement enhanced the development of undergraduates’ skills (e.g., decision making), teamwork, and working under pressure.

Interest and Engagement

What engagement occurs prior to triggering interest needs to be further explored. It is still unknown whether each individual is engaging in an activity in the same way and of which manner he or she is engaged in (cognitively, behaviorally, affectively), and the impact of varying forms of engagement on continued engagement (Renninger & Bachrach, 2015). The state of interest is a key element of engagement (Ainley et al., 2002) and the constructs of engagement and interest have been defined as curiosity (Arnone et al., 2011). Arnone and colleagues argued that without engagement, curiosity cannot progress into a well-developed interest. They also stated that technology, in which I argue digital games are categorized, can play a bigger role in triggering interest and sustaining engagement. While studies have focused on the measurement of engagement using games (refer to Boyle et al., 2012 for a systematic review; Burke et al., 2009), there are few studies that distinctly measure interest as its own variable, and in conjunction with other motivational variables such as engagement.

Motivation and Interest

The five characteristics of interest as a motivational variable summarized from the past 30 years of interest studies by Renninger and Hidi (2011) are the following:

> 1) interest refers to an individual's focused attention and/or engagement with particular events and objects,
> 2) interest involves a particular relation between a person and the environment that can be sustained through interaction,
> 3) interest has both cognitive and affective components,
> 4) a person is not always aware that his or her interest is being triggered, and
> 5) brain activations differ when a learner is and is not engaged with interest.

Renninger and Hidi continued to state that interest had been recognized as a critical motivational variable that guides attention, facilitates learning across content areas, is applicable for learners of all ages, and develops through experience. In addition, they stated that interest shared a reciprocal relation to goals, self-efficacy, self-regulation, and achievement value, all of which are motivational variables. Using these definitions, there is a clear overlap between interest and motivation, the latter of which draws upon the interaction between an individual and his or her environment.

Early research literature on interest development is largely focused on proposing different models of interest rather than possible assessments in real world settings (e.g., Hidi & Renninger, 2006; Renninger & Hidi, 2011; Schraw & Lehman, 2001). Studies concerning interest assessment are largely text-based, testing relationships between interest and text call (cf. Hidi & Baird, 1988; Schraw et al., 1995; Schiefele & Krapp, 1996; Sadoski, et al., 2000) and focused on the seductiveness, vividness, and coherence features of text (Wang & Adescope, 2016; Schraw & Lehman, 2001). It is evident that research on interest needs to move beyond text-based studies.

2.2 Interest Triggers in Digital Learning Environments

Several literature reviews have concluded that videogames, when designed in ways that reflect the science of learning, generally have a positive impact on learning (Kirriemuir and Mcfarlane, 2004; Dondlinger, 2007; Papastergiou, 2009; Connolly et al., 2012; Nebel et al., 2016; Wouters & van Oostendorp, 2017). Do games have the power to trigger interest in the content areas they emphasize or do games just trigger interest in playing the game but nothing more? More research is needed to understand when videogame learning environments triggers interest, how that interest is triggered and to what extent. The question of which genre of videogames (e.g., shooter, puzzle, sandbox) is best suited for learning and interest development also remains unknown at this time. However, the reviews cited earlier in this chapter sheds light on the types of games compatible with learning goals, such as collaborative games to learn mathematic concepts.

Generally speaking, the literature on interest is scattered across disciplines and the construct does not always receive the theoretical rigor it needs. Interest as an aspect of cognition has historically been neglected in favor of curiosity, motivation, and flow until the 1980's (Hidi, 1990; Krapp, 1999). As far as I am aware today, there is not a literature review that examines the relationship between video games and interest. Existing literature reviews focus on mostly positive learning outcomes from games (Connolly et al., 2012; Boyle et al., 2016; Hainey et al., 2016), the use of specific games or game features in education and research (Dondlinger, 2007;

Evans et al., 2015; Qian & Clark, 2016; Nebel et al., 2017), and cognitive perspectives such as aggression and immersion (Anderson & Bushman, 2001; Ferguson, 2007; Hamari et al., 2016).

2.3 The Benefits of Interest Research for STEM

The necessary skills for workers in the 21st century require a combination of science and mathematics skills, creativity, and information literacy, as well as the ability to problem-solve and collaborate (Breivik, 2005; Annetta, 2008; Storksdieck, 2016; Dede, 2010). Maltese et al. (2014) surveyed nearly 8,000 individuals from 70 community colleges, colleges, and universities and found that those who complete STEM degrees have varied histories and that interest triggering happened across a wide range of ages.

The literature shows that the majority those who chose to pursue a STEM degree in college made the choice prior to entering high school, which suggests that early experiences were critical for recruiting, but the timing of STEM interest triggering remained unclear (Maltese et al., 2014). Maltese and colleagues stated that early experiences were dominated by free-choice learning activities—building/tinkering, playing, exposure to media, activities with family—and as school becomes more formalized, classes become the most cited type of interest trigger.

Diversity has been a pressing and long-term issue in the American workforce where minorities and women are likely to prematurely leave the STEM pipeline (Griffith, 2010; Lyon, Jafri, & St. Louis, 2012; Watt et al., 2006). In 2013-14, 17% of the 1.8 million bachelor's degrees awarded to U.S. citizens were in STEM fields (National Center for Education Statistics, 2017). However, the rate at which STEM degrees were awarded to Black, American Indian/Alaska Native, Hispanic, and Pacific Islander students and for those who identified as female were still alarmingly low in proportion (National Center for Education Statistics, 2017; Cromley, et al., 2016; Maltese & Cooper, 2017). A number of factors played into STEM retention, such as positive or negative experiences in the college classroom and performance on introductory courses (Maltese et al., 2014). While there were multiple pathways to STEM careers, there were with no clear preferential pathways (Maltese et al., 2014).

It is evident that the United States would benefit from specific strategies to generate excitement around STEM fields and future career opportunities from its youth population, especially those who are underrepresented and identify as female, if the country desires to increase its domestic workforce in such fields. Recently, researchers argued for the use of videogame to promote interest in STEM (Ball et al., 2018; Jenkins, 2014; A. Lee, 2015; Mayo, 2009), however further work is needed to develop applicable research procedures and learning structures across a diverse range of students.

While some reviews have shown mixed results for educational games, there have been many successful examples of using videogames for STEM learning. Educational technologies commonly require use of logic, memory, problem-solving, critical thinking skills, and discovery (Annetta, 2008; Turkay, et al., 2014). Findings from a five-week summer program in a low-income area of Chicago suggested that game-based learning can promote teamwork and collaboration and the narrative aspect of games providing relevancy of STEM to the real-world (Gilliam et al., 2017). Games have a number of features that can be advantageous to leaners: adapting to the pace of the user, offering simultaneous presentation of information in multiple visual and auditory modes, effectively scaffolding complex tasks, and reinforcing information acquisition (Mayo, 2009). Videogames in particular may serve as a textbook replacement as text in videogames is tends to progress the narrative, easy access, and allow for distance education (Annetta, 2008).

2.4 The Case for Using Minecraft for STEM

Videogames, often which involve STEM concepts in one form or another, are one potentially strategic approach to the cultivation of interest on a larger scale. The videogame industry has almost an universal reach, valued at over one billion dollars and generating more profit than the music industry and Hollywood combined (Kirriemuir & Mcfarlane, 2004; Ell, 2018). Videogames have served as an applicable context for students to engage with and form deep understandings of STEM subjects in a manner suited for the 21st century workplace (Games & Kane, 2011; Gilliam et al., 2017; A. Lee, 2015) and have been linked to increase or maintain intrinsic motivation for learning (Gee, 2004; Habgood & Ainsworth, 2011).

A nationally representative sample of young adults in America revealed that the frequent use of computer or video games was strongly related to students' STEM major selections in 4-year postsecondary institutions after accounting for demographic characteristics and math achievement scores (Lee, 2015). Moreover, videogame experiences have shown to influence STEM attitudes through the increase of computer self-efficacy and decrease of emotional costs for predominantly early adolescent minority students (Ball, Huang, Cotten, & Rikard, 2018). It seems likely that games used for STEM learning would have some influence over learners' attitudes and feelings toward STEM topics, however the question of *how* to design games intentionally to trigger interest in STEM remains an open scientific question.

Sandbox games like Minecraft, which offers learners engagement both in and outside the classroom, can be tailored to enhance subject interest (Pusey & Pusey, 2015) and possesses the technical flexibility and freedom to study interest development (Gadbury et al., in-press; Lane et al., 2017; Yi & Krist, 2019; Yi, 2021). The game offers two modes: 1) in creative, players can collaborate with each other to build and 2) in survival, players can compete with each other and/or against monsters. Minecraft has been used in a variety of ways for STEM education and has been emerging as an ideal environment for educational research (Lane & Yi, 2017), used for teaching topics such as:

- sustainable planning (West & Bleiberg, 2013; Opmeer et al., 2018),
- architecture (Valls et al., 2016),
- computer programming (Bayliss, 2012),
- artificial intelligence (Zorn et al., 2013),
- engineering education (Zhu et al., 2019),
- spatial geometry (Foerster, 2017), and
- spatial training (Nguyen & Rank, 2016).

The possession of spatial abilities and undergoing spatial training is likely helpful in improving STEM learning since students who struggle to think well spatially have more trouble getting through early courses that lead to dropout (Uttal & Cohen, 2012).

As of 2018, Minecraft is the dominant title interacted by children ages 3-12 in America from a sample of 753 responses (37% parents of 3- to 5-year-old children, 32% parents of 6- to 8-year-old children, and 31% parents of 9- to 12-year-old children) collected by Mavoa, Carter, and Gibbs (2018). A survey of 753 parents of children ages 3-12 in residing in Melbourne showed that boys were more likely to play Minecraft than girls early on, however this difference is negated at age 9, and the effect is reversed at age 11 likely due to boys moving onto play different game titles (Mavoa et al., 2018).

It is important to bear in mind that the use of videogame tools may not appeal to all learners especially those with little to no experience with those tools and can present specific technical challenges (Bayliss, 2012). For instance, players with no previous experience with Minecraft may experience frustration when asked to complete an in-game task or find the task intimidating (Bayliss, 2012). Experienced players raise their own set of considerations as well, as they may revert to their previous actions or habits as they have experience with the game (Nebel et al., 2016) and, in turn, pre-existing ideas of players may persist even when the current environment contradicts them (de Jong, 2006). Proficient players may dominate in a collaborative or competitive scenario (Hanghøj et al., 2014; Marklund et al., 2013) or may experience frustration when the version of Minecraft implemented in a study differs from the original gameplay (Nebel et al., 2016). Experienced players may likely engage in off-task behaviors if the task presented lacks sufficient amount of challenge or novelty.

2.5 A Constructivist Framework

Scholars have argued that the design and development of videogames, as opposed to playing them, uses a constructionist approach to learning with games (Robertson et al., 2004; Robertson & Good, 2005; Dondlinger, 2007). Actions such as modding, the altering of content within an existing game, play to the constructivist notion that knowledge is constructed and that the creation of personally relevant products contribute to new meanings and understandings (El-Nasr & Smith, 2006). Arguably, these creations require a level of productive failure to learn the mechanics and functions of the game and offer an opportunity for hands-on experience, feedback for others, companionship, competition and collaboration, and immersion.

When learning with videogames is presented with instruction or an expert player, this leads to opportunities for conversation and guidance and feedback from others. Kamberelis and Dimitriadis (2005) eloquently described the creation of meaning through constructivism as "a function of our engagement with the world," going on to state:

> Meaning is not discovered but is constituted or constructed in interactions with objective (but not inherently meaningful) reality. Among other things, this means that the meaning of reality is likely to be constructed differently as a function of the position of perspective taken by a culture, a social formation, or an individual person. Knowledge and meaning are always partial and perspectival (p.14).

Participants in this dissertation were allocated time to design and construct their own creations and took on the role of design partners, improving the technology being consumed as well as gaining educational benefits (Steiner et al., 2006). Instructors inquired about participants' creation processes and the intent behind such creations and were asked for feedback their camp experience (e.g., what they liked or did not like or specific features they would like to see in future reiterations).

The answers sought through the proposed case studies for my dissertation work relies on the interpretations of the learner's experience (e.g., science knowledge gained, in-game and real-life behaviors) and sensemaking within a specific learning context for select individuals (a summer camp videogame intervention) in relation to changes in STEM interest. The case studies presented are a specific, complex, and functioning thing that acts like a "bounded system" that draws attention to an object or person rather than an event or process (Stake, 1995, p. 2).

The proposed case studies examine an underlying phenomenon within real-life context and the case study methodology is especially useful "when the boundaries between a phenomenon and context are not clear and the researcher has little control over the phenomenon and context" (Yin, 2002, p. 13). In other words, case studies can be a comprehensive research strategy that takes multiple factors into account when other strategies such as survey or history are not sufficient to inquire into the case of interest for researchers (Yazan, 2015; Yin, 2002). As previously mentioned, the traditional measurement for interest has mostly been based on self-report. In this dissertation, I utilized five measures (including self-report) to present four cases of adolescent learners and their changes in STEM during a game-based science intervention.

The focus of this dissertation is to construct a clearer reality of learner participants and provide sufficient "good raw material" for readers to make their own generalizations through descriptions and sophisticated interpretations (Stake, 1995, p. 101-102). Constructivism befits the art of case studies as the paradigm focuses on informed reconstruction of vicarious experience as opposed to other traditional paradigms, such as positivism and positivism approaches, that seek to establish verified hypotheses as facts or laws (Lincoln & Guba, 2003).

2.6 Exploring Interest Triggers in Digital Contexts

Videogames, in the same vein as real-life interest triggering programs, can be designed with opportunities for conversation and guidance, feedback from others, hands-on experience, and offer structural support for learners. Videogame designers have the freedom of creating an experience that specifically build these aspects into the game. For players, videogame environments can serve as a safe space to imagine and experiment with actions (Barab et al., 2010; Stevens et al., 2008; Yi, 2019) and appearances (McCreery et al., 2012; Vasalou & Joinson, 2009; Vermeulen et al., 2014; Villani et al., 2012) that are otherwise unlikely in the real-world. We know little about how the change in learning environments, from the physical to digital, impacts interest development. The understanding this phenomenon could lead to novel and meaningful learning experiences that effectively trigger interest, and perhaps one day to the creation of individual-specific interest triggering learning technologies.

Before we can begin to completely reimagine digital learning experiences, further empirical work is needed to better understand successful interest triggering design features and the development of interest within digital learning environments. I aim to contribute to this research area through this dissertation. Replicating what we understand about the physical world into digital environments is a necessary next step to test if and what interest triggers work across these two environments (e.g., one can feel the texture and temperature of a starfish in a touch pool as opposed to interacting with a starfish in a videogame).

2.7 Chapter Summary

In this chapter, I provided a brief overview and definitions for foundational aspects of this dissertation. The primary concepts covered include:

- **What's the Difference between Motivation, Engagement, and Interest?** Motivation is the will to engage, to set goals, and to accomplish those goals. Engagement is the behavioral, affective, and cognitive responses to an individual's context of participation. Interest is the individual's voluntary engagement and reengagement with particular content over time. These variables should be distinct when being reported in empirical works.
- **Individual vs. Situational Interest.** *Individual interest* is a person's predisposition to focus on certain stimuli, events, and objects and develops slowly over time. *Situational interest* is a person's response to the environment or situation. Repeated interactions between the person and content or environment is necessary for situational interest to develop to an individual interest. The path from situational interest to individual interest, while seemingly linear, is one that is highly individualized and involves multiple external factors.
- **Current Interest Triggering Trends.** The current trends of interest triggers between physical and digital interest triggering programs include conversation and guidance, feedback from others, hands-on experience, and structural support. Today, little is known about interest triggering within digital learning environments, and this dissertation contributes to its initial understanding.
- **Using Minecraft to Investigate STEM Interest Triggers.** The literature on interest can inform on ways to improve STEM recruitment and retention in the United States. The use of a popular videogame, Minecraft, is one method of triggering interest for those with little to no interest in STEM.

CHAPTER 3: THE CONTEXT OF SUMMER CAMPS

Before diving into the fine grain details of the study's results, the focus of this chapter focuses on the larger context of the summer camps. Stake (2013) described a case as composed of an inside and outside. Certain components of the case are within the boundaries of the case. Other components, such as the context and environment, lie outside the case. While the inside of cases (e.g., personal relationships) are covered in the next chapter, in this chapter we explore the contexts surrounding these cases (representing the outside). Importantly this speaks to the suitability of using the case study methodology to study interest triggering.

To briefly list the main camp activities, we planned for participants to explore of hypothetical planets, followed by a whole group discussion explaining the various phenomena participants noticed (e.g., high wind speeds). At the end of each day, participants were provided free time to work on Minecraft projects of their choosing (refer to Chapter 4 for full descriptions of each camp activity).

3.1 Defining Interest Triggering Episodes

The measures used to analyze interest triggers across camps were drawn from fieldnotes. The unit of analysis I chose is an *episode*, defined as a moment when interest triggering of STEM topic(s) occurs. Interest triggering episodes serves as our exploratory approach in identifying and categorizing different types of interest triggers in an informal and digital learning environment. Fieldnotes were analyzed for interest triggering episodes across all participants using our modified coding scheme based on the work of Renninger et al. (2019). As previously mentioned, interest triggering consisted of one or multiple of the following indicators: expression of positive affect, willingness to reengage, a sense of the content value, reflections about the content, and the ability to find connections to content based on existing ills, knowledge, or prior experience (Hidi & Renninger, 2006; 2019). The selection of cases occurred after fieldnotes were recorded, and consequently, fieldnotes were skewed toward certain participants and their utterances and behaviors over others (details discussed in Section 4.7).

We based our work on Renninger and colleagues' (2019) analysis of interest triggers of middle school-aged learners in an out-of-school biology workshop context. Notably, they adapted literature from different content areas such as reading or math for the science workshop context. I, in a similar attempt, adapted the codes from Renninger et al. (2019) to a STEM-focused videogame learning context and stayed open to any additions to the coding scheme that may arise.

Renninger et al. (2015) used a five-step content analysis on existing interest literature and theory and developed eight codes describing triggers for interest within the workshop context: *autonomy, challenge, computers/technology, group work, hands-on activity, instructional conversation, novelty,* and personal *relevance*. More recently, Renninger et al. (2019) updated their descriptions for their original findings and added the following to the initial set of codes based on further review of the interest literature*: affect, character identification*, and *ownership* (refer to Table 1 for definitions). The source of interest triggers for my dissertation were mostly based on reactions and the experience of camp content rather than on contextual or previous experiences. However, codes such *as personal relevance, ownership, challenge*, and *character identification* tended to rely more on the latter.

In our modified scheme, instances not captured in Renninger and Bachrach's codes were labeled *unknown* and analyzed for patterns and themes using MAXQDA, a qualitative data analysis software most suited to coding interviews, focus groups, and other text-based data. The new codes that emerged were the *intent to reengage; personal relevance – family influence;*

Table 1

Potential interest triggers for interest in biology from Renninger et al. (2019)

Triggers for Interest	Working Definition
Affect	Heightened emotion that emerges during activity or some aspect of an activity.
Autonomy	Learner-directed activity, often involving answering a personal question.
Challenge	Content, skills, or anything else that is difficult for the learner.
Character identification	Seeing oneself as a scientist (or other relevant character).
Computers, technology	Work with computers or another form of technology.
Group work	Work with others, where others are peers and not the instructor.
Hands-on activity	An activity (or component of an activity) that is interactive or involves the use of one's hands.
Instructional conversation	A conversation that engages content and enables a learner to each a new understanding.
Novelty	Anything that is new, including new insight about something that is familiar.
Ownership	A learner's feeling that some aspect of an activity is "his" or "hers" or belongs to him or her.
Personal relevance	A connection between an activity (or aspect of an activity) and a learner's past experience.

computers/technology – popular media, Minecraft learning, and *Minecraft play* (discussed in detail in Chapter 5). Data analysis was a hybrid approach of mostly top-down and potential for bottom-up using a four-step analysis process (details in Section 4.3.1).

3.2 Interest Trigger Trends During Summer Camps

Based on our coded data, more interest triggering events were identified in the 2020 data (N = 45) than the 2018 data (N = 28). In 2018, six interest triggers were absent from the program (*character identification, autonomy, popular media, family, hands-on activity*, and *novelty*) whereas the 2020 camp had five interest triggers absent (*computers/technology, popular media, hands-on activity,* and *family*).The absence of *popular media* and *family*, codes initially developed to code interviews, illustrated that participants did not refer to STEM-related popular media or mention STEM-related stories involving families to their peers during camp. *Hands-on activity*, as defined by Renninger et al. (2019), describes an activity that involves the use of one's hands, which was irrelevant in our game-based camp context. However, the inclusion of hands-on activities in future iterations of the camp has potential to increase the total amount of interest triggers. The absence of other codes is discussed in detail below.

3.3 Initial Camp Interest Triggers

Figure 1

Screenshot of WorldPainter

In 2018, our team incorporated tutorials on WorldPainter, a third-party tool that allowed for mass construction and manipulation of Minecraft terrains, into our camp schedule (Figure 1). Participants were initially receptive to WorldPainter upon introduction and were less enthusiastic during the follow-up WorldPainter tutorial. Interest was triggered most during free time, where the majority of codes were present, but surprisingly not *autonomy*. The second activity that triggered the most interest was the Redstone tutorial, which offered *challenge, Minecraft learning, instructional conversation*, and a willingness to *reengage in the topic*.

Table 2

Triggers by topics of 2018 camp schedule

Camp schedule	Affect	Ownership	Challenge	Computers/ Technology	Computers/ Technology – Minecraft learning	Computers/ Technology – Minecraft play	Groupwork	Instructional conversation	Personal relevance	Intent to reengage
Introduction and camp orientation										
No Moon map					X	X		X		
No Moon discussion										
WorldPainter tutorial I		X		X					X	X
Skin customization	X		X	X						
Colder Sun map					X		X			
Colder Sun discussion								X		
WorldPainter tutorial II								X		
Skin customization (cont.)										X
Tilted Earth map					X					
Tilted Earth discussion								X		
Redstone tutorial			X		X			X		X
Free time	X	X			X		X	X		X

The following interest triggers were not present in the camp: character identification*, *autonomy*, *computers/technology – popular media*, *hands-on activity*, *personal relevance – family*, and *novelty*.

Table 3

Triggers by topics of 2020 camp schedule

Camp schedule	Affect	Character identification	Ownership	Autonomy	Challenge	Computers/ Technology – Minecraft learning	Computers/ Technology – Minecraft play	Groupwork	Instructional conversation	Novelty	Personal relevance	Intent to reengage
Introduction and camp orientation	X											
Avatar customization				X								
Launch base								X				
Moon base	X		X	X						X		
Earth map			X	X						X		
NOVA Lab	X	X						X		X		
No Moon map						X	X	X	X			
No Moon discussion									X			
Colder Sun map						X	X					
Colder Sun discussion		X				X			X	X	X	
Redstone tutorial					X	X	X	X	X			
Tilted Earth map							X		X			
Tilted Earth discussion									X		X	
Exoplanets	X				X				X			
Free time			X	X		X	X	X	X			X

*The following interest triggers were not present in the camp: *computers/technology*, *computers/technology – popular media*, *hands-on activity*, and *personal relevance – family*

The *intent to reengage* occurred more often in 2018 (n = 4) than in 2020 (n = 1). Participants in 2018 expressed the *intent to reengage* during the first WorldPainter tutorial (but not the second), during the Redstone tutorial, during the second skin customization session that participants specifically requested, and during free time. Free time portions of the camp across five-days were counted as one activity on Table 2 and 3. In 2020, the *intent to reengage* was only expressed during free time. This may indicate that the 2020 camp schedule was better streamlined than the 2018 camp schedule; rather than requesting previous activities, some of which were not on the original agenda, participants in 2020 may have felt more satisfied with the overall flow of activities.

Upon further inspection, the types of interest that were triggered in 2020 that were missing from 2018 were crucial to a cohesive experience: *character identification, autonomy*, and *novelty*. Participants in 2020 were able to engage in interest triggering activities that were learner-directed, provided new insight or aroused curiosity, and opportunities to see oneself as a scientist. To construe the 2018 camp as uninteresting would be a misapprehension. There were still many successes, such as consistency of instructional conversation during the map and discussion activities; in-game learning occurred across all map explorations and the Redstone tutorial; and the clear desire from participants for skin customization was crucial in improving future camp schedules. In 2018, we were able to ascertain what appealed the most to participants and change the design of our camp to better meet those needs.

3.4 Developing More Interest Triggering Opportunities

Case 1: *[…] the high schoolers said, it's not even that fun and I said, and then the first day. I was like, "Oh, this is about to be boring." I said, "What? It's not boring." I like this.*

In 2020, Case 1 was enthusiastic about returning to next year's camp, cutting my questions short by saying, "No, I didn't even let you finish. If I hear my mom say they doing Minecraft. I'm coming." This eagerness contrasted with some of his high school peers, few who have attended the Minecraft camp every year since middle school. I asked one of the returning high school participants why she decided to re-enroll and she replied, "It was my mom's decision," which echoed her sentiment two years earlier when she expressed during camp that she was unwilling to participate and was "forced" to by her guardian. Our camp was designed for adolescent learners between the ages of 10- through 13-years-old and was not designed to be repeated, meaning the returning high schoolers experienced similar camp schedules every year.

Figure 2

Screenshots of Launch Base, Moon Base and the Exoplanet Gliese (top to bottom)

Our goal when revising our camp was to develop more opportunities for interest triggering. The Launch Base, Moon Base, and Exoplanet map additions, in place of WorldPainter, was a crucial difference between the camp schedules (Figure 2). The choice to exclude WorldPainter, a program that functions outside of Minecraft, explains the absence of the computers/technology code from 2020 (all other computers/technology codes function within Minecraft). The Launch Base served as an interactive introduction to our server; the play is spawned in front of a building filled with non-person characters (NPC) such as researchers and maintenance workers, and the basement holds a minecart that leads the player to a rocket launch site.

Upon entering the rocket, the player is then transported to the Moon Base map, where there is a noticeable difference in gravity. The player is greeted by the NPC Roger, an astronaut who teaches the player about completing quests around the Moon Base, and the player is prompted to equip a spacesuit before venturing onto the Moon. Exoplanets feature three different hypotheticals to explore (Cancri, Trappist, and Gliese), including a planet completely covered in ice on fire. Lastly, another new addition in 2020 was our partnership with NOVA Labs to help prototype an early version of their astronomy-focused game through small groups.

The new additions to the 2020 camp contributed to overall feelings of *affect, character identification, ownership, autonomy*, and *novelty*. For instance, there was a general enthusiastic response when Dr. Lane asked if everyone wanted to try the minecarts discovered by one participant in Launch Base. Upon reaching Moon Base, one participant exclaimed, “This part is so cool!” During the NOVA Labs session, a participant asked to confirm that we were the makers of the game in a tone of disbelief and said, “I like how it’s designed.” *Groupwork* was also a more frequent interest trigger in 2020 than 2018. Based on interest triggers identified in fieldnotes, players were generally eager to help one another transition from one map to another, kept each other on track during NOVA Labs, and worked together on constructing a rollercoaster during free time.

Another source of data served as evidence of interest triggers across camps was participants' in-game observations. While visiting each hypothetical world, we asked participants to place signs about what they observed. In-game observations counted towards one's total if it was on topic (related to our camp or STEM) and not a duplicate statement. We created a custom command that players could use to find the temperature, wind speed, and pressure relative to their location in-game. Some chose to utilize this feature and reported their findings (e.g., "the temperature here is 80.41F!"), while others focused more on factual statements (e.g., "the trees are very tall"). In 2018, Case 2 made 8 observations while Case 3 made 9 observations. In 2020, Case 4 made 11 observations and Case 1 made 93 observations. The case with the lowest incoming STEM interest and Minecraft mastery from 2020 was able to make more observations than both participants in 2018. This could mean that the 2020 camp featured more interest triggering maps. However, it is also possible that having more content led to more opportunities for interest triggering.

CHAPTER 4: RESEARCH DESIGN AND METHOD

Thus far, I have argued that further research is needed to uncover the design, impact, and effectiveness of interest triggers in digital learning environments. To help fill in these gaps, my dissertation focuses on the impact of a sandbox game intervention on STEM interest and the influence of an individual's prior gameplay experience in relation to their STEM interest. In this chapter I review some of the important aspects of my research context and provide an overview of the methods used to analyze my data.

This study is part of a National Science Foundation project at the University of Illinois at Urbana-Champaign titled Fostering Enduring Interest in STEM through Exoplanet Education and Interactive Exploration and Creation of Potentially Habitable Worlds. The goal of this project is to advance the science of designing technologies for promoting interest in STEM and informal astronomy education. My specific focus is on unpacking the various influences on interest that may be in play and elaborating on interest triggering events that occur with a selected group of participants.

The current phase of the project is to develop simulations of hypothetical worlds based on what-if questions (e.g., what if the Earth had no Moon?) and feasible models of known exoplanets. Our project aims to provide learners an opportunity to understand the challenges of finding a habitable world and learning about what is needed to survive there. In 2020, we partnered with PBS Nova Lab to help them develop a complementary web-based science activity with the goal of teaching players about how planets are formed and the requirements for supporting life.

Participants of the 2020 camp were invited to play test the PBS NOVA Lab science game and think aloud. The intention behind these astronomy- and STEM-related digital learning activities, from Minecraft to PBS NOVA, was to act as potential interest triggering events for STEM. While we have collected data across different learning contexts—such as museums, makerspaces, and private academies—in this dissertation, I focused on our data collection from a youth center.

4.1 Participants

Participants were recruited from the Urbana Neighborhood Connections Center (UNCC), a center largely serving underrepresented youth in a Midwestern university town, for one-week summer camps in June 2018 and July 2020. We established our relationship with UNCC through Dr. Jeff Ginger, a co-principal investigator on the NSF project and a past director of a university-affiliated makerspace. Funding for research and provided materials (e.g., headphones, laptop) for both camps were covered as part of the National Science Foundation-funded project and with the support of the Champaign-Urbana Community Fab Lab, who provide technical support for UNCC. Participants were informed that we were conducting research on how videogames could help in learning, and possibly even influence the use of games at school. While participants were unaware that the study was focused on interest development, we consistently expressed our goal to generate excitement for science.

The self-reported demographic for these camps were predominantly African American (11 out of 16 in 2018; 4 out of 7 in 2020) among others (1 American Indian or Alaskan Native, 2 White or Caucasian, 2 biracial in 2018; 1 White or Caucasian and 2 biracial in 2020). It is suspected that in 2018 a participant selected 'American Indian or Alaskan Native' based on seeing the word, 'American,' and confusion about the word 'ethnicity' based on past questions received from younger camp participants. The target age group for our intervention was between 10 to 13 years old, as interest in STEM tends to be established prior to entering high school

(Faber, 2013; Lyon, 2012; Sadler et al., 2012). The average age of participants in 2018 and 2020 was 12 years old. Participants' self-reported gender was mostly female in 2018 (63% female) and was distributed almost equally in 2020 (43% female).

Traditionally, this summer camp intervention took place face-to-face, however the outbreak of COVID-19 and issue of social distancing placed restrictions on how data was collected in 2020. In the end, the camp was a hybridization of the camp participants going to UNCC in-person while the research team met participants remotely on Zoom. While the contexts in which learning takes place is of importance, the focus of this dissertation remained on STEM interest in a digital learning environment.

4.2 Method

RQ1: To what extent does a digital sandbox game intervention that enables freedom of choice and peer-to-peer interactions trigger interest in STEM?

To address RQ1, I analyzed several measurements related to interest triggering: coded interviews and fieldnotes, STEM interest surveys, knowledge assessments, and self-reported level of Minecraft mastery. Interest triggers are often identified by researchers using qualitative data, however the advantage of using qualitative and quantitative measures together for data analysis is that one measurement addresses the weakness of another. For example, while numerical assessments track changes in interest, interviews offer verbal explanations that goes beyond numerical outcomes; tests provide us with an understanding of the before and after of an intervention, whereas interviews and fieldnotes provide insight of how content is perceived and understood by participants.

First, interest triggering that occurred within interview transcripts were sectioned into episodes, then analyzed based on the following categories: spontaneous utterances by the participant versus prompted responses by the interviewer and explicit versus implicit utterances of interest by the participant. Following the definition of interest by Hidi and Renninger (2006; 2019), interest triggering consisted of one or multiple of the following indicators: expression of positive affect, willingness to reengage, a sense of the content value, reflections about the content, and the ability to find connections to content based on existing ills, knowledge, or prior experience. All episodes identified in this dissertation were STEM-related.

Explicit episodes indicated that interest was directly mentioned by the interviewee whether spontaneously (e.g., "This camp is interesting") or prompted by the interviewer (e.g., "What is your favorite class in school?). *Implicit episodes* illustrated an indication toward interest; however, verbal mentions of interest were not used by the interviewee. Examples of implicit episodes could include questions expressing curiosity towards instructors or self-reports of experiencing a particular activity as fun or enjoyable without mentioning the word 'interest.' Learners, especially in early phases of interest development, may not be aware of interest being triggered during or after interactions with content. Importantly, implicit responses may suggest that interest is present for learners in early phases of interest.

Furthermore, a *spontaneous episode* was where the participant willingly volunteers in their response to offer additional information that goes beyond the prompt asked. In the same sense as an implicit response, spontaneous responses may indirectly suggest interest is present in learners who expressed little to no interest in STEM prior to the intervention. Conversely, a participant who expressed high interest in STEM prior to the intervention may deliberately offer additional information to the interviewer and affirm their interest in STEM. A *prompted episode* indicated that the participant answered the interviewer's question and did not offer any additional information. Next, interest triggering episodes were coded into specific *types* of interest triggers using codes developed by Renninger et al. (2019) for out-of-school learning contexts. The *frequency* of interest triggering episodes and the *types* that occur were informative to how and what interest was triggered during the out-of-school program.

> RQ2: What is the influence of prior gameplay experience on changes in STEM interest when using a game-based science learning intervention?

To address RQ2, I aimed to elaborate on learners' changes in STEM interest and Minecraft mastery using checklist matrices. A checklist matrix, advocated by Miles and Huberman (1984) in a highly cited textbook on qualitative methodology, aids researchers in noting patterns and themes when analyzing qualitative data and is used to study a single underlying variable, in this case interest in STEM. Multiple factors were considered during case selection, including audibility, absences, willingness to participate in the camp, and interest score criteria. Case studies are ideal when studying phenomena with multiple factors, especially when strategies such as survey or history are not sufficient to inquire into the case of interest (Yazan, 2015; Yin, 2002).

Thus, to examine the multiple factors surrounding interest triggering, an overall STEM interest score was reported for each case in addition to subtopics of science and technology. The relevancy of subtopics was due to the focus on science content in the camp and the use of a game, which may change participants' attitudes toward technology. The result of this study were four detailed case studies that included levels of STEM interest pre- and post-intervention accompanied by descriptions of each participant's engagements during the out-of-school program and other contextual information (e.g., relationship of participant to the interviewer).

I hypothesize that our Minecraft scenarios will act as interest triggers to some extent across learners with varied Minecraft experience prior to the intervention, and that the strength of this change will be connected to their number of interest triggering episodes from camp as a whole. We expect results to align with the work of Renninger and Bachrach (2015) in that interest triggers are fluid (i.e., an interest trigger that works one day may not work the next) and that interest triggers are not generalizable across people, illustrated by the differences found across the four case studies. Detailed information is provided about each of these instruments in the following section.

4.3 Measures

A total of five measures are used: interviews, STEM interest surveys, knowledge assessments, self-reported Minecraft mastery, and fieldnotes. The data sources for each instrument are outlined in Table 4 and in the sections below.

Table 4

Measures and Respective Data Sources

Measurement	Data Source
Interviews	One-on-one or paired semi-structured interviews
STEM interest surveys	Condensed version of S-STEM survey (used in 2018) Lab developed survey (used in 2020)
Knowledge assessments	Astronomy-focused questions (during interviews) Habitability definition assessment (during interviews, and in 2020 additionally through pre- and post-surveys)
Minecraft mastery	Pre- and post-survey
Fieldnotes	Taken by myself while present during camps

4.3.1 Interviews (see Appendix B)

The duration of our interview protocol lasted approximately 10 to 15 minutes for middle school students and coveed the following sections: home and school life, long-term interest, Minecraft play, astronomy knowledge, and camp feedback. In 2018, participants were interviewed in pairs in a separate room from the camp intervention whereas in 2020 all interviews were conducted one-on-one in a separate Zoom room.

Interviews were used to identify interest triggering episodes for cases. First, interviews were transcribed and categorized into episodes of STEM-related interest triggers. Further, each episode was coded as either an *explicit* or *implicit* episode of interest triggering and marked as a *spontaneous* utterance or *prompted* response. The purpose of distinguishing between *explicit* episodes, where interest is directly mentioned by the participant, and *implicit* episodes, where the verbal mentions of interest are absent, was to explore how the manifestation of these two different interest triggers during interviews relate to overall changes in STEM interest for learners with different levels of STEM interest prior to the intervention and with varying levels of mastery over Minecraft.

Explicit episodes served as a clear indication that the learner was conscious of an interest trigger and *implicit* episodes may have referred to unconscious interest triggering instances (refer to Chapter 1). While the *explicit*/*implicit* codes indicated whether or not interest was directly mentioned by the interviewee, it did not inform *how* the interest was formed. Therefore, each episode was marked as either a spontaneous utterance by the participant or a prompted response by the interviewer. A spontaneous utterance may have indicated participants' recollection of content learned from camp and allowed opportunities for the verbalization of interest triggers such as *novelty, affect*, and so on.

The two researchers involved in data analysis were me and a second-year graduate student in educational psychology also working at the Lane Laboratory. We were familiar with empirical studies involving interest development prior to conducting the data analysis, having both taken a course focused on interest development taught by our advisor in the previous year. Neither of us had applied Renninger's coding scheme to a project prior to this study.

First, for the purpose of data reduction, we met to outline our data analysis outline. Next, we coded two interviews separately with *the sole purpose of identifying STEM-focused interest triggering episodes*. There was a substantial agreement between the two researchers' initial coding on identifying interest triggering episode across two interviews, $\varkappa = .73$. After the two researchers met again to discuss initial disagreements across two interviews, there was almost perfect agreement between the two researchers on the identification of STEM-focused interest triggering episodes, $\varkappa = .82$.

After interest triggering episodes were identified**,** episodes were then coded for interest triggers based on Renninger and colleagues' (2019) analysis of interest triggers of middle school-aged learners in an out-of-school biology workshop context. There was an almost perfect agreement between two researchers when using Renninger and colleagues' coding scheme to code interest triggering episodes from two interviews, $\varkappa = .94$. Finally, we coded the identified episodes using my developed code (*explicit/implicit, spontaneous/prompted*). There was an almost perfect agreement between two researchers for coding interest triggering episodes using my developed code, $\varkappa = .95$. The following is an excerpt from an interest triggering episode:

SY: Like, have you looked up more information about space?

Case 1: Yes, I have. I have.

SY Okay.

Case 1: I think, uh, yeah.

SY: What, what um.

Case 1: I've been more interested.

SY: What kind of things do you look up?

Case 1: Like um. Uh. Exactly. Um... I'm trying to think. I could look through my search history [my note: on his cellphone], but I don't know. Um.

SY: Yes but. Off the top of your head.

Case 1: Like probably what's them things called exoplanets, exoplanets.

SY: Okay. Well, you Googled it.

Case 1: Yeah.

The excerpt is an example of an *explicit* and *spontaneous* interest triggering episode. Case 1 stated, "I've been more interested" (explicit) about space and exoplanets without the interviewer asking about interest specifically (spontaneous). More specifically, the excerpt illustrates an interest trigger of *novelty*, or anything that is new to the learner, including new insight about something that is familiar. In instances where two or more codes applied to one episode, we agreed to code the episode using the dominant code, or the code that was more consistently referenced throughout the entire interest triggering episode (discussed in Section 4.7).

4.3.2 STEM Interest Surveys (see Appendix D)

The overall score of the STEM interest surveys was reported alongside profile scores. There were two STEM interest surveys implemented through SurveyMonkey across the 2018 and 2020 data set: 1) a condensed version of the Middle/High School Student Attitudes toward STEM (S-STEM) survey instruments initially developed by Faber and colleagues (2013) and 2) the STEM interest survey developed by the Lane Laboratory in consultation with Dr. Ann K. Renninger, a leading expert in interest research.

The S-STEM survey consisted of 94 Likert-scale items for student attitudes toward technology based on the Student Learning Conditions Survey (Friday Institute, 2010) across subscales of math, science, engineering and technology, 21st century skills, and career paths for the future. The average completion time for the condensed S-STEM survey was 7 minutes (N = 129) while the Lane Laboratory survey took an average of 3 minutes (N = 13), both implemented through SurveyMonkey. Notably, the 2018 camp participants took the S-STEM survey while the 2020 camp participants took the Lane Laboratory survey. The total amount of participants was higher for the S-STEM survey because the survey was used across multiple data collection sites, including UNCC. I discuss what and how each survey measures STEM interest and justifications for developing the laboratory version below.

Faber and colleagues first created a survey measuring student interest in STEM careers based on the Bureau of Labor Statistics' (2011) Occupational Outlook Handbook using a 4-point Likert scale. Unfried et al. (2015) later tested the S-STEM survey using exploratory factor analysis and a four-factor solution was found, suggesting a structure consisting of attitudes toward science, math, engineering/technology, and 21st century skills. Factor correlations ranged from .16 to .37, and they also found that the four first-order factors loaded significantly on one second-order factor, considered a broader "STEM attitudes" factor. The second-order STEM attitudes factor explained 26.1% of the extracted variance, and the four first-order factors explained 73.9% of the extracted variance. Cronbach's alpha was used to measure international-consistency reliability for each of the four constructs (.89-.92).

Unfried and colleagues used confirmatory factor analysis to examine measurement invariance, which is critical when comparing two or more groups with the same measurement instrument. Measurement invariance assesses a construct across groups or across time. Measurement noninvariance suggested that a construct has a different structure or meaning to different groups or on different occasions in the same group, and therefore the construct cannot be meaningfully tested across groups or across time (Putnick & Bornstein, 2016). They examined invariance across races/ethnicities and across gender across the racial/ethnic groups most represented in their data: White/Caucasian, Black/African American, and Hispanic/Latino.

ΔCFI never exceeded .006, which suggested that both surveys demonstrated full configural, metric, and scalar invariance. All subscales in the Middle/High S-STEM survey showed evidence of configural, metric, and scalar invariance across grade levels, races/ethnicities, and genders.

A shortened version of the S-STEM survey (from 94 items to 32 items) was implemented in 2018 for middle school participants (*N* = 129). The original length of the S-STEM survey proved difficult for middle school students to complete, and we aimed to condense the S-STEM survey sing factor analysis and dropped items with the weakest correlations. For the purposes of this dissertation, the 32-item survey was translated to 160 total points with consideration of one reverse coded statement ("Math is hard for me"). The following is a breakdown of each subscale and the condensed number of items compared to the original: math (4 out of 9), science (4 out of 9), engineering and technology (7 out of 9), 21^{st} century skills (5 out of 11), and lastly, all questions under 'Your Future' in the original survey was implemented (12 items total).

To ensure the measured variables represent STEM interest, we conducted a confirmatory factor analysis on the condensed S-STEM survey (Table 5). First, we tested a second order model, where the general STEM latent variable encompasses each subdiscipline latent variable, and a bifactor model. The second order model was a mediocre fit: RMSEA = 0.082 (90% confidence interval [CI]: 0.062-0.092; CFI = 0.929; TLI = 0.915; SRMR = 0.061. Second, we tested a bifactor model where both general STEM and subdisciplines were assessed by individual items. In the bifactor model, subdisciplines and STEM general were orthogonal. The bifactor model indicated a good fit: RMSEA = 0.064 (90% confidence interval [CI]: 0.034-0.089); CFI = 0.968; TLI = 0.954; SRMR = 0.047 and was a significantly better fit than the second factor model..

Table 5

Fit Indices from Confirmatory Factory Analyses of STEM and STEM Subdisciplines

	$\chi 2$	*df*	RMSEA	CFI	TLI	SRMR	*p*
Second factor	157.043***	87	0.082	0.929	0.915	0.061	0.000
Bifactor	**93.93*** **	**63**	**0.064**	**0.968**	**0.954**	**0.047**	**0.007**

Note. CFI = comparative fit index; TBL = Tucker-Lewis index; RMSEA = root mean square error of approximation; SRMR = standardized root mean square residual; df = degrees of freedom. Bold indicates best fitting model. ***$p < .001$.

The S-STEM survey captured student attitudes towards STEM broadly, relying on general statements (e.g., "I like mathematics"). However, some students may have difficulty understanding or interpreting the broad term of 'mathematics,' referring to their class experience (e.g., whether or not they like their math teacher or interpreting 'mathematics' as one specific class such as algebra) instead of their personal enjoyment of the topic in general. Another issue with the design of the S-STEM survey was that it did not account for different preferences of individuals. For instance, two biologists with doctorate degrees could score high on the science section of S-STEM but enjoy completely different activities—one enjoying the teaching of biology courses to undergraduates, and the other preferring to work with farm animals.

To combat these issues, Dr. Lane's research team first developed a 20-item survey that asked about basic knowledge of a topic ("how much do you know about math?") and career choice ("do you plan to get a job that uses math in the future?) after an initial consultation with Dr. Renninger. The same phrasing for math was used for the remaining topics: science, engineering and technology, problem-solving, and astronomy. Then after consulting a statistical expert, a graduate student hired on the project to examine the validity of the survey, the team decided to vary the items to allow more freedom for the respondent (e.g., reflecting the differences different people choose to engage in) and a more accurate pinpoint of subject interests. As a result, the 2020 version of the survey had 26-items with a single underlying variable of STEM interest that attempts to measure interest in STEM through concrete action statements (e.g., "install a new computer system"). The laboratory developed survey was implemented for 13 middle schoolers in 2020.

A profile of pre- and post-subtopic scores relevant to the out-of-school intervention were reported for each case after the overall STEM score. Lastly, I also draw on specific subtopics within the STEM interest surveys. In the S-STEM survey, I focused on the science section that included items about career choice, knowledge mastery, and self-perceived ability in the science domain. In the Lane Laboratory survey, participants' self-reported interest levels to "study the movement of planets" were used to indicate changes in interest of astronomy in particular, a focal topic during the game-based science program.

4.3.3 Knowledge Assessments (see Appendix E)

Near the end of the five-day intervention, we tested participants for astronomy knowledge and habitability definitions garnered from our camp curriculum. The aim of astronomy knowledge scores was to track changes to knowledge across the 5-day camp as interest builds on existing knowledge and develops over time (Renninger & Hidi, 2019). Habitability definitions were not scored, rather responses from participants were taken verbatim and illustrate change in knowledge about a scientific concept covered during the game-based science intervention.

In 2018, both astronomy knowledge and habitability questions were asked during interviews. In 2020, astronomy knowledge questions were asked during interviews while the definition for habitability were asked three periods of time over the course of the camp (one week before our intervention, during the camp, and in a follow up survey). A follow-up survey was originally planned for one month after the intervention, however due to uncontrollable circumstances, only one out of four responses were collected in the 23-week follow-up survey.

The scoring key for the astronomy knowledge assessment was first developed by me and another graduate student at the Lane Laboratory. We aligned what we deemed as correct answers with information presented during the summer camp (e.g., science lessons, observable traits in hypothetical worlds participants experienced firsthand). Next, the accuracy of the answer key was confirmed by Dr. Neil Comins, a co-principal investigator on the National Science Foundation funding this work. Dr. Comins is a well-known professor of astronomy at the University of Maine (Comins, n.d.) and the author of the second most widely used textbook in the U.S. on astronomy. The scoring for each question was as follows:

- 0 - "I don't know" or response is off-topic, or student is absent
- 1 - answers prompt but answer is unclear or generally incorrect
- 2 - answers prompt with one or more key ideas indicated by black bullets, but does not go into reasoning why it is the case
- 3 - answers prompt with examples and provides reasoning why it is the case

First, my colleague from the Lane Laboratory, the same individual who identified and coded interest triggering episodes, and I scored the astronomy knowledge portions of two interviews from the 2020 data set. Next, we met to discuss disagreements and found that we were in complete agreement for astronomy knowledge scores. We then coded remaining interviews from both 2018 and 2020 separately. In the following meeting, we found that there was substantial agreement between two researchers on astronomy knowledge scores, $\varkappa = .70$. The same procedure with the same researchers was followed for habitability definition scores. There was substantial agreement between two researchers on habitability definition scores, $\varkappa = .64$.

4.3.4 Minecraft Mastery (see Appendix F)

Prior experience in playing Minecraft was incorporated into the Minecraft survey, which focused on play preferences. This survey remained the same across the 2018 and 2020 camps. The Minecraft survey took participants an average of 5 minutes to complete with a 78% completion rate. Near the end of the Minecraft survey, participants were asked to report their experience level in Minecraft on a 5-point Likert scale:

1. I am still new at it.
2. I have played a fair amount and have nailed down the basics.
3. I play often - even hours at a time sometimes - and can do quite a lot in the game.
4. I play a lot (or used to) and consider myself an expert. I use advanced features regularly.
5. I play way too much and all my friends ask me Minecraft questions (that I can answer). I use mods, set up servers, and more.

4.3.5 Fieldnotes

Fieldnotes offered a record of which participants were present during the five-day camp, the time in which events occurred, and utterances by participants that stood out, accompanied by our reflections of such instances. The research team debriefed at the end of each day to discuss the day's events, to evaluate the moods of the participants and the camp schedule, and to adjust next day's plans as necessary. In 2018, a visiting scholar and I compared and merged our fieldnotes at the end of each day. In 2020, the entire team (I, Dr. Lane, a graduate research assistant, and an undergraduate assistant) discussed the day in detail during the debrief meeting. These meetings allowed for opportunities to confirm or gain further insight about the day's occurrences through our different perspectives and realities.

Fieldnotes were coded using the same procedure as interviews, however interest triggering episodes were identified within the context of the whole group and not specific individuals, due to the recording of fieldnotes prior to case selections. Another difference was that interest triggering episodes identified in the fieldnotes were not as in-depth as those in the interview. Due to a general focus across all participants, episodes in fieldnotes were not further identified as *explicit/implicit* or *spontaneous/prompted*.

Fieldnotes served as valuable reference in providing the *specific context and/or circumstance* for each case (e.g., familial relationships or influences), highlighting the differences between the 2018 and 2020 interventions, providing the overall mood, feeling, and experience of the intervention that took place, and serve as a standalone chapter in the dissertation (see Chapter 3). Notably, 2018 was one of my first fieldwork experiences and the length, quality, and depth of detail recorded in fieldnotes differed from that of 2020. The average word count per day for fieldnotes was 475 words for 2018 and 2,128 words for 2020.

4.4 Researcher Positionality

Since 2017, I have worked on Dr. Lane's National Science Foundation funded project and had the opportunity to experience the pilot phase of the project, as well as data collection across different sites (i.e., makerspaces, private schools, museums). My responsibilities as an on-site research assistant include administering surveys and interviews, taking fieldnotes, and aiding in classroom management and troubleshooting technology. The title of research assistant does not capture my role wholly; I considered my role as a mix of being a teacher, technical support, researcher, and authority figure. I focused on building rapport with the participants and, in the process of doing so, could not stay entirely objective. Children are a vulnerable population and disempowered by their position in relation to adults in general (Ringland, 2019) and I felt a strong urge to protect and care for the participants as if they were students in my own classroom. I emphasized on working together with participants to understand their perceived experience of the camp as opposed to observing participants objectively under a microscope.

I often tried to perceive situations from participants' point of view and, as a result, automatically placed myself 'on their team,' so to speak. I viewed the research team as 'Other,' a foreign entity taking charge of the participants' familiar home, even when I was aware that I belonged to this Other-ness. I understood that participants viewed me as an authority figure, an Other, and may not feel comfortable expressing their true opinions. If participants criticized our intervention, as I often pushed them to do (and reminding them there was no negative consequence), I was eager to understand when and what caused feelings of confusion, frustration, or boredom, and inquired participants on *how* to avoid a similar scenario in the future.

For instance, in the 2017 summer camp participants complained to me during an interview that our intervention was akin to classroom lessons during the fall. They elaborated by saying that summer should be filled with fun activities such as swimming at the pool, and I asked them for in-game activities they would have preferred to participate in. Understanding that our summer camp was occurring simultaneously with other programs (such as ones that took participants to a swimming pool), this led the research team to revise and model the design of our intervention closer to a videogame experience (i.e., walk through a tutorial, complete quests, talk with non-computer players). In the same vein as prodding participants for criticism, I wanted to know the types of activities participants found exciting and reported these findings back to the entire team. I believe my approach tended to encourage participants to express their genuine opinions, viewpoints, and ideas.

Prior to my role as a research assistant, I worked as technical support for the College of Education and had worked one-on-one with a fifth grader through a volunteer program for one semester, which was my only experience working with K-12 students. During interviews for the pilot project, I was consciously aware that my nervousness from my inexperience as an interviewer and researcher transferred to the interviewee. Following the pilot, I began to take qualitative methodology courses that focused on interview techniques and practiced interview skills through my early research project (i.e., interviewing 11 college students one-on-one) in preparation for future data collections.

An audit trail was established in a shared folder accessible to members on the NSF project, including drafts and revisions of camp and interview protocols, curriculum schedules, analysis procedures, and memos on data collection. In 2021, I member checked each case with leaders at the youth center. A portion of our camp activities required breaking into small groups and, as a consequence, I formed closer relationships with my group members over others. I believed this closeness increased participants' level of comfort in sharing their opinions during interviews. However, the inverse may also be true, and thus my relationship with each proposed case is disclosed in Chapter 5. Overall, my approach to fieldwork was to observe quietly in the background and only engage with participants when necessary, in effort to preserve and capture their authentic experience.

4.5 Selection of Cases

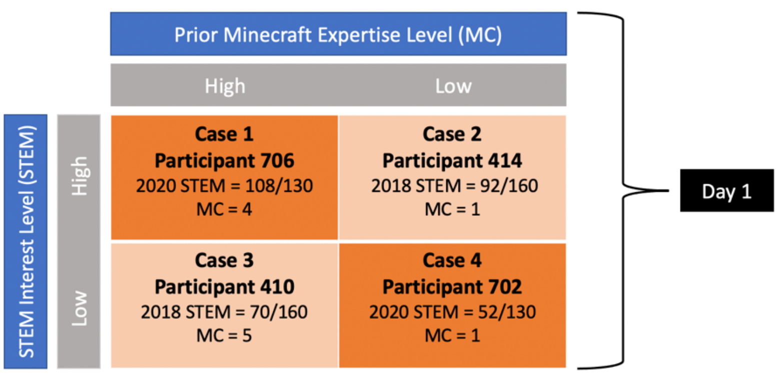
The goal of choosing cases is to maximize what can be learned and on providing balance and variety in what is presented (Stake, 1995, p. 5-6). Stake (2013) argued that multiple case study analysis requires the researcher to consider many features of the case and to select a few to study thoroughly. In accordance with Stake's advice, the cases presented should have potential to lead to understandings that may modify our generalizations. In other words, cases that contradict theoretical predictions have higher potential to lead researchers to insights that support theory revision through additional study compared to cases that align with theoretical predictions.

Therefore, the selection of cases encompassed the highest and lowest reports of STEM interest and Minecraft expertise reported on the first day of the intervention by participants (Table 6; refer to Section 6.5 for my reflection on case selection process).

The pre-test scores on STEM interest were likely the best indicators from the dataset available of interest levels prior the intervention (Appendix G). High and low scores were considered relative within respective groups due to the implementation of two different STEM surveys. The highest and lowest scores from the 2020 group were considered first, followed by the highest and lowest scores in the 2018 group. For self-reported Minecraft expertise which was rated on a five-point Likert scale, five and four are considered high while one and two are considered low.

Table 6

Matrix for Selected Cases



STEM surveys are indicated by year administered followed by their total, which differs between 2018 and 2020. MC indicates self-reported Minecraft mastery scores.

The STEM surveys implemented between the 2018 and 2020 group differed, thus leading to varying total scores (refer to Section 3.3.2). In the Lane Laboratory survey administered in 2018, the highest STEM interest score was 108 and the lowest STEM interest score was 52 out of 130 points ($N = 6$, $M = 76$). The highest (Case 1) and lowest scoring participant (Case 4) reported high and low scores of Minecraft expertise respectively, and thus became selected proposed Cases 1 and 2. In the S-STEM interest survey administered in 2018 (N = 11, M = 78), the highest S-STEM score was 116 and the lowest score was 44 out of a total of 160. We considered multiple factors in the selection of these cases: missing data, absences and/or continuous early pick-up, incomplete surveys, and willingness to participate in the camp. After accounting for these factors, we selected Case 2 (92/160) and Case 3 (70/160) to fulfill the remaining matrix quadrants.

4.5.1 The Significance of Each Case

Having described my approach in selecting the four cases of analysis, I now provide additional rationale for their selection by describing each cases' unique challenges for interest triggering. For Case 1 (high STEM interest, high Minecraft expertise), the literature suggests that those with previous gameplay experience may experience frustration when encountering the same game in a study (refer to Section 2.4). The frustration in these cases might be one or a combination of factors, such as reverting to habits developed in previous play sessions, feelings of boredom, or experiencing confusion when using modified features of the intervention's game. Those who are an expert on a topic need an appropriate level of challenge to prevent a loss in interest (Tin, 2009). If the camp experience presented an inappropriate level of challenge for Case 1, they may lose sight of learning goals preferring instead to pursue entertainment goals.

However, I hypothesize that Case 1 will result in the highest number of explicit and spontaneous interest triggering episodes throughout the camp experience, leading to an increase of interest in STEM, Minecraft, science, and technology (Table 7). Based on Case 1's high level of interest in STEM and Minecraft, Case 1 is likely aware of their interest in both topics and elicit explicit and spontaneous interest triggers. In other words, I expect Case 1 to verbally showcase their interest in STEM to the interviewer voluntarily and to explicitly mention ‘interest’ in their responses.

Table 7

Hypothesized Results for Each Case

	Interest triggering episodes	STEM interest	Minecraft mastery	Science interest	Technology interest
Case 1	Highest number of explicit and spontaneous	↑	↑	↑	↑
Case 2	Lower amount of interest triggering episodes than Case 1, majority explicit and prompted	↑	↑	↑	↑
Case 3	Majority spontaneous and explicit	↑	↑	↑	↓
Case 4	Highest number of prompted and implicit	↑	↑	↓	↓

↑ indicates a predicted score increase.
↓ indicates a predicted score decrease.
↔ indicates no change in predicted score.
. indicates missing data.

In Case 2, the learner possesses a high level of interest in STEM and a low level of mastery over Minecraft. What makes this case intriguing is the learner’s strong interest in the subject but lacks the technical skills to play the game with competence. This adds the pressure of comparing oneself with peers who, like Case 1, are both skilled in Minecraft and possess a high interest in STEM. Understandably, a learner who possesses an understanding and interest of content but not the technical mastery of the tool being used for learning may lead to feelings of frustration (Nebel et al., 2016). For this reason, I expect Case 2 to exhibit more explicit and prompted episodes than implicit and spontaneous episodes; Case 2 is aware of their interest in STEM but may not know enough about Minecraft to offer spontaneous insight about their interest triggering experience. This technical barrier is also the reason why I predict that Case 2 will have a lower total number of interest triggering episodes than Case 1. If Case 2 is properly supported during their experience to overcome technical challenges, I predict that interest for Minecraft, STEM, science, and technology will increase.

Cases 3 and 4 are particularly important when considering overall efforts to generate interest in STEM for learners with little to no interest. Case 3 is an example of an avid Minecraft player who has little interest in STEM topics and encounter the same issues as Case 1: needing an appropriate level of challenge, the temptation to revert to old habits, feelings of frustrations at new features in the videogame intervention that varies from the original game. However, Case 3 is missing Case 1's high level of interest in STEM, a key motivator for interest triggering episodes throughout the camp and may be more likely to stray from the activity at-hand and focus on playing the game rather than using the game as a tool to learn.

If Case 3's STEM interest increase, this suggests that a game-based science intervention triggered interest in STEM to an extent for a learner with little to no interest in STEM. I hypothesize that increased interest in STEM, science, and Minecraft would indicate more instances of spontaneous and explicit episodes due to the interest triggers in STEM. For Case 3, I predicted a decrease of interest in technology due to Case 3's high level of game mastery prior to the intervention and the experiences of unfamiliarity using our server as opposed to unmodified version of the game.

Finally, Case 4 represents a learner with low interest in STEM and is inexperienced with Minecraft. Case 4 carries the most cognitive load out of all the cases; they must overcome the challenges that the instructors present in addition to understanding the functions and innerworkings of the game. Unlike any of the other cases, Case 4 possess neither an initial motivation to engage in STEM topics nor sufficient knowledge to perform desired actions within the game. The relation of low motivation and low incoming interest in learners such as Case 4 presents educators with a grand challenge. If any gains are detected from Case 4, it will be critical to understand what helped produce such gains and build on them in future research.

Case 4 may likely be unaware of their interest being triggered as they are in the early phases of interest for STEM topics and possess a higher need for direction, and therefore I expect the highest number of implicit and prompted interest triggering episodes from Case 4. If Case 4 is well-supported during encounters with technical challenges, I expect an increase in interest for Minecraft, STEM, science, and technology.

If Case 4's for STEM interest and Minecraft increases, this would indicate that the intervention had some positive impact and that it supports at least some STEM interest triggering events for an inexperienced Minecraft player with little to no interest in STEM prior to the intervention. If results show that only STEM interest increase but not Minecraft mastery, it could likely indicate that the curriculum was informative and triggered interest while the technicality of the game was too difficult. If Minecraft mastery increases but STEM interest does not increase after the intervention, then this likely suggests that Case 4 prioritized mastering the game over learning the STEM content presented throughout the camp.

4.5.2 Triangulation

How can we ensure that the observations made across these four case studies are accurate and reflect authentic experiences as close as possible? To answer this question, I draw from qualitative inquiry and employ triangulation protocols that aims to gain confirmation and increase credence in the interpretation of data (Denzin, 1978). To describe the nature of triangulation, Miles and Huberman (1984) fittingly related the role of an academic researcher to that of a police detective. The nature of triangulation relies on multiple sources of evidence—hair follicles, fingerprints, interviews, or phone records—that must be collected to build a strong case against a suspect. I attempt the same endeavor in this dissertation by pointing to evidence from interviews, fieldnotes, and a variety of surveys to examine interest development. By bringing together multiple streams of evidence, this effort increases our confidence that the observations made are more accurate and ultimately, that we derive a clearer picture of how interest was triggered in the four cases.

First, for *investigator triangulation* (Stake, 1995, p.112-113), all observations I have made was accompanied by another member of Dr. Lane's research team. This ensured that multiple researchers examined the same phenomenon and provided two sets of fieldnotes per day (note: only my set of fieldnotes were analyzed in this dissertation), which allowed for the researchers present to find commonalities in assertations and for opportunities to challenge or suggest a different interpretation of a scene. Second, multiple approaches within a single study were used to achieve *methodological triangulation* (Stake, 1995, p. 114). The use of STEM interest surveys, interviews, and knowledge assessments utilize different data collection methods focused on interest in STEM, and as Miles and Huberman (1984) described, these instruments are mostly corroborative indicators of success with a possibility of inferential and contrasting indicators (p. 234). I also included a section on researcher positionality for both research sites.

To make sense of multiple data sources, I utilized checklist matrices (Section 3.1) specifically examining conditions for STEM interest triggering mentioned during the four proposed cases' interviews. Non-STEM interest triggers or triggers not captured by Renninger and Bachrach's coding scheme were labeled *unknown* and analyzed thematically. The purpose of matrices is to arrange "participant roles, themes, variables, emerging data sources into rows and columns to provide a broad visual representation that grounds findings in the data and context" (Castleberry & Nolen, 2018, p. 1).

First, the frequency of interest triggering episodes were summarized for each case and then each interest triggering episode was distinguished by type using the coding scheme from Renninger et al. (2019) and my own set of developed codes (*explicit, implicit, spontaneous, prompted*). While this offered numeric insight, it remained unknown what was said in each episode. Consequently, a separate table was created to show illustrative quotes from interviews. The purpose of scoring this second matrix was to show the richness of participant responses within their respective coding categories. Next, I sort data into a site-ordered descriptive matrix, which contains descriptive data from all sites and organizes the matrix in order of main variable being examined, in this case STEM interest triggers (Miles and Huberman, 1984, p. 160). Site-ordered descriptive matrices allow for the comparison of different subjects across different contexts and is one approach to uncovering trends within data sets. The reason a site-ordered matrix was necessary even when both data collections took place at UNCC was that the environmental conditions between 2018 and 2020 were vastly different (refer to Chapter 3).

The site-ordered descriptive matrix included descriptive statistics gathered from the pre- and post-STEM interest, astronomy knowledge, and self-reported level of Minecraft play experience prior to the intervention), demographic information (age, gender, and ethnicity), organized in the order of the greatest total number of interest triggering episodes to the least from the checklist matrix. All scores for measurements account for positive valences toward STEM; any reverse coding needed was taken into consideration when calculating total scores. Importantly, the verbosity of each case was reported to account for differences in personality and the closeness of interviewer and interviewee relationships. Verbosity was calculated through the average number of words used to respond to prompts.

4.6 Procedures

The data collected from camps for this dissertation proposal were optional sign-ups exclusive to the community center's summer program and was advertised as a Minecraft- and STEM-focused option and needed parental consent and child assent. Priority entry to the camp was given to students who were in middle grades. We followed a timeline for both camps with most days ending in free time to build and explore our server. Each day revolved around a specific hypothetical world, and the scientific implications of such world are supplemented by brief science lectures from the research team. The 2018 and 2020 camp structure at UNCC were similar, the biggest difference between the two interventions was the new addition of exoplanets, a new rocket launch map for participants to explore in 2020, and the hybrid setting of in-person and Zoom (Figure 3).

Figure 3

Camp Set-Up for 2018 (left) and 2020 (right and bottom)

4.6.1 Minecraft Server Features

The goal of our custom server is to develop a fantasy experience anchored on real-life science concepts and to trigger interest in STEM. Our server features a main "hub" where anyone who enters can access portals that teleport to Earth in the following conditions: 1.) normal baseline Earth, 2.) Earth with a different tilt, and 4.) Earth with a cooler Sun. Portals were color coded to ease navigation of the entire group (e.g., the instructor could say, “Everybody go to the red gate!”). We designed the maps to encourage exploration of each terrain and to create a sense of adventure, thus we decided on using an aircraft as means of transporting between different spots on a single map. This was particularly important to highlight how vastly different the terrain can differ within one planet, and to raise questions from participants on the conditions that can or cannot sustain life.

These world explorations are supplemented by short science lectures about each world. For example, the lecture on colder-Sun explains why a planet’s color emission was counterintuitive; red-hot actually means that the planet is much cooler, whereas the hottest glow on the sun emits a blue-green color. Following lectures, participants were asked to write out scientific observations on wooden signs, a preexisting object in the game commonly used to denote a message to other players. After campers were prepped with knowledge about Minecraft and ways to build and manipulate within the game, we asked them to form their own “what-if” hypothetical questions.

4.6.2 2018 Camp Procedures

The camp lasted five weekdays for a total of 25 hours per week. Learning activities included technical tutorials, lecture, discussion, and in-game guided explorations followed by free time to work on individual or group projects; no grades were assigned for these activities. Minecraft and S-STEM surveys were administered on the first and last days of camp (Table 8). On the last two days of camp, we invited participants for interviews that lasted approximately 15- to 30-minutes.

Table 8

Camp Schedule Implemented in 2018

Day of the Week	Lesson Plan	Measurement Implemented
Monday	Introductions, avatar customization, exploration of Earth and Earth without a Moon, followed by a brief science lecture and WorldPainter tutorial.	Minecraft survey S-STEM survey Fieldnotes
Tuesday	Avatar customization, followed by recap of Earth without a Moon, exploration of Earth with a colder Sun, followed by a brief science lecture. We end with free time to build on Earth with a colder Sun and another WorldPainter tutorial.	Fieldnotes
Wednesday	Avatar customization. A brief science lecture begins the day, and participants are grouped into teams and quizzed on previous science lessons. Then, participants explore of Earth on a tilted axis compared to baseline Earth. Participants devise their own hypothetical questions.	Fieldnotes
Thursday	Redstone tutorial involving circuits and switches (e.g., making a light switch). There is free time to build on any of the hypothetical worlds on our server.	Interviews Fieldnotes
Friday	More time allocated for building followed by a show-and-tell in front of the whole class.	Interviews Fieldnotes Minecraft survey S-STEM survey

Semi-structured interviews are regarded as informal but guided conversations (Kvale, 2008; Gideon, 2012). The informality matched the environment of the youth center to help alleviate any unnecessary pressures experienced by participants during interviews, and the guiding of conversations served to benefit our research inquiries. Semi-structured interviews serve to collect descriptions of the interviewee's perceptions with respect to interpretation of the meaning behind such descriptions (Driver & Easley, 1978). In other words, semi-structured interviews provided an opportunity for us to gain deeper insight into how participants perceive our Minecraft camp and shed light on participants' understandings of science concepts.

We were aware that our presence was new to participants and that participants may not have had prior experience working with researchers. Therefore, myself and a visiting scholar to the team decided to conduct paired interviews to account for social desirability bias and attempt to put participants at ease (Kvale, 2008): one researcher was male and the other female, and we took turns leading the interviews. Those who were asked to participate in 1-on-1 interviews were either missing consent for audio recording or researchers encountered an odd number of campers on that particular day. Interview questions centered around STEM-related aspects of play in Minecraft, feelings toward STEM subjects in school, personal preferences when it comes to gameplay, and connections between Minecraft and the real world. The last portion of the interview focused on astronomy knowledge, which tested the effectiveness of our hypothetical worlds and lecture series.

4.6.3 2020 Camp Procedures

The camp ran for five weekdays for a total of 17.5 hours per week. Learning activities include technical tutorials, brief lectures that lasted less than 10-minute with discussion, guided explorations within the game and free time to work on individual or group projects; no grades were assigned for these activities (camp's week schedule shown in Table 9). Minecraft and S-STEM surveys were administered on the first and last days of camp. An additional measurement that was taken at the end of each day is the ICAN survey, modified from Renninger et al. (2014), which prompted camp participants to self-reflect on the lessons learned for the day. The ICAN survey was a research endeavor by a colleague in the Lane Laboratory and did not provide information relevant to this dissertation proposal, and therefore the use of this measurement is not discussed further. Participants were asked on the last day of camp to participate in a 1-on-1 semi-structured interview that lasted 10- to 15-minutes by three separate interviewers.

Table 9

Camp Schedule Implemented in 2020

Day of the Week	Lesson Plan	Measurement Implemented
Monday	Introductions and time for skin customizations for participants, followed by exploration of Launch Base and Moon Base.	Minecraft survey Lane Laboratory STEM survey ICAN survey (not discussed and irrelevant to this dissertation)
Tuesday	NOVA Lab prototype sessions, then the exploration of Earth without a Moon and a following science lesson. We discuss hypothetical questions. The remainder of the day is free time on Minecraft.	ICAN survey
Wednesday	Earth with a colder Sun, followed by lessons on how to use Redstone. Participants then explore Earth on a tilted axis.	ICAN survey
Thursday	Exploration of exoplanets and introduction of the habitability challenge or building a structure that would allow for habitability on any of the hypothetical planets.	ICAN survey Interviews
Friday	Time dedicated to the habitability challenge, ending on a showcase of participants' creations.	ICAN survey Interviews Minecraft survey STEM survey

4.7 Limitations

Although the 2018 and 2020 camps shared the same theme of science and had significant overlap, they clearly differed due to new in-game content and COVID-19 restrictions. While every attempt had been made to incorporate these differences into my analysis, they also represent limitations to the project. The number of staff and rules enforced under the pandemic limited the total amount of participants allowed to enroll in our camps. While the number of participants may be small, the group emerged as an ideal context to conduct rich case studies that offer insight into *what extent* and *if* interest can be triggered using a game-based science intervention.

We followed a mostly top-down approach when applying the coding scheme of Renninger et al. (2019) to interest triggering episodes. This meant that interest triggering episodes were coded for one type of interest trigger, even if we felt that two or more codes could be applied to the same episode. This limited the richness that could have stemmed from a more elaborate coding process of interest triggering episodes. Future studies are encouraged to utilize more advanced statistical procedures to identify interest triggering episodes with more than one code attached. There were instances in fieldnotes that pointed to non-verbal indicators of interest, such as choosing to stay indoors instead of taking break outdoors. Some participants continued to play on our Minecraft server, while others derailed from our server to play in their own server, looked up videos on YouTube, surfed the web, or played other games like Roblox. While it is possible to monitor these activities, such as checking the browser history of each participant post-intervention, I omitted this level of monitoring. However, future studies that require fine grain detail or a detailed timeline of interest triggering behaviors could benefit from this method.

Admittedly, interest development from situational interest to individual interest requires extensive reengagement with a topic beyond the scope of the one-week camp. The follow-up survey addressed the brevity of the intervention and account for changes in interest. The unique composition of participant groups was another factor to consider. More specifically, the pre-existing relationships and dynamics of each group reacted differently to our intervention to some extent depending on the presence of those in attendance (exemplified in Section 5.1).

As previously mentioned, the quality of fieldnotes between 2018 and 2020 differed; the first was written by a visiting quantitative scholar and me as an inexperienced graduate student, and the latter by myself as an advanced graduate student. The level of expertise of the researcher impacted what interest triggers were recorded and what utterances and behaviors were overlooked while working in the field. The fieldnotes used for this study examined all participants. A more advantageous strategy would be to select cases ahead of time, preferably after the initial pre-test on STEM interest, and then record fieldnotes solely focused on those select cases. In scenarios where more than one researcher is present, members can be tasked with different focuses (e.g., one dedicated to select cases, the other dedicated to all participants). However, the risk of this strategy is that it relies on the consistency of participants (e.g., active participation, present physically and mentally during intervention), and this may prove to be a challenge when conducting research in real-world settings. An alternative method is to select initial cases of interest as well as 'back up' sets of cases, in case of any unexpected occurrence that would force the researcher to omit the original case during analysis.

This study was conducted in an out-of-school setting and was not immune to researcher errors that led to missing data. In the scenario where there was no missing data, then we would have a more complete idea of how all cases progressed from before to after the game-based science intervention. For instance, there would be added value and insight about the extent a sandbox game could trigger interest by knowing whether all cases were able to retain knowledge about the definition of habitability weeks after the intervention. The missing data would also shed light on how Minecraft mastery impacts these learning gains, as we would be able to compare answers across all cases. Thankfully, the majority of the data for all four cases were available for comparison purposes and steps had been taken to ensure the rigor of the research (e.g., triangulation, audit trail). We deliberately omitted certain measures when adjusting to participants' moods and when participants expressed survey fatigue.

4.8 Chapter Summary

This chapter dove into the research design and methods of my dissertation. The following were key components to my research design:

- **Cases.** I purposefully chose outliers as my cases, or those who reported the highest and lowest levels of STEM interest and Minecraft mastery prior to the intervention, as outliers have potential to change our initial understandings and generalizations.
- **Measures.** Interviews and fieldnotes served as integral evidence of interest triggering, categorized into episodes and coded using the scheme developed by Renninger et al. (2019). To further dissect interest triggering and explore new ways of analyzing interest triggers, I differentiate between *explicit*/*implicit* and *prompted*/*spontaneous* episodes of interest triggering for interview data (Section 4.3.1). The examples provided below are my own creation and are not quotes from participants.
  - Explicit episodes: Interest is directly mentioned by the participant (e.g., "I'm interested in space," "I like to think about the possibility of meeting alien life")
  - Implicit episodes: Direct verbal mentions of interest is absent but still present (e.g., "I wonder what living on an exoplanet would be like")
  - Prompted episodes: The participant responds strictly as a response to the interviewer's prompting and does not offer additional information beyond the prompt.
  - Spontaneous episodes: The participant volunteers unprompted information.

  Additional measures included STEM interest surveys, knowledge assessments, self-reported levels of Minecraft mastery, and fieldnotes.
- **Procedures.** Overall, the research team followed similar camp schedules for 2018 and 2020 with exception to new map additions to the 2020 camp (i.e., lunar crater, NOVA Labs play testing, and exoplanets). While the 2018 camp was conducted in-person, due to COVID-19, the 2020 camp was conducted through a hybrid model of participants and staff attending in-person at the center while research staff attended remotely.

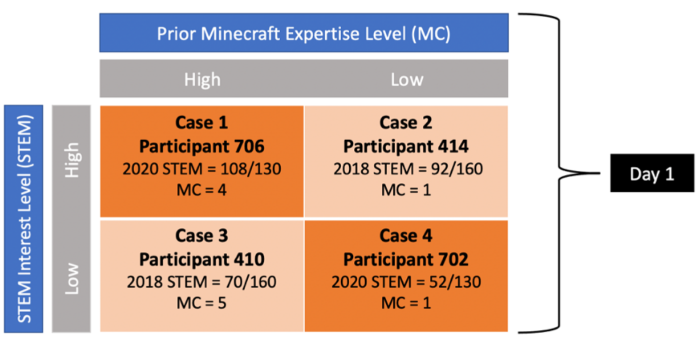
CHAPTER 5: RESULTS

Now that the context of the camp has been established, we now dive more deeply into each case and present results of my analysis. In this chapter, we first examine the behaviors of each case in detail based on interviews, fieldnotes, and member checking. Next, the codes by Renninger et al. (2019) developed for an out-of-school biology workshop are unpacked and modified to better capture interest triggers that occurred in our game-based digital learning context. The latter half of this chapter reports the frequency and types (explicit/implicit, prompted/spontaneous) of interest triggering episodes that occurred for each case; the overall changes in interest for STEM, science, and technology; and lastly, the verbatim responses for habitability definitions are shared.

5.1 Getting to Know the Participants

Table 10

Matrix for Selected Cases



In this section, the relationship between participant and researcher are disclosed. We weighed multiple factors during case selection, including audibility, absences, and willingness to participate in the camp, alongside survey score criteria (Table 10). All participants identified as Black or African American and ranged between 12- and 13-years-old (Table 11). Out of the cases, only Case 1 attended UNCC activities year-round whereas the others attend UNCC during the summer. The number of in-game observations were included in Table 7 as the number of signs placed could have indicated interest in the task at hand, however I decided not to pursue a full analysis of observations after discovering that the observations made were mostly factual (e.g., “dead trees,” “theres a lot of snow”). The setting for interviews in 2018 was a quiet room that was attached to a hallway leading to the large group. In 2020 on Zoom, there were background noise and distractions that occurred during interviews, which were filtered from quotes for the sake of clarity.

Table 11

Demographic Information

	Age	Gender	Ethnicity	Verbosity (average per question)	Number of in-game observations
Case 1	13	Male	Black or African American	63 words	93
Case 2	12	Female	Black or African American	29 words	8
Case 3	13	Male	Black or African American	141 words	9
Case 4	12	Female	Black or African American	57 words	11

5.1.1 Case 1: High Interest in STEM, High Mastery of Minecraft

I think education is very important for my future. Uh, I like all of my classes, but I think I stand out in math the most, but I'm good at everything.

Case 1 exemplified a learner with high interest in STEM and high mastery of Minecraft prior to the intervention. My initial impression of Case 1 was that of a driven, ambitious, and hard-working young man, and this was affirmed during member check with the leaders of UNCC. In an email where both leaders reflected on their relationship with Case 1, they wrote that Case 1 “is respectful and well-liked by staff. His behavior is mature for a youth of his age. […] As a matter of fact, in addition to getting excellent grades both quarters this year, he is earning stipends helping out the younger kids at the Center." Another evidence of his high achievements occurred within the first few minutes of our 1-on-1 interview when he described himself as having an "A plus in every class" and a 5.0 GPA ("I'm not trying to brag," he stated shortly after). When I asked about the motivation behind his ambition, he credited witnessing the efforts of his single mother—who worked as an elementary teacher, attained her master's degree, and became actively involved in the youth center—as his inspiration. He cited that the portrayal of African American stereotypes pushed him to "do better" and to "prove" that he did not belong to "one of those stereotypes."

I had multiple opportunities to interact with Case 1 throughout the camp as part of small group activities and during the NOVA Labs prototyping session with one of their researchers, Lorena Lyon. In the latter session, Case 1 was the only participant left in our Zoom breakout room after his groupmate was picked up early for the day and Case 1 finished the demo with 20 minutes left to spare. This led to a conversation between Case 1, Lorena, and me about Case 1's career path:

> Case 1 has been researching into different colleges (he has his eyes set on Howard in Washington) and degrees, stating that he wants to become a "businessman" and "CEO," and that he doesn't like the idea of working for someone else.
>
> I suggested for him to reach out to those at Research Park to chat with the people there and also the Technology Entrepreneur Center (TEC), where I used to work [...] Lorena spoke about how a science degree ("logic") can be applicable across all things in life, whereas solely a business degree person applying a "company" principle might not. I asked Lorena what she got her degree in ("human developmental and regenerative biology") and Case 1 asks what that is, and what types of jobs a person can get from that degree.
>
> Lorena explained her field (e.g., taking stem cells and "telling them what to do" like repair a part of the body or growing a heart) and introduced Case 1 to the idea of industry and academia. She pointed that many of those in academia are the ones conducting research into a product, and then build a company based on results from their research. I suggested that he could always do a minor in business and have a major centered on science. I raised examples that people at TEC have advanced degrees (e.g., physics, electrical engineering) but also own successful businesses.

> Lorena and I emphasized that people with science degrees have the technical knowledge to create and develop a product, whereas a solely businessperson might not know how to do those things. Lorena inferred that business skills can be "picked up." Lorena continued to push on the importance of a science degree until we had to return to the main lobby. I sent a private message to Case 1 explaining the idea of a tenured professor and that a professor can be focused on research, teaching, or a mix of both.

The next day during discussion with Dr. Comins, I followed a participant's question, "Is being a scientist a good job?" by asking what business ventures and opportunities were available to those with a science degree with Case 1 in mind. His response:

> *Case 1 seemed immediately interested—leaning forward in his chair until his face was very close to the laptop, eyes widened, and seeming to concentrate on what was being said (e.g., pressing his headphones closer to his ear, narrowing his eyes as if to focus).*

These particular discussions were strong potential interest triggers of instructional conversation as well as *novelty*.

Case 1 clearly recognized his own academic excellence across all school subjects. Interestingly, he actively disassociated himself from the science identity:

SY:	Okay. And so, do you see yourself as a science person?
Case 1:	(sucks air in) I, I have to because I like math and math and science go hand-in-hand. So, I learned that. I learned that so I, I, I like I can do science.
SY:	*Mhmm*. You can do science, but do you actually, are you interested in it?
Case 1:	I think I told you this the last time [during the NOVA Lab session], if science comes to save my life, I would do it.

Case 1 understood that math and science go topically "hand-in-hand" and acknowledged his ability to achieve in science, however he only partook in the subject if he was in a life-threatening situation. After a period of twenty-three weeks had passed, he formulated a clearer sense of his science identity: "I am a science person, but I do not want to make a career out of it," he wrote as a response to a survey, suggesting that he may follow his original trajectory of pursuing a degree outside of science in particular. His original pursuit to become a businessman was later confirmed by a leader at the youth center in February 2021.

The first time Case 1 played Minecraft was in kindergarten through fourth grade, and our camp was the longest duration he had played Minecraft since. In terms of work, Case 1 stated, "I do, I do my work, I think doing work is fun." He described to a family member that he woke up early to attend "fun camp" and, despite his older peers' negative perceptions of the camp, he thought, "'What? It's not boring.' I like this."

To exemplify his view of work as play, Case 1 made a record-breaking number of scientific observations across all of our camps with a total of 93 observations. The average number of observations made within Case 1's group was 30 observations per participant ranging from 9 to 93 total observations. In the conversation where I revealed his total amount of observations, Case 1 kept referring to his record as his "legacy" and jokingly said he deserved a plaque. His mother was notified of his accomplishment through email and the potential sense for *ownership* and *autonomy* may have contributed to his overall interest triggering experience. At the very least, knowing that he broke a record across our camps made a lasting impression. In the 23-week follow-up survey, after reporting his first and last name, he wrote in parenthesis, "Remember im the record breaker."

5.1.2 Case 2: High Interest in STEM, Low Mastery of Minecraft

I don't like just building stuff, so.

Unlike her interview partner, participant 415, Case 2 was a first-time Minecraft player and stated that she played mobile games rather than PC games. When asked if she owned a console, she replied, "My brother got a Nintendo Switch" and that she only played it when she experienced boredom. This seemed to indicate that she and her brother did not have co-ownership over the game console, but she exerted ownership over her phone, perhaps pointing to *ownership* and *autonomy* as reasons for her preference of mobile games. Case 2 openly stated that she did not enjoy Minecraft early on in the interview, which I further prodded:

SY:	Oh, you were saying earlier like you for Minecraft you don't like games like that.
Case 2:	No.
SY:	Can you tell me more about that? What do you mean?
Case 2:	Like why I don't like it?
SY:	Yeah, yeah.
Case 2:	It's just my type of game like. It's, it's. You go in the world and search and I don't like just building stuff, so.
SY:	So, would you guys prefer. What would it be a preferable model? Like if you guys, we threw into survival or?
Case 2:	*Mhmm*. I like games like that. It's, it's fun, sometimes.
415:	I don't like games like that. It's too pressuring on me.
Case 2:	I like it.

This excerpt suggested that Case 2 views Minecraft as a game that was predominantly about building and lacked the appropriate amount of challenge. Case 2 may feel differently if she had experienced survival mode, where pressure and challenge are more present than in creative mode, and *challenge* seems to serve as a potential interest trigger in games she selects to play. Further, her inexperience with Minecraft was highlighted when she repeatedly stated that there was no connection between Redstone, a Minecraft block equivalent of electricity, and the real-world:

Case 2:	Like you can make lights, but you like can't make it like Redstone. Like the people that make light bulbs and stuff, yeah, it's just like making the Redstone lights turn on and off cause they like mini. Um. Uh. Light bulbs, but it's actually real and stuff so.

OD: *Mhmm*. Is there anything similar to the Redstone in the world? Do we have anything like that?

Case 2: I don't think so.

OD: It might not be named Redstone but anything that's similar to what Redstone does.

Case 2: I don't think there. No not that I've heard.

Despite her inexperience and lack of interest in Minecraft, her interest in STEM prevailed during the Redstone tutorial where I described the content as being "challenging and novel enough for the majority of campers." As noted earlier, *challenge* and *autonomy* were likely interest triggers for Case 2. In my fieldnotes, it was recorded that "Case 2 has been putting in consistent effort in keeping up with each tutorial, raising her hand when she needs help, whereas her friend 415 seems uninterested (but 415 will look at Case 2's screen)." It seemed that a low level of interest in a particular game platform (e.g., Minecraft) can be offset through the use of in-game interest triggers (e.g., circuits) related to particular content (e.g., STEM).

5.1.3 Case 3: Low Interest in STEM, High Mastery of Minecraft

Science you're not going to need in life pretty much.

Case 3 informed us that he loved to play Minecraft and videogames in general. He referred to himself as a professional Minecraft player ("a pro at minecraft A.K.A. me") and often willingly provided rich answers to Minecraft-related questions in a paired interview with participant 409. The excerpt below was Case 3's response to our question on comparing Minecraft to the real-world:

Case 3: Like, like pouring water on lava makes it obsidian in the way how that works is lava cools by itself to make obsidian. The things that the only way I know how it there was the real world as those cringey-ness cringey horrible Minecraft animations that they make.

Most of that stuff that I watch is actually resembling the real world there. But in reality [indistinguishable], I wouldn't say thing that resembled the world, like it's raining and one biome and actually like when you go to snow biome it's actually snowing or say for instance, I don't know, um.

OD: So, think about all the materials. Think about how you create things or make, build things from those materials. A think about the chemical elements in the world. Do you see any similarities in between those? Do you see any differences?

409: Not really.

Case 3: I mean I, I could say the villages is kinda kind of resembles a normal life is way because. Because like they have the houses there but they each have their own specific job. Like this is back. This is back. Way back into like 17 or 1600's when it comes to these villages. And like farmers resemble their jobs, they break, they break the new crops and plant new ones. I mean they're the only ones that actually do something there, but they all have their own jobs.

Librarians would be in their own set of library house, priests would do some sort of religious act, blacksmiths would use their furnaces for smelting and outside of that little table that they have. […] So, I would say that the villagers play a big part in this. And the biomes, I guess for some […] of the animals in locations like polar bears in the snow biomes or a lot of birds A.K.A. parrots in the jungle cause those animals you will commonly see there.

Case 3 further affirmed his identity as an advanced Minecraft player when he and 409 discussed materials needed in survival mode:

409: Metal. You need metal. Metal's second.

Case 3: Did you—did you just say "metal"?

409: Oh, no. Never mind.

Case 3: The correct definition was "ore". I'm— I'm a Minecraft nerd. I knew it for like. I knew Minecraft for like seven or six years. So.

Case 3 presents an interesting conundrum: he stated science as one of his favorite classes, yet he clearly disregarded science in its value and application to daily life. The following excerpt shows his reasoning and highlights the dynamic back-and-forth between Case 3 and 409 (bold indicates author’s emphasis):

409: I like I like math; I like to do math.

Case 3: Well, actually never mind I kinda like social studies a lot and, and maybe language arts and science.

409: And science.

Case 3: **Yeah, definitely science.**

OD: So why, why do you like math?

409: 'Cause it's fun.

Case 3: No, it's not.

OD: Math is fun?

409: Well, you ain't gone be. You ain't gonna need it in life.

Case 3: You are you are gonna need it in life**. Science you're not going to need in life pretty much.**

409: Reading you definitely need in life.

Case 3: **The only two things you're gonna need in life is language arts and math.** That's really it.

409: And reading.

Case 3: That's what that's what reading is. It's.

OD: You will need them all in life, believe me. (laughs)

Case 3: English.

409: You don't need—

Case 3: Social studies I don't see you needing life unless you're trying to impress somebody.

409: I don't see, I don't see, I don't see math.

Case 3: I see math—

409: Involving, involving you in life.
Case 3: Oh, I could see that.

409: The only thing you need math if you become like an engineer. No, no, no, that would be...

Case 3: Or, or paying things.

409: Yeah.

Case 3: Or buying things.

409: Oh, yeah.

Case 3: Or doing a whole bunch of stuff or trying to afford your scholarship in the future.

409: Damn.

Case 3: *Mhmm*. Yeah, **there's a lot of stuff math is used for but science is used for nothing.**

409: (scoffs) What you gone do. "Uhhh..."

Case 3: **What you gone do, study some biolo- what are you going to do? Study some rocks that are at or get that were a few days ago.**

409: What you gone—you don't need—you don't. You definitely don't need social studies up.

Case 3: The only time you'll need social studies is when you was like, when you're trying, when you're correcting a person on what they said wrong. Like if they say Christopher Columbus found to America, even though you're saying even though he—

409: Yeah.

Case 3: Actually, he tried—

409: Tried.

Case 3: to find the. Cari. He was trying to find the Caribbean, but he thought he did even though he found even though he did not find America because there are people already settled here.

[OD, 409, and Case 3 all speak simultaneously, I was unable to discern what is being said]

OD: Okay, okay. I get your points.

The remainder of the interview maintained the same back-and-forth between the two participants, an off-topic conversation often sparked by the other's response to our question, and their fast-paced exchange created difficulty for the interviewers to interject. In 2018, the average for the eight paired interviews was approximately fourteen minutes rounded to the nearest minute. The cut-off for Participant 409 and Case 3's interview was close to twenty-seven minutes. Understandably, we decided to omit the astronomy knowledge questions to prevent burnout of the participants and to ensure there was enough time to conduct remaining interviews, therefore Case 3 is missing both astronomy and habitability responses in Chapter 4.

I am unclear about the relationship between 409 and Case 3, however a staff member informed me that both participants only attend the youth center during the summer (as opposed to year- round like Case 1). Participant 409 often relied on Case 3's help during camp and they were seated next to each other. Participants were free to choose their seats on the first day of camp and had to remain in the same seat throughout for data tracking purposes. Participant 409 was the youngest out of his group at 10-years-old (M = 12 years old) and joined our camp from Tuesday onwards.

In a four-day period, 409 was involved with a fight with another youth center participant and had two outbursts about how his mother forced him into our camp. On one of those occasions, he refused to participate because he wanted to play outdoors and physically left the room, but later returned to follow along the ongoing lesson after a staff member intervened. These instances point to rebellious tendencies, including the active use of profanity during (and outside of) the interview. The combination of 409 and Case 3's personalities resulted in a rapid exchange of opinions at the expense of answering all interview questions.

5.1.4 Case 4: Low Interest in STEM, Low Mastery of Minecraft

The one thing I'm interested in is science is about like […] about how water, like for instance, in fourth grade we learned […] something about the vapor and like when you boil water, the steam comes up.

One of the requirements in our camp advertisement was a basic mastery of Minecraft; players should understand how to move in-game and understand other basic functions to gain from our curriculum. If an inexperienced Minecraft player enrolled in our camp, we did our best to accommodate the participant—usually by helping them directly 1-on-1—or the participant will choose to enroll in another synchronous camp. We made the assumption that all participants who signed up for our summer camp had met the minimum requirements. Near the end of the first day, we realized Case 4's character movements had stopped completely. Dr. Lane asked if she had stopped playing the game, and she confirmed, revealing that she was a first-time Minecraft player. Case 4 continued to struggle with technical aspects of the camp throughout the week and was often placed in a separate Zoom breakout room with a member of the research team for tutorials on how to play.

Her inexperience with Minecraft was exemplified during the Redstone tutorial. She continuously asked for help and repeatedly disrupted the progression of the Redstone tutorial within a 20-minute span:

1:25 pm	Case 4 leaves the server. Aidan [our undergraduate assistant] asks [Case 4] for the error message. […] Case 4 cannot figure out how to view both Zoom and have Minecraft in window mode side-by-side. […] Now back on the server, Case 4 says she cannot get to the lamp block. She does not know how to scroll across her hotkeys.
1:30 pm	Case 4 is having trouble getting a lever into her hotkeys. She is saying, "It's not letting me." Chad puts a pause on the tutorial to help Case 4 through the process and praises her when she completes the task. As Chad proceeds to the next step, Case 4 chimes in, "How many plates?" and Chad alongside irked participants say, "One."
1:35 pm	I've been trying to help Case 4 with the tutorial in-game, showing her the steps she needs to do. Case 4 says I have kept destroying her structure, and when Chad and I say 'SnappyCabbage' [clarification: my in-game handle] is me, Case 4 says, "Oh." Chad gives everyone a few moments to play with what they learned about Redstone. He is helping Case 4 in the main lobby call again.
1:40pm	Case 4 says she needs help. She does not know how to fill in a hole when she destroys a block on accident. Chad answers this question. Case 4 does not know how to add another item once her hotkeys are full. After Chad gives his next set of instructions, he addresses Case 4's question.
1:50 pm	Chad asks if Case 4 and 701 need help and they say yes. Chad places Aidan and the girls into a breakout room.

Case 4 faced technical challenges both in and outside of Minecraft. She grappled with learning the basic functions of Minecraft, such as knowing how to scroll across hotkeys, identifying objects (e.g., plate), and placing a block to replace a missing one. Her efforts to learn took time away from the group, and as a result, derailed other participants from advancing in the Redstone tutorial. Other technical issues such as knowing how to go back-and-forth between Zoom and Minecraft presented another layer of obstacles. On the one hand, Case 4's efforts to learn slowed down the overall progress of the group, but on the other her learning sparked multiple opportunities for *instructional conversation, challenge*, and *groupwork* as an interest trigger.

While I did not have opportunities to interact 1-on-1 with Case 4, my colleague, a second-year doctoral student studying educational psychology, worked closely with Case 4 during small group activities. I asked for his description of her close to five months after the intervention. He described Case 4 as "really sweet. She was up for doing whatever we asked of her, but she did need a lot of help with [Minecraft] because she had never played. She was very thoughtful and did help try to keep others on track, especially during [NOVA Labs]." The same colleague interviewed Case 4 about her science views:

MG: Do you see yourself as a science person? Are you, are you, would you be, could you be a scientist someday? No?

Case 4: Yeah.

MG: Why not?

Case 4: Well, because. I mean. I'm not really that type of, not nature. Well, I'm not a nature person, but that's, I mean, that kind of has something to do with it, but not really, but I'm just not really that interested. The one thing I'm interested in is science is about like water, like about how water, like for instance, in fourth grade we learned like how, like the vapor, something about the vapor and like when you boil water, the steam comes up. So we learned, I was interested in that kind of science.

MG: Okay. So you actually like water, like learning about water huh and kind of like earth science a little bit?

Case 4: Yeah. I guess that's earth science. Yeah.

MG: Yeah, okay that's cool.

Case 4: Yeah, that was pretty cool. And I liked doing experiments. I like experimenting things like even at home, I'll just mix stuff together and just kinda like, see like.

MG: Huh.

Case 4: The alternative.

MG: Well, that's really cool. I mean, to me it sounds like you kind of are a science person then if you'd like to do experiments. (laughs)

Case 4: Not. Okay. Not like, I guess not astronomy, not. It, certain types of science.

MG: Okay. That's fine.

Case 4: Okay, I'll say it like that.

Interestingly, Case 4 associated science with nature. First, she stated her disinterest of nature, then mentioned a specific example of evaporation as the "type" of science she was interested in, ones that involved mixing and conducting experiments. When the interviewer pointed to her contradiction, she clarified that she was particularly disinterested in astronomy and "certain types of science." It was implied that Case 4's understanding of astronomy was linked to nature, however that creates another contradiction, as learning the process of evaporation often involves learning the rain cycle, which was interlinked with natural factors. It is possible that Case 4 was still in the process of sensemaking, and similar to Case 1's initial hesitancy with science identity, may have needed more time to solidify her interest(s) in science.

The most surprising utterance occurred near the end of the interview. After Case 4 was asked if she would enroll in our camp again next year, she spontaneously asked, "Will [camp] be on Zoom next year?" She went on to express her liking of Zoom, and when asked why, she elaborated:

> Like, 'cause. Actually. It's half and half. I like, I don't like doing it on Zoom because. [...] In-person because first of all, like everybody won't be talking over each other at on at one time, like some people were doing today. Um, and then it won't be like this little headphone thing it won't keep disconnecting 'cause like [...] It keeps disconnecting and un-disconnecting. And then in

> person, I mean, on Zoom because I just feel like I like doing Zoom I guess. […] Yeah, that's really about it (laughs). […] I still like [Zoom] better. I like it.

While she offered reasons for liking in-person camps (i.e., no overlapping talk or worry about headsets), she did not articulate reasons for why she preferred Zoom over in-person camps. She followed the Zoom inquiry with another, asking if the interviewer lived in town. When the interviewer confirmed this, she said, “Oh” without further elaboration. Her intention for knowing the interviewer’s location remained unclear, but his answer may have caught her by surprise—perhaps making her wonder why we were not at the youth center in-person if we lived within the same area.

5.2 Initial Hypotheses

The section above contained rich details about each participant gathered from interviews (with cases and member check with staff) and fieldnotes. To help frame the outcomes of this study, Table 12 displays initial predictions (refer to Section 3.5.1) and actual results of scores across Minecraft mastery and interest in STEM, science, and technology. Indications of changes in scores helped answer my research questions:

> RQ1: To what extent does a digital sandbox game intervention that enables freedom of choice and peer-to-peer interactions trigger interest in STEM?
>
> RQ2: What is the influence of prior gameplay experience on changes in STEM interest when using a game-based science learning intervention?

Predictions of interest triggering episodes were mostly accurate for Case 1, 2, and 4. Results for Case 3 was the opposite of what was predicted. More detailed scores are outlined in the sections below.

Table 12

Hypothesized versus Actual Interest Score Comparisons

	STEM interest	Minecraft mastery	Science interest	Technology interest
Case 1	↑ (↑)	↑ (↓)	↑ (↔)	↑ (↑)
Case 2	↑ (↓)	↑ (↔)	↑ (↓)	↑ (↓)
Case 3	↑ (↑)	↑ (.)	↑ (↔)	↓ (↑)
Case 4	↑ (↑)	↑ (↔)	↓ (↑)	↓ (↑)

Blue indicates supported predictions.
Orange indicates predictions that actual scores differentiated from predictions.
(Sections in parenthesis indicate actual score)
↑ indicates a score increase.
↓ indicates a score decrease.
↔ indicates no change in score.
. indicates missing data.

5.3 Refining Interest Triggering Episodes

In this section, codes for interest triggering episodes from interviews and fieldnotes are discussed. As previously mentioned, we categorized interest triggering episodes as *unknown* in instances where the codes developed by Renninger et al. (2019) did not accurately capture the experience. *Unknown* codes constituted 23% (18 out of 77) of interest triggering episodes in 2020. We examined *unknown* as well as *personal relevance* (18%) and *computer/technology* (18%) interest triggering episodes due to their high frequency compared to other codes. We conducted a thematic analysis on *unknown, personal relevance*, and *computer/technology* codes using MAXQDA.

There were multiple episodes where participants, responding to one of our prompts, informed us how family members played a role in their involvement with our camp and/or with STEM content. These unknown episodes were later categorized as a subcodes of codes established by Renninger et al. (2019): *personal relevance – family*. As our camp largely relied on Minecraft and most interactions took place within a digital learning platform, we felt on multiple occasions that what Renninger and colleagues would consider *computers/technology* was too general for our learning context. Thus, we developed subcodes for existing coding categories that captured the digital learning experiences more specifically, such as *computers/technology – Minecraft* and *computers/technology – Minecraft learning*. The entirety of new codes and subcodes we developed are summarized below:

- **Intent to reengage:** Willingness to reengage in a learning activity in the future.
- **Personal relevance – family influence:** Interaction with family members that engages content and influences engagement with content.
- **Computers/technology – popular media:** Cultural references to movies, television shows, games (non-Minecraft), and books.
- **Computers/technology – Minecraft learning:** Play preferences or interactions with Minecraft that lead to new knowledge and understanding of content or builds on prior knowledge about content.
- **Computers/technology – Minecraft play:** Play preferences or interactions with Minecraft that do not result in learning of the content.

It is unclear why *intent to reengage* was not originally captured in the work of Renninger et al. (2019) despite their description of interest triggering involving the intent to reengage in content. A possibility for the absence of this code in the original scheme is the nature of measurements. In our interviews, we directly asked participants whether they would be willing to reengage in content, whereas other forms of measurement (e.g., retroactive analysis of fieldnotes, as Renninger and colleagues had done) may not include this type of data.

When we encountered disagreements in coding, the team decided that some of the definitions developed by Renninger and colleagues needed clarification (italics indicating our modifications):

- **Challenge:** content, skills, or anything else that is difficult for the learner *including problem-solving*.
- **Novelty:** Anything that is new or *arouses curiosity*, including new insight about something that is familiar.
- **Personal relevance:** A connection between an activity (or aspect of an activity) and a learner's past experience *or an attempt to build on prior knowledge/experience*.

The purpose of these definition modifications was to help our researchers distinguish between codes and in deciding which code to best captures the entire interest triggering episode. Our top-down approach narrowed interest triggering types to one code per episode, even when we were in agreement that more than one code suited an episode.

Table 13

Total Interest Triggers, Categorized by Case and Interest Type

	Explicit	Implicit	Prompted	Spontaneous	**Total**
Case 1	11	5	14	2	**16**
Case 2	6	1	7	0	**7**
Case 3	2	5	5	2	**7**
Case 4	5	6	6	5	**11**

5.4 Interest Triggering Episodes Found in Interviews

We used my exploratory coding scheme for interest triggering episodes (*explicit*/*implicit, spontaneous*/*prompted*) identified across interview data. The frequency of episodes and episode types were summarized in Table 13. To briefly reiterate, *explicit* episodes described instances where the interviewee directly references interest in directly their utterance (e.g., "I'm interested in science"), whereas *implicit* described utterances without the direct mention of interest, however interest still persists (e.g., "I'd attend next year's camp"). *Spontaneous* meant that information was unprompted, voluntary, or additional information that was not directly requested by the interviewer, whereas *prompted* indicated a response to an interviewer's question and nothing further. The following were my hypotheses made for each case followed by results in italics (unexpected findings highlighted in red):

- Case 1: Highest number of explicit and spontaneous episodes.
    - *Highest number of explicit and prompted episodes.*
- Case 2: Lower episode total than Case 1, majority of episodes explicit and prompted.
    - *Lower episode total than Case 1, majority explicit and prompted.*
- Case 3: Majority of episodes explicit and spontaneous.
    - *Majority implicit and prompted.*
- Case 4: Highest number of implicit and prompted.
    - *While not the highest out of all cases, implicit and prompted episodes were the highest for Case 4 in particular.*

All cases exhibited majority *prompted* interest triggering episodes rather than *spontaneous*. An unexpected result was that Case 1 had the highest number of *prompted* episodes out of all cases. For Case 3, the predicted majority of episodes was the complete opposite. Interestingly, those with the highest (Case 1) and lowest (Case 4) interest in STEM and mastery of Minecraft had the highest number of interest triggering episodes. In Table 14, interest triggering episodes were coded into types using the scheme developed by Renninger et al. (2019). In Table 15, interest triggering episodes were coded using our set of new codes and subcodes that accurately captured our digital learning context using Minecraft in particular.

Relating back to RQ1, these interest triggering episodes indicate that a sandbox game that allows for autonomy and peer-to-peer interactions can trigger interest in STEM. As previously defined, the features of interest triggering involved a willingness to reengage with content, express positive affect, view a subject as having value, reflect about the learning content, or connect content based on prior knowledge or experience, and these manifestations of interest are reflected in interest episodes of cases (Table 16). This broad definition of interest triggering should not be confused with interest trigger codes, which describe the *cause* of interest triggering (e.g., *challenge, autonomy*).

Table 14

Interest Trigger Checklist Matrix

Interest triggers*	Affect	Character identification	Ownership	Autonomy	Computers/ technology	Novelty	Personal Relevance
Case 1	**Uh, this my first time and I learned a lot and I felt like, it's great. Um, and I feel like I should get a, I should get a plaque. Um, I'm just saying.**	**I like all of my classes, but I think I stand out in math the most, but I'm good at everything. I mean, I had A plus in every class I'm not trying to.**		Gravity. I want to dance up [*in space*].	**Well, when I was smaller and when I was with my dad, he had these iPads and I used to play on these iPads, and I used to make houses and buildings like churches and all the types of different buildings. But then I stopped playing for like a good four years.**	**I've been more interested [*in looking up more information about space*] […] What's them things called exoplanets, exoplanets.**	So, I make something big [*in Minecraft*] and then I have to limit my hours. So, because […] I make Legos too. But the thing I do Legos, like I built a 3,000, 4,000-piece um Lego Batmobile.
Case 2			I thought that that thing, that fire-like switch […] Like when you made your own light switch.		***Mhmm.* I like games like that. It's, it's fun, sometimes.**		
Case 3		[…] if you're an intermediate at Minecraft and if you're a pro at Minecraft A.K.A. me […]					The only thing that I thought was pretty, pretty weird was like, like when you, like when you guys said earlier when the earth was close to the sun. I have a feeling that just resembles a lot like Mars because of all that orange sand there and like [the sun] was so high for some reason.
Case 4		**[*When asked if she sees herself as a science person, she replies*] Yeah. […] I liked doing experiments. I like experimenting things like even at home, I'll just mix stuff together […]**			**Will it. Will it be on Zoom next year? […] I like Zoom.**	So last night the moon, the moon was like in the sky, but it was kinda different. […] I never seen, like, I never pay no attention to like the colors, like when the clouds get in front of the moon before. So that was pretty cool.	[…] second grade I had like this question about like, how come like when the earth rotates, how come like we don't go along with the, what the earth, like have come everything doesn't turn.

*The following interest triggers were not found in these four cases: challenge, groupwork, hands-on activity, and instructional conversation.
Bolded quotes indicate an explicit episode.
Underlined quotes indicate a spontaneous utterance.
Italicized quotes indicate clarifications from the author.

Table 15

Interest Trigger Checklist Matrix of Sub-codes

Interest Triggers	Computers/ technology – Popular media	Computers/ technology – Minecraft learning	Computers/ technology – Minecraft play	Personal relevance - Family influence	Intent to Reengage
Case 1		Okay, I have to go back to Minecraft. 'Cause when we went to the map without moon. […] So much wind. And I just think that that's realistic, because there's no moon. Dark.	I would build the house, right? […] And then they would be these trees and then I'll make up a path to the tree, like a tree house to the church. […] It was so cool.	**I think it just came from looking at my mom because she's a teacher and she graduated with her masters and I just think when I see that and I see uh, how African Americans are portrayed as I just want to do better.**	**No, I didn't even let you finish. If I hear my mom say they doing Minecraft. I'm coming.**
Case 2		And like if Earth was like really close to Sun, we might die.	**For my first try, I like to build houses too.**		
Case 3		<u>[…] another thing that doesn't make sense in Minecraft when it comes to chemicals, poison and reality, and the rat poison would actually kill you for some reason it does not kill you in the game.</u>	**At one point I did, I did play, but for some I didn't get on for one month and the game the game kicks me out and now I have to purchase it again, which was. Which sucks, but I did play Minecraft often. […] I love to play.**		
Case 4	It was the movie Wonder? […] Auggie. He like wanted to be an astronaut.		**Alright so I liked, um, what did we do yesterday. Oh! The um Redstone world.**		I think [*I would join again*]. I guess just to learn more about [*Minecraft camp*] and just to be on here.

Bolded quotes indicate an explicit episode.
<u>Underlined quotes indicate a spontaneous utterance.</u>
Italicized quotes indicate clarifications from the author.

Table 16

Interest Triggering Features Identified in Interviews

Interest triggering features	Interview excerpts
Willingness to reengage	Case 1: No, I didn't even let you finish. If I hear my mom say they doing Minecraft. I'm coming.
Express positive affect	Case 2: For my first try, I like to build houses too.
View a subject as having value	Case 4: [When asked if she sees herself as a science person, she replies] Yeah. […] I liked doing experiments. I like experimenting things like even at home, I'll just mix stuff together […]
Reflect about learning content	Case 2: And like if Earth was like really close to Sun, we might die.
Connect content based on prior knowledge or experience	Case 3: I have a feeling that just resembles a lot like Mars because of all that orange sand […]

While surveys and categorizations of interest triggering episodes provided a numerical overview of cases (Table 14 and 15), interviews offered rich data to investigate the verbal manifestations of interest triggers. The responses that were chosen for Tables 14 and 15 were utterances that can be interpreted on its own; they did not require in-depth contextual information to reach an understanding. The purpose of Tables 14 and 15 was not on the *frequency* of interest triggers, but rather the *content* of interest triggers. Responses from the four cases speak to the extent to which a digital sandbox game can trigger interest in STEM (RQ1) and influences of Minecraft mastery (RQ2) by illustrating interest triggering features and connecting to interest triggering codes. Readers may notice that not every column of interest triggers was filled, and this variety demonstrates the individualistic nature of interest triggers; what triggers interest in one person may not work for the next.

5.5 Overall Interest in STEM and Subtopics

This section explores the results from the STEM survey, knowledge assessments, and self-reported Minecraft expertise. The site-ordered descriptive matrix (Table 17) examined STEM interest and was organized from the greatest total number of interest triggering episodes to the least with a tie between Case 2 and 3 (listed sequentially). Change in knowledge was quantified through scored interview transcripts on astronomy knowledge as well as a survey administered prior to camp for 2020 camp participants (Case 1 and Case 4). As previously stated, the STEM survey administered in 2018 and in 2020 differed, thus, resulted in different score totals (refer Section 3.3.2). The astronomy knowledge score for Case 2 differs from Case 1 and 4 due to omissions of questions by the leading interviewer and were completely omitted for Case 3. In 2018, the overall trend was a decrease in science and technology profile scores. In 2020, the overall trend was an increase in science and technology profile scores.

Table 17

Site-ordered Descriptive Matrix Examining STEM Interest

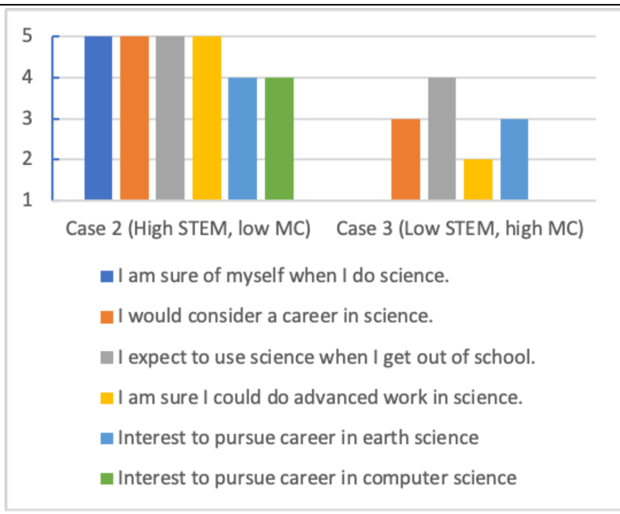
	Total number of interest triggering episodes	Pre-test STEM interest survey	Post-test STEM interest survey	Astronomy knowledge score	Pre-self-reported Minecraft expertise
Case 1	16	108/130 (83%)	110/130 (85%)	12/21 (57%)	4/5
Case 4	11	52/130 (40%)	74/130 (57%)	5/21 (24%)	1/5
Case 2	7	92/160 (58%)	75/160 (47%)	8/15 (53%)	1/5
Case 3	7	70/160 (44%)	72/160 (45%)	N/A*	5/5

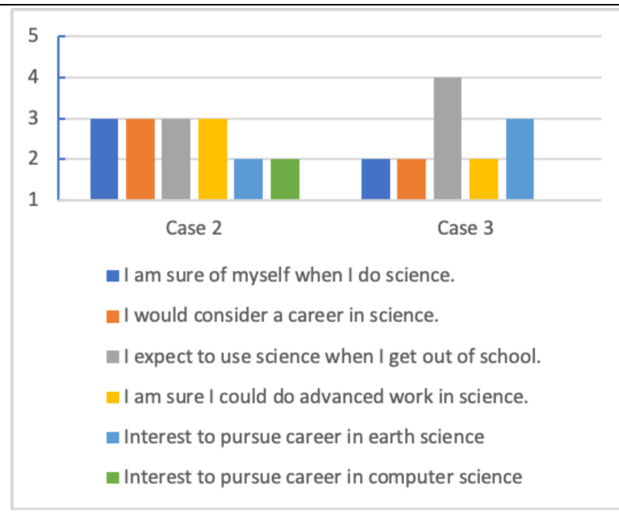
Scores were rounded to the nearest tenth.
*Case 3 was not asked astronomy knowledge questions.

Table 18

Science Profile Scores for 2018 Cases

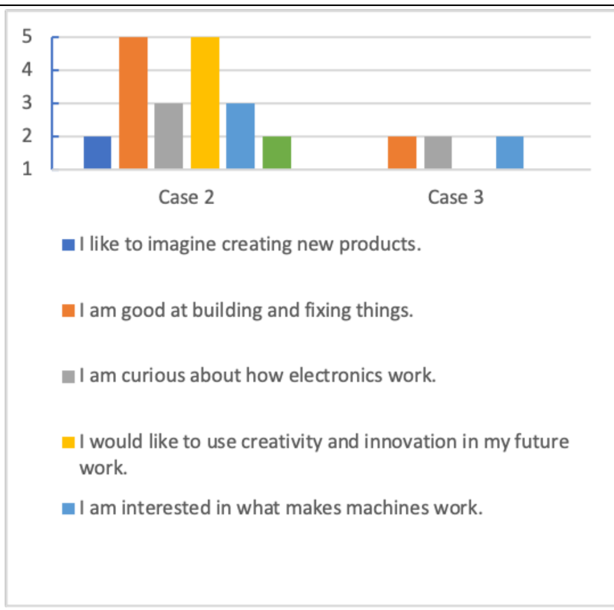
Day 1	Day 5





Technology Profile Scores for 2018 Cases

Day 1	Day 5



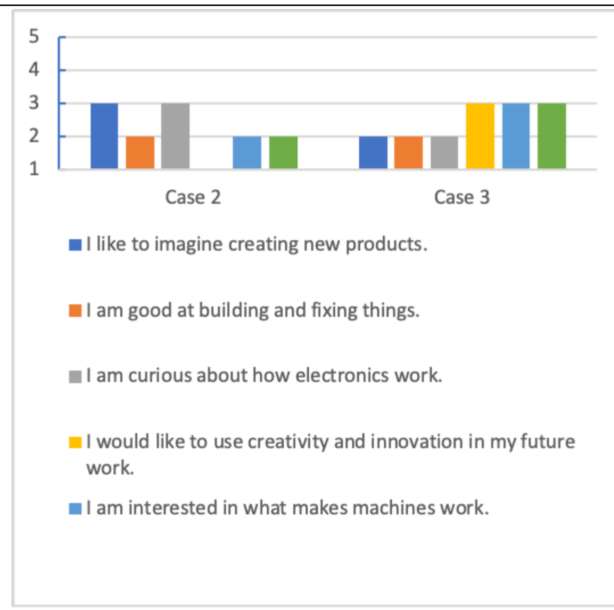
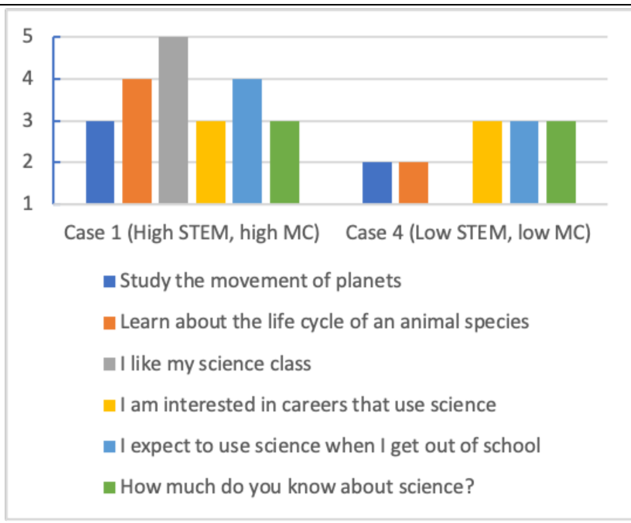
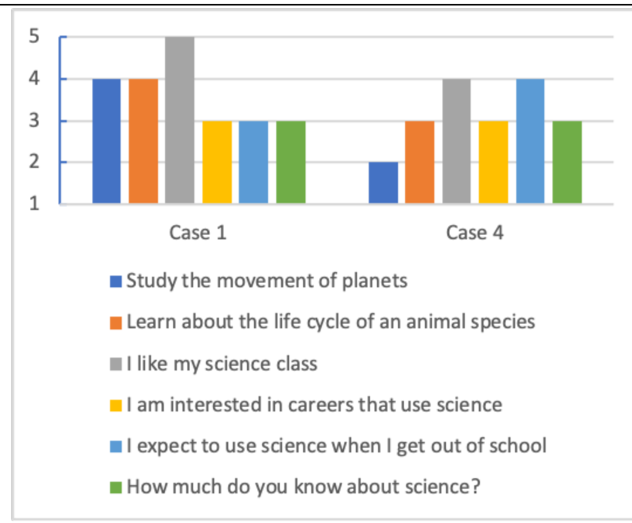


Table 19

Science Profile Scores for 2020 Cases

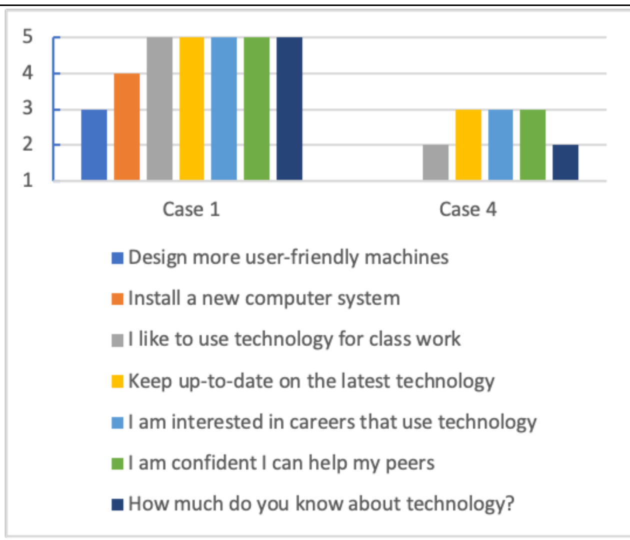
Day 1	Day 5

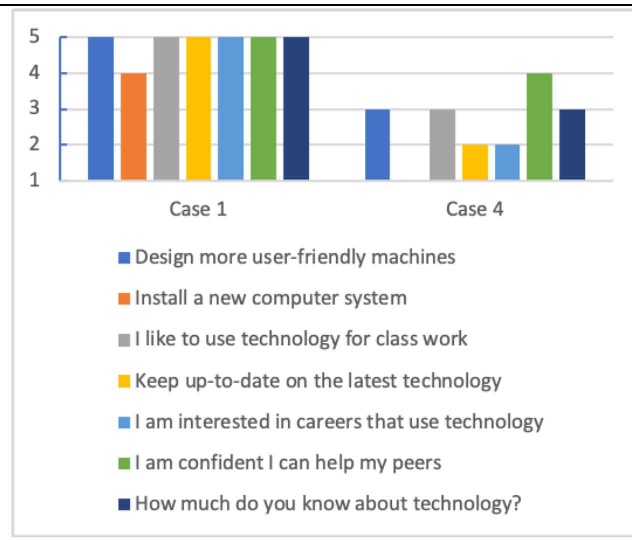




Technology Profile Scores for 2020 Cases

Day 1	Day 5





5.6 Habitability Definitions

Habitability was a key scientific concept covered during the summer camp. Participants were asked for the definition of habitability during the astronomy knowledge portion of the interview (Table 20). Case 2 was missing data due to an interviewer error and the habitability definition was provided to the participants. For Case 3, astronomy knowledge questions were omitted based on the judgement of the leading interviewer (refer to Chapter 3).

Table 20

Explanations for Habitability by Case

	Case 1	Case 4
Prior to intervention	I do not know how to explain what it is. If there is water and life it can be a habitat.	To make a place suitable for a human to live in. I guess.
Interview response	I remember it from the little game they [my note: from PBS Nova] had. Um, so that's the perfect place for a, a planet to be where it is livable on. So basically that, in that zone it's, it's close enough to the sun.	Oh, oh yeah, so. I answered it on Minecraft I'm trying to think what I said. Oh, I said, yeah, I think I said kind of similar to what you said. So, like the availability to live. That's what I say.
	It's not too far from the sun. It's close enough to the moon. It will have enough water. So basically, it means that animals in all types of life will be able to live there. And if it's in the habita... Like the sun, the earth is in the habitable zone.	The availability to live, um, to live in a, in a home. Not in a home. […] Like the yeah availability to live um, and like to, yeah, yeah, that's it.
Follow-up response	I would say it is something that makes a place able to have life on it. (23-week)	N/A

*Case 2 encountered an interviewer error. Case 3 was not asked for his habitability definition.

CHAPTER 6: DISCUSSION

In this last chapter, I discuss the implications of this study's outcomes. The main topics for discussion include interest triggering for all cases, methods to reach low interest learners, how prior gameplay experience affects interest for these four cases, and the meaning behind interest triggering episodes and its types (*explicit/implicit, prompted/spontaneous*). The results of the four cases are summarized in Table 21.

Table 21

Summary of Case Findings

	Case 1	Case 2	Case 3	Case 4
Age	13	12	13	12
Gender	Male	Female	Male	Female
STEM interest	↑	↓	↑	↑
Science interest	↔	↓	↔	↑
Technology interest	↑	↓	↑	↑
Minecraft mastery	↓	↔	Missing	↔
Total interest triggering episodes	16	7	7	11
Most frequent episode type	*Explicit / Prompted*	*Explicit / Prompted*	*Implicit / Prompted*	*Implicit / Prompted*

6.1 Interest Triggering for All Cases

RQ1: To what extent does a digital sandbox game intervention that enables freedom of choice and peer-to-peer interactions trigger interest in STEM?

To answer RQ1, interest triggering episodes were identified in interviews and fieldnotes for all cases across learners of both high and low interest in STEM prior to the intervention. My predictions did not capture all actual results. In Case 1, his high science score remained unaffected and serves as an indication that our camp presented the appropriate level of challenge for him to sustain interest in the topic. Another indication of an appropriate level of challenge was his decrease in Minecraft mastery; having considered himself an advanced player prior to our camp, his interaction with our content may have made him reconsider the extent of his existing knowledge about Minecraft capabilities. The results of Case 1 supports the idea that a game-based science intervention can be an affirming learning experience for an individual with high interest in STEM and high mastery of the technology used at hand.

For Case 2, scores for STEM, science, and technology interest decreased. Her astronomy knowledge score was similar to Case 1's, supporting her own report of having high interest in STEM prior to the intervention. Notably, Case 2 rated her science items the highest on a 5-point Likert scale prior to the intervention, and in the post-survey she rated these same items as 3's. A possible link to her decrease in interest across these topics is her low level of Minecraft mastery, which remained the same after camp. Case 2 was predominantly a mobile game player and a first-time Minecraft user, and our camp was designed for PC players with at least a basic understanding of how to play Minecraft.

The combination of technical challenges and a novice understanding of Minecraft and its features led to a scenario where a game-based science intervention was ineffective at increasing or maintaining interest in content. In instances like Case 2, novice players should be informed on the basics of the game and view it as a versatile learning tool. While interest triggering still occurred for Case 2, a misunderstanding or lack of information on how to use the game tool may result in decrease in interest of content.

In an interview, Case 2 stated her preference of challenging games. Based on fieldnotes, challenging activities such as the Redstone tutorial seemed to hold Case 2's attention. Yet Case 2's novice understanding of Minecraft was that it was a game that revolved around building and one that, through implication, was absent of challenge (refer to Section 5.1). Another possible link was the differing interest triggering experience between 2018 and 2020. In the 2018 camp, interest triggers *character identification, novelty,* and *autonomy* were absent whereas in 2020 they were present. Perhaps one or all of these interest triggers may have positively impacted Case 2's overall interest scores in STEM, science, and technology. Importantly, this speaks to individual differences of interest triggers from one individual to the next (Hidi & Renninger, 2006). The personalities of each participant and their relationship with the research team should be taken into consideration when interpreting and replicating these results.

For Case 3, science interest remained the same while technology interest unexpectedly increased. Though his Minecraft mastery score is unknown, the combination of an increased STEM and technology interest score point likely point to an unchanged mastery of Minecraft. It seemed that the 2018 intervention could not persuade Case 3 to change his mind on the value of science and its application to daily life. However, the intervention succeeded in increasing interest in STEM for a learner with low interest in STEM prior and increased interest in technology, the latter of which might be explained by his high level of mastery prior to the intervention; in other words, the camp may have served as an affirming experience of his mastery over Minecraft and technology in general.

Lastly, there was a surprising increase in science and technology interest for Case 4. I originally predicted that the combination of technical challenges and low Minecraft mastery would deter interest triggering for those with low STEM interest prior to the intervention, similar to the outcome of Case 2. Though Case 4 struggled with technical difficulties throughout the week, these hurdles did not prevent interest triggering for STEM and related topics throughout camp. This means that a game-based intervention had a positive affect not only on STEM interest, but science and technology as well, for a learner with little to no interest in STEM prior to the intervention and with low mastery of the game.

Notedly, our camp experience was initially designed for learners with basic understandings of Minecraft and not novice players (e.g., struggling to learn basic movements in-game). Case 4's unchanged, low level of Minecraft mastery suggested room for improvement in our intervention for learners with low incoming mastery of Minecraft. Perhaps with the appropriate amount of support to learn how to use Minecraft and with repeated exposure to both Minecraft and STEM content, Case 4's early phases of interest can develop form situational to that of individual interest. The results from Case 4 are promising for the future of interest triggering use videogames given her incoming interest level and knowledge about STEM and Minecraft.

6.2 Interest Triggering for Low Interest Learners

For Case 2 and Case 4, both who identified low mastery of Minecraft, the likelihood of interest triggered in STEM seemed reliant on what types of potential interest triggers were most effective based on their own preferences, their attitudes toward learning, and their unique personalities. Case 2 expressed a need for challenge in games she played and did not view Minecraft as a game that could present challenges, despite challenge as an interest triggering for her during the Redstone tutorial. While Case 2 remained quiet compared to her peers, Case 4 was more direct and frequent in asking for help throughout camp. Possible reasons could be that we identified Case 4 as a novice player early on in the week, while it seems we did not know Case 2 was a novice player until the end of camp; Case 4 received intensive one-on-one or small group support for navigating Minecraft and technology-related issues; and Case 4 might have felt more comfortable with staff and research team members than Case 2, and one of the contributing factors was Case 4's strong liking of Zoom.

It is possible that Case 2 quietly struggled with aspects of Minecraft without our knowing, leading to a decrease in STEM, technology, and science interest scores. However, the increase for Case 4 in STEM, technology, and science scores suggest that learners who identify low mastery of a game can benefit from the intervention when provided with active support. A suggestion for future studies in digital learning contexts is to utilize log files or generated user data to study these moments of silent struggle and present yet another layer of behavior data as evidence of interest triggering.

6.3 The Effect of Prior Gameplay Experience on Interest

> RQ2: What is the influence of prior gameplay experience on changes in STEM interest when using a game-based science learning intervention?

As technologies become integral to research studies, it is crucial for scholars to consider the experience level of participants prior to implementing the intervention. In a case similar to the classic tale of *Goldilocks and the Three Bears*, content that is too difficult or too easy for learners could deter them from becoming interested in the content presented. Novice players may become frustrated when attempting to complete an in-game task or be intimidated by the task despite interest in content (Bayliss, 2012). Experienced players may revert to their previous actions or habits (Nebel et al., 2016) and, as a result, preexisting ideas may persist even when the current environment contradicts them (de Jong, 2006).

To answer RQ2, the influence of prior gameplay experience did seem to impact changes in STEM interest during a game-based science learning intervention. Those who reported high Minecraft mastery prior to the intervention resulted in increases in STEM scores (Case 1 and Case 3). However, for those who reported low Minecraft mastery prior to the intervention, the influence of prior gameplay experience on changes in STEM interest remains unclear in the four analyzed. It is possible that the technical issues that arise for novices may be offset by specific interest triggers suitable for specific individuals. For instance, Case 2 could have benefitted from more interest triggers related to challenge throughout the camp and resulted in a neutral or increase in interest scores. The influence of prior gameplay experience on changes in STEM during game-based learning interventions should be further investigated.

The results of these cases point to the improvements made in the 2020 camp schedule compared to the 2018 camp schedule. Overall, the addition of a Launch Base, Moon Base, and Exoplanet maps, as well as the collaboration with PBS's NOVA Labs, resulted in more learner-directed interest triggers, more instances of encountering novelty, and identifying oneself in a scientist role. This is quantified by the total number of interest triggering episodes experienced by each case with 2020 participants outperforming 2018 participants (refer to Chapter 4). The 2020 camp successfully increased STEM interest for Case 1 and Case 4, the exemplars of the top and lowest performers of STEM interest and Minecraft mastery.

An assessment in 2020 tracked participants' knowledge retention of habitability, a key concept covered during camp, over three periods of time (prior to camp, during camp, and after camp). Prior to camp, both Case 1 and Case 4 admitted their uncertainty of what the term 'habitability' means and made educated guesses. During interviews, both cases drew on camp experiences when constructing a more sophisticated version of their initial guesses. Importantly, these cases referred back to camp experiences when they begin to formulate their answers, which serves as an indication that interest in content was triggered during those recollected instances. These cases are therefore examples of how Minecraft and an interest-focused design can help promote learning of targeted content. Due to the pandemic and reasons beyond our control, only Case 1 completed a 23-week follow-up survey in which he retained the definition of habitability.

6.4 Making Sense of Interest Triggering Episodes

In my exploratory approach to interest triggers, we coded interest triggering episodes as *explicit*/*implicit* and *spontaneous*/*prompted* (refer to Section 3.2). Case 2 exhibited more *explicit* and *prompted* episodes than *implicit* and *spontaneous* as predicted, likely because she was aware of their high interest in STEM but possessed little knowledge about Minecraft's capabilities (refer to Section 5.1). Interest triggering episode predictions for Case 4 was accurate in that implicit and prompted episodes were dominant. Case 4 was in an early phase of interest development for STEM topics and was more likely to rely on prompts from the interviewer to reflect on interest triggers, and less likely to mention 'interest' directly in her response. It is unclear how overcoming the technical challenges she faced (e.g., understanding how to operate Zoom and Minecraft, learning STEM content while learning to navigate in-game) impacted interest development and would benefit from a longitudinal study.

While the prediction for Case 2 and Case 4 were accurate, Case 1 and Case 3 yielded unexpected findings. I hypothesized that Case 1 would have the highest number of *explicit* and *spontaneous* episodes, however actual results showed highest number of *explicit* and ***prompted*** episodes. The reason for such high reports of prompted episodes could be explained by Case 1's high achieving behavior in school and respect for his mother, an elementary school teacher; Case 1 is eager to please those in educator roles and might view spontaneous utterances as disruptive or disrespectful to adults. Another possibility is the unique personality of individuals. While Case 1, Case 2, and Case 3 all exhibited largely prompted interest triggering episodes, their verbosity ranged from 29 to 141 words used for response per question.

In another unexpected finding, Case 3 exhibited majority *implicit* and *prompted* interest triggering episodes instead of *explicit* and *spontaneous* interest triggering episodes as hypothesized. Case 3 was the most talkative out of the four cases, but despite his high verbosity, his reflections on interest triggering needed prompting from interviewers. The high number of implicit episodes may have occurred because interest triggers identified were focused on STEM content and not Minecraft content. A question that remains unanswered regards the appropriate level of prompting required for participants of different ages to reflect on interest triggers experienced. Do adolescent learners need more prompting than adult learners? How do learners vary in early phases of interest when prompting reflections on interest triggers?

In sum, based on these four cases, learners with low mastery of a game tool exhibited largely prompted over *spontaneous* interest triggering episodes. Learners with low interest in content prior to the intervention exhibited mostly *implicit* and *prompted* interest triggering episodes. Learners who possessed high interest in content were more likely to yield *explicit* and *prompted* episodes. These patterns support the four-phase model in that those who are in the early phases of interest development may not be aware of their interest being triggered, leading to more instances of implicit interest triggers.

Most interest triggering relied on the prompting of the interviewers to reflect on interest triggering experiences, with spontaneous utterances in the minority. Interestingly, Case 4 had the highest number of *spontaneous* interest triggering episodes out of the four cases despite having the lowest incoming interest in STEM and level of Minecraft mastery. It is suspected that spontaneous utterances depend on the individual's personality and relationship with the interviewer, however more investigation is needed to understand spontaneity in relation to interest development. Another question that arose from this investigation is whether adults, who may have decades of experience to draw from compared to adolescent learners, would exhibit the same trend of mostly *prompted* interest triggering episodes. It is suspected that adults may feel more at ease to make a spontaneous utterance during interviews as opposed to an adolescent learner with an interviewer, whom the adolescent may view as a largely authoritative figure.

Future research studies targeting learners with a range of incoming interest can design measurements with these interest triggering trends in mind—realizing that interest triggers heavily rely on prompts from researchers—and to focus on further exploring the relationship between *explicit*/*implicit* interest triggering episodes and overall interest development in a digital learning context.

6.5 Reflections on Data Collection

In this dissertation, I investigated interest triggers within a digital learning environment, the first study of its kind. Several lessons can be learned from this study for those who wish to pursue similar endeavors. My selection of cases was based on theories on interest, my knowledge of the literature, and intuition which ones would best support answering my research questions. Prior to selecting my cases, I first dug into the literature and identified gaps within interest development and digital games research. There was a clear need to explore the unknown territory of how interest functions within digital learning environments. I then wondered how prior gameplay experience would impact changes in interest, drawing from my own experience as a gamer (knowing how to play a variety of games), past technical supporter (witnessing the challenges and frustrations of those with low technology mastery face, sometimes with basic tasks), and only child (reliving the memories of my parents' continuous struggle with technology and their reliance on my knowledge).

My curiosity drove me experiment with different ways to present my newfound research direction, ultimately leading to the creation of the matrix table that examined the four selected cases. While extreme cases may not be the most accurate representation of an entire population, they nonetheless can provide new insight and understanding. For instance, in America it is common to examine or read about comments from left-wing and right-wing extremists. This polarized, almost dichotomous relationship is not an accurate representation of the entire public (e.g., not every Republican is racist; not every Democrat is pro-choice), but it does show clear and opposing values from those that strongly identify with one identity over the other.

In the same sense, I wanted to examine the extremes of the highest and lowest performers of STEM interest and Minecraft mastery. How do these learners, some whom see themselves as very much a STEM-oriented person and others as completely uninterested, perform before and after our game-based intervention? How do they behave and react to the same game but with such contrasting degrees of gameplay experience? I also wanted to include cases that would represent a sort of middle ground (Case 2 and Case 3) in attempt to isolate the impact of either STEM interest or Minecraft mastery.

The most informative measure for interest triggers was the combination of surveys and interviews. Surveys served as a summative assessment of interest in STEM and self-perceived ability of Minecraft, providing the structural frame for each case. Interviews provided the unique painting that went into each frame, and the combination of these two measures allowed for these paintings to be mounted on the wall for the researcher to examine up-close and from far away—to examine just one painting in close detail or to compare broadly across these paintings that fall under one exhibition (e.g., what were the themes and patterns?).

The greatest contribution came from interviews as it was possible to draw both qualitative and quantitative results from the same sets of data. I was able to gather the total number and types of interest triggering episodes across cases and link these numbers to direct utterances of participants to interest and explore the relationship of *explicit*/*implicit* and *spontaneous*/*prompted* codes. Interviews may also serve the function of a survey, such as the astronomy knowledge assessment. At the bare minimum, semi-structured interviews (that have a short survey built into the structure) should be used to study interest triggers.

Measurements used in addition to surveys and interviews can only enhance the accuracy and representation of changes in interest. For instance, fieldnotes provided contextual information that was comparable across two years of data collection and provided insight about each participants' personalities (in alignment with their interview responses). As mentioned previously in Limitations (Section 4.7), there are different advantages and disadvantages to general versus case-specific fieldnotes. If cases are selected ahead of time, fieldnotes can be focused specifically on a set of participants, offering rich descriptions and a timeline of behaviors and utterances pertaining to interest.

However, the risk is that the participant is not guaranteed to participate fully (whether physically or mentally) in real-life research settings. The benefit of inspecting participants broadly is that upon retroactive analysis, the data may include information about other cases that may inform the researcher closely to the original selection of cases. In situations where more than one researcher is present, the team should decide among themselves which participants should be prioritized (case-specific) or divide the participants among themselves evenly (general, but ensuring all participants receive attention).

I strongly encourage those in different disciplines or subject focus to utilize the coding scheme by Renninger et al. (2019) and apply them to other informal digital learning contexts. To summarize the coding process used in this study:

1. Data was reduced to focus on STEM-related interest topics.
2. My colleague and I coded two datasets separately, isolating only interest triggering episodes (as in the identification of timestamps, or the duration of when an episode begins and ends).
3. We met and ran our first Cronbach's Alpha for agreement across identified interest triggering episodes. Next, we discussed our disagreements and ran Cronbach's Alpha again for agreement. The analysis for fieldnotes ended at this step.
4. Now that interest triggering episodes were identified, we coded interviews using the coding scheme developed by Renninger et al. (2019). Any codes that did not fall under this scheme was labeled *unknown* and further dissected later on. We first coded two datasets separately, met to run Cronbach's Alpha, discussed disagreements, then ran Cronbach's Alpha again.
5. Lastly, the same procedure for Step 4 was followed for my developed codes (*explicit*/*implicit, spontaneous*/*prompted*).

The codes developed by Renninger and colleagues provided a strong basis of identifying interest triggers, however since the original research was based in real-life and not in a digital context, divergence from their coding scheme should be expected. These new set of codes will likely emerge as context specific (in our case, with Minecraft) or fall under existing categories (specific instances of mentioning family members, which we categorized under personal relevance). It remained unclear why our developed code, *intent to reengage,* was not a part of the coding scheme considering that reengagement is critical in the development of interest. I strongly encourage future researchers to consider using our addition to Renninger and colleagues' coding scheme on reengagement.

6.6 Conclusion

The results of these four case studies showed promising and positive effects of using a sandbox game to trigger interest in STEM for learners with varying degrees of prior interest and game mastery. In three out of four cases, the experience of a game-based science learning intervention improved interest in technology regardless of changes in STEM interest or self-reported levels of Minecraft mastery. The variation found in my results reflect the complex and individualized nature of interest. The future of interest-centered game technologies should rely on interest triggers that are effective for each individual, ultimately leading to a personalized interest triggering environment for learning.

For our game-based intervention to increase interest in STEM, participants needed to have at least basic mastery of the game used in the intervention or have access to available staff and resources to support novice players. Support for novice players will likely need to be intensive 1-on-1 or small group tutorials and take place outside of the main curriculum. More investigation is needed to understand the effects of a sandbox game intervention on changes in interest of a topic, particularly for novice players.

Future researchers who wish to replicate this study using Renninger and colleagues' interest triggering codes for out-of-school settings should develop subcodes that fully captures the specific context and experience. In this game-based science intervention, subcodes about family and popular media were needed for the computers/technology category and personal relevance during interviews but not fieldnotes. While we agreed that many interest triggering episodes identified suited more than one code, our strict bottom-up approach with room for top-down limited the nuance in the types of interest triggering that occurred. Future studies should explore the use of multiple codes per episode to provide a nuanced outlook of interest triggers.

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APPENDIX A: PRE-SURVEY QUESTIONS

1. What does it mean to be a scientist? What does an astronomer do? (science-as-theory)
2. Do you see yourself as a science person? Why or why not? Could you see yourself becoming a scientist someday? (identity/interest)
3. Is there anything that interests you about space? Given the opportunity, would you walk on the moon? (interest)
4. Imagine this: you just won a pair of tickets to the Moon and you can take anyone in the world. Who would you take with you and what would you need to pack? What are the "must have's" you'll need to survive on the moon? (problem-solving, science-as-practice)
5. Can you tell me what habitability is? What makes a planet habitable?
6. Have you ever participated in our Minecraft camps before?

APPENDIX B: INTERVIEW PROTOCOL

2020 Version

Thank you for chatting with me today. My name is ____ and I work with Dr. Chad Lane on his National Science Foundation project. We want to learn more about how videogames impact learning. All of this is voluntary. You can also turn your camera off if you feel more comfortable that way. It would also help us a lot if I could record this session on Zoom so we can refer back to it later. Please let me know at any point if you feel uncomfortable or want to skip a question. Do I have your consent to record this session?

Home and School Life

1. How do you like school? Which class is your favorite and why?

Long-term Interest

2. Have you read any books or comics, television shows, movies, or museum visits about space after enrolling in our camp? Or look up any additional information regarding space on the Internet?
3. Could you give me an example of where you've talked about camp with your family or friends?

Minecraft Play

4. How often do you play Minecraft? About how long do you play each time? Where and how do you play it? Do you play alone, or with friends?

5. What's your favorite thing to build in Minecraft in either mode? How do you plan on building it?

Astronomy Knowledge

6. Can you tell me about the Moon? How does it affect us here on Earth?

7. What do you think Earth would be like if the Moon were twice as large as it is now?

8. Can you tell me what the Earth's axis of rotation is? Why is it important?

9. What do you think Earth would be like if it didn't rotate?

10. Can you describe what a “habitable zone” is? A “habitat” is a natural home of an animal, plant, or another living organism like you and me.

11. What do you think would happen if the Earth, as it is now, were closer to the sun, like Venus? Follow-up: Why would we not be able to survive?

12. What does it mean to be a scientist? What does an astronomer do?

13. Do you see yourself as a science person? Why or why not?

14. Is there anything that interests you about space?

15. What are the "must have’s” you'll need to survive on the moon?

Camp Feedback

16. If you could choose to go more in-depth about any of the hypothetical worlds, we explored this week, which one would you choose and why?
17. (For those applicable) I noticed you didn't make any observations (remind them what it is). Is there a reason why? Was it too hard to do?
18. Would you want to join our Minecraft camp again if we offer it next summer? (Ask for reasons)

2018 Version

Thank you for chatting with me today. My name is ____ and I work with Dr. Chad Lane on his National Science Foundation project. We want to learn more about how videogames impact learning. All of this is voluntary. It would help us a lot if we could record this session so we can refer back to it later. Please let me know at any point if you feel uncomfortable or want to skip a question. Do I have your consent to record this session?

Home and School

1. How do you like school? Which class is your favorite and why?
2. How often do you play video games? Tell me 3 games that you like the most and 3 you don’t like.

3. Do you like playing video games? Where do you play them mostly? Do you have to
4. follow any special rules? Ex: you can only play for an hour on the computer

Minecraft Play

5. How often do you play Minecraft? About how long do you play each time? Where and how do you play it? Do you play alone, or with friends?
6. Walk me through the first steps of how you'd play in your favorite mode (creative or survival).
7. What's your favorite thing to build in Minecraft in either mode? How do you plan on building it?
8. Which mode of the game do you like to play the most? Why do you like it best?

Minecraft and the Real World

9. Was there anything cool you saw in Minecraft and thought it would be great to have in the real world? Why? What do you do in Minecraft that you wish you could in the real world?
10. How does Minecraft resemble real life for you or how does it not? Could you provide an example?
    a. If needed: An example from me is that I think about how lava turns into stone when it touches water. The same thing happens in the real world and in-game.

Astronomy Knowledge

11. Can you tell me about the Moon? How does it affect us here on Earth?
12. What do you think Earth would be like if the Moon were twice as large as it is now?
13. Can you tell me what the Earth's axis of rotation is? Why is it important?
14. What do you think Earth would be like if it didn't rotate?
15. Can you describe what a "habitable zone" is?
16. What do you think would happen if the Earth, as it is now, were closer to the sun, like Venus? Follow-up: Why would we not be able to survive?

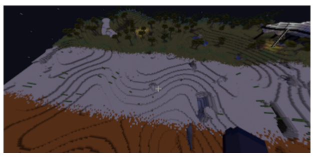
Lower-priority / Time-permitting

17. Are there any topics from any of your classes that came into your mind while playing Minecraft? Could you give me an example?
18. Is there anything that can be built in Minecraft that would not be possible in the real world?

    14. Could you make some comparisons between scientific attributes between the Minecraft and the real world (e.g., temperature, gravity, physical and chemical rules).

APPENDIX C: 5-WEEK FOLLOW-UP SURVEY

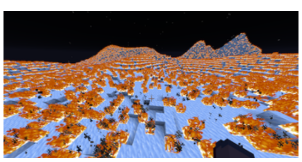
1. Thinking back to camp in July, what do you remember about playing on the Earth with No Moon map?



2. What do you remember about the Colder Sun map?

3. What do you remember about the Tilted Earth map?

4. What do you remember about the Lunar Crater map?



5. What do you remember about Exoplanets?
6. How would you explain what habitability is to a friend?
7. Do you see yourself as a science person? Why or why not?
8. What was most interesting about the Minecraft camp?
9. What is your first and last name?

APPENDIX D: STEM INTEREST ASSESSMENTS

S-STEM Survey for Grades 6th through 12th (Faber et al., 2013; Unfried et al., 2015)

* indicates that the item was included in the implementation at UNCC 2018.

1. (Exclusive to our lab version) What is your participant number?

Fill in the circle that describes how much you agree or disagree. (1-Strongly Agree, 2-Agree, 3-Neither Agree or Disagree, 4-Disagree, 5-Strongly Disagree)

Math

2. Math has been my worst subject.
3. I would consider choosing a career that uses math.*
4. Math is hard for me.*
5. I am the type of student to do well in math.
6. I can handle most subjects well, but I cannot do a good job with math.
7. I am sure I cannot do a good job with math.
8. I am sure I could do advanced work in math.*
9. I can get good grades in math.*
10. I am good at math.

Science

11. I am sure of myself when I do science.*
12. I would consider a career in science.*
13. I expect to use science when I get out of school.*
14. Knowing science will help me earn a living.
15. I will need science for my future work.
16. I know I can do well in science.
17. Science will be important to me in my life's work.
18. I can handle most subjects well, but I cannot do a good job with science.
19. I am sure I could do advanced work in science.*

Engineering and Technology

Engineers use math, science, and creativity to research and solve problems that improve everyone's life and to invent new products. There are many different types of engineering, such as chemical, electrical, computer, mechanical, civil, environmental, and biomedical. Engineers design and improve things like bridges, cars, fabrics, foods, and virtual reality amusement parks. Technologists implement the designs that engineers develop; they build, test, and maintain products and processes.

20. I like to imagine creating new products.*
21. If I learn engineering, then I can improve things that people use every day.
22. I am good at building and fixing things.*
23. I am interested in what makes machines work.*
24. Designing products or structures will be important for my future work.*
25. I am curious about how electronics work.*
26. I would like to use creativity and innovation in my future work.*
27. Knowing how to use math and science together will allow me to invent useful things.*
28. I believe I can be successful in a career in engineering.

21st Century Skills

29. I am confident I can lead others to accomplish a goal.
30. I am confident I can encourage others to do their best.
31. I am confident I can produce high quality work.
32. I am confident I can respect the differences of my peers.
33. I am confident I can help my peers.*
34. I am confident I can include others' perspectives when making decisions.*
35. I am confident I can make changes when things do not go as planned.*
36. I am confident I can set my own learning goals.
37. I am confident I can manage my time wisely when working on my own.*

38. When I have many assignments, I can choose which ones need to be done first.*

39. I am confident I can work well with students from different backgrounds.

Your Future (All questions were asked in this section for UNCC 2018 participants)

Here are descriptions of subject areas that involve math, science, engineering and/or technology, and lists of jobs connected to each subject area. As you read the list below, you will know how interested you are in the subject and the job. (1-Not interested at all, 2-Not so interested, 3-Interested, 4-Very interested)

Physics*: is the study of basic laws governing the motion, energy, structure, and interactions of matter. This can include studying the nature of the universe. (aviation engineer, alternative energy technician, lab technician, physicist, astronomer)

Environmental Work*: involves learning about physical and biological processes that govern nature and working to improve the environment. This includes finding and designing solutions to problems like pollution, reusing waste and recycling. (pollution control analyst, environmental engineer or scientist, erosion control specialist, energy systems engineer and maintenance technician)

Biology and Zoology*: involve the study of living organisms (such as plants and animals) and the processes of life. This includes working with farm animals and in areas like nutrition and breeding. (biological technician, biological scientist, plant breeder, crop lab technician, animal scientist, geneticist, zoologist)

Veterinary Work*: involves the science of preventing or treating disease in animals. (veterinary assistant, veterinarian, livestock producer, animal caretaker)

Mathematics*: is the science of numbers and their operations. It involves computation, algorithms and theory used to solve problems and summarize data. (accountant, applied mathematician, economist, financial analyst, mathematician, statistician, market researcher, stock market analyst)

Medicine*: involves maintaining health and preventing and treating disease. (physician's assistant, nurse, doctor, nutritionist, emergency medical technician, physical therapist, dentist)

Earth Science*: is the study of earth, including the air, land, and ocean. (geologist, weather forecaster, archaeologist, geoscientist)

Computer Science*: consists of the development and testing of computer systems, designing new programs and helping others to use computers. (computer support specialist, computer programmer, computer and network technician, gaming designer, computer software engineer, information technology specialist)

Medical Science*: involves researching human disease and working to find new solutions to human health problems. (clinical laboratory technologist, medical scientist, biomedical engineer, epidemiologist, pharmacologist)

Chemistry*: uses math and experiments to search for new chemicals, and to study the structure of matter and how it behaves. (chemical technician, chemist, chemical engineer)

Energy*: involves the study and generation of power, such as heat or electricity. (electrician, electrical engineer, heating, ventilation, and air conditioning (HVAC) technician, nuclear engineer, systems engineer, alternative energy systems installer or technician)

Engineering*: involves designing, testing, and manufacturing new products (like machines, bridges, buildings, and electronics) through the use of math, science, and computers. (civil, industrial, agricultural, or mechanical engineers, welder, auto- mechanic, engineering technician, construction manager)

The 'About Yourself' section was excluded from the UNCC 2018 data collection.

About Yourself

1. How well do you expect to do this year in your:

	Not Very Well	OK/Pretty Well	Very Well
English/Language Arts Class?	○	○	○
Math Class?	○	○	○
Science Class?	○	○	○

2. In the future, do you plan to take advanced classes in:

	Yes	No	Not Sure
Mathematics?	○	○	○
Science?	○	○	○

3. Do you plan to go to college?
   - ❍ Yes
   - ❍ No
   - ❍ Not Sure

4. More about you.

	Yes	No	Not Sure
Do you know any adults who work as scientists?	○	○	○
Do you know any adults who work as engineers?	○	○	○
Do you know any adults who work as mathematicians?	○	○	○
Do you know any adults who work as technologists?	○	○	○

STEM Interest Survey July 2020 Version at UNCC

*indicates integration of questions from 2018 S-STEM surveys with the exact same wording for baseline comparison.

Please indicate how much are you interested in each of the following activities. Respond ONLY based on how you FEEL about doing the activity. Do NOT think about whether you have the skills or knowledge to do the activity. (1-Not at all interested, 2-Not so interested, 3-Somewhat interested, 4-Very interested, 5-Extremely interested)

1. Study why earthquakes occur
2. Study the movement of planets
3. Learn about the life cycle of an animal species
4. Identify and classify bacteria
5. Install a new computer system
6. Keep up-to-date on the latest technology
7. Analyze problems in designing an airplane
8. Design more user-friendly machines
9. Use mathematics to solve problems
10. Take a course in advance mathematics

Please indicate how much do you agree with the following statements. (1-Strongly disagree, 2-Disagree, 3-Neither agree nor disagree, 4-Agree, 5-Strongly agree)

11. I like my science class
12. I like to use technology for class work
13. I like my mathematics class
14. I like activities that involve engineering
15. I am interested in careers that use science
16. I am interested in careers that use technology
17. I am interested in careers that use mathematics
18. I am interested in careers that use engineering
19. I expect to use science when I get out of school* (science)
20. I would like to use creativity and innovation in my future work* (engineering and technology)
21. I would consider choosing a career that uses math* (math)
22. I am confident I can help my peers* (21st century skills)

How much do you know about the following topics? (1-None at all, 2-A little, 3-A moderate amount, 4-A lot, 5-A great deal)

23. How much do you know about science?
24. How much do you know about technology?
25. How much do you know about engineering?
26. How much do you know about mathematics?

Demographics

27. What is the number of your laptop?

APPENDIX E: KNOWLEDGE ASSESSMENTS

Astronomy Questions Scoring Key (21 points)

Scores:

0 - "I don't know" or response is off-topic, or student is absent

1 - answers prompt but answer is unclear or generally incorrect

2 - answers prompt with one or more key ideas indicated by black bullets, but does not go into reasoning why it is the case (i.e. makes the tides bigger or smaller).

3 - answers prompt with examples and provides reasoning why it is the case or what would happen - inference (at least one use of white bullets).

Q1: Can you tell me about the Moon? How does it affect us here on Earth?

- Tides
    - Result of gravitational pull of moon
    - High tide on side facing moon and opposite side
    - Two high tides and low tides at all times as Earth spins
    - Pulls moon forward, giving moon energy, causes moon to spiral away
- Earth loses energy it gives to moon by slowing down
    - Days are getting longer
    - Reduced wind speed
    - This allows humans and nature to grow upwards
- Light at night for nocturnal animals

Q2 TRANSFER: What do you think Earth would be like if the Moon were twice as large as it is now?

- Gravitational force of moon on Earth stronger.
- Tides higher
    - Threatening to coastal cities

- Rotation slowed even more
    - Days and nights longer
- Brighter nights
    - Less stars visible

Q3: Can you tell me what the Earth's axis of rotation is? Why is it important?

- Line from North Pole to South Pole that Earth rotates around
- 23.5 degree tilt
- Results in seasons
    - Seasons are not proximity but amount of light hitting Earth's surface and for how long
    - Summer sees more concentrated sunlight for longer times
    - More concentrated light provides more heat
- Results in day and night
    - If tilted more parts of earth would not see sun for up to six months at a time

Q4: TRANSFER: What Earth you think Earth would be like if it didn't rotate?

- Every place on earth would have months of only darkness and months of only light
    - Habitability would be difficult on dark side.

Q5: What do you think would happen if the Earth was closer to the sun, like Venus? Why would we not be able to survive?

- We are at a distance where temperatures are not extreme
    - If closer, temperatures would be unbearable for life
- We are at a distance where liquid does not evaporate
    - If closer, oceans would evaporate because of heat

Q6: What does an Astronomer do?

- Use physics and math to study starts, planets, moons, galaxies, black holes, comets, and other phenomena outside Earth.
    - Study motion of these objects
- Sometimes find new planets and other objects in space.
- They make observations and use math to explain them.
- They collect data using telescopes
    - They test hypotheses and analyze data to determine whether or not hypothesis was correct, needs further testing, or needs to be discarded.

Q7: What are the "must have's" you'll need to survive on the moon?

- Shelter from radiation
- Dirt, seeds, water for farming
- Source for electricity
- Oxygen supply
- Suit and helmet
- Air pressure
- Regulated temperature
- Communication
- Transportation
- Medical supplies
- Other people
- Entertainment

Habitability Definition Score (23 points)

- A habitable zone is a region of Earth, or any celestial body, that has conditions suitable for maintaining life. Necessities of such conditions are:

- Water
- Oxygen
- Pressure
- Gravity
- Land
- Temperate climate (temperature is not too extreme)
- Light

The Tracking of Habitability Responses Across Time

- **Pre-survey:** Can you tell me what habitability is? What makes a planet habitable?
- **Interview:** Can you describe what a "habitable zone" is? A "habitat" is a natural home of an animal, plant, or another living organism like you and me.
- **5-Week follow up:** How would you explain what habitability is to a friend?

APPENDIX F: MINECRAFT SURVEY

Emoji representations of responses for 1 through 5 from left to right. An additional box will be available for “I don’t know.”

1. What is your laptop number?
2. Please rate how much you like each of the following Minecraft activities.
    a. Exploring a brand-new map.
    b. Exploring caves and finding new underground structures and resources.
    c. Playing in creative mode.
    d. Playing in survival mode.
    e. Building a safehouse or base for protection.
    f. Fighting off creepers, zombies, and other enemies.
    g. Building structures that could exist in the real world (Eiffel Tower, Sears Tower, bridges)
    h. Building fantasy buildings that could not exist in the real world (Star Wars ships, sky castles)
    i. Decorating buildings (inside and out).
3. Please rate how much you like each of the following Minecraft activities.
    a. Planning and designing buildings
    b. Calculating and measuring distances when building a large structure
    c. Playing Minecraft alone
    d. Playing Minecraft with friends
    e. Playing Minecraft on a server
    f. Building a redstone circuit
    g. Using command blocks

h. Collecting common resources (stone, wood, dirt)

i. Crafting tools for farming (axe, hoe, water bucket)

4. Please rate how much you like each of the following Minecraft activities.

    a. Building an automated irrigation system

    b. Building and using a piston

    c. Spawning/breeding animals

    d. Mining for resources (stones, jewels)

    e. Using bows for hunting

    f. Discovering and visiting different biomes

    g. Riding animals (pigs, horses)

    h. Creating and maintaining a server

5. Please rate how much you like each of the following Minecraft activities.

    a. Planting seeds and harvesting a crop

    b. Watching the sky (sunrise, sunset, moon)

    c. Crafting a fishing rod and going fishing

    d. Crafting armor and shields

    e. Watching YouTube videos about mods, construction, or other advanced topics

    f. Watching Minecraft story videos (fiction)

    g. Building a cannon (e.g. pig cannon using sticky pistons)

    h. Playing around with different resource packs, shaders, etc.

6. Please rate how much you like each of the following Minecraft activities.

    a. Building a calculator

    b. Smelting (iron ore, gold ore)

    c. Destroying things / blowing things up with TNT (mountains, trees, buildings)

    d. Building a minecart system

    e. Swimming or sailing in oceans, lakes, and rivers

f. Customizing Minecraft with mods, shader packs, and new skins

g. Taming a wild animal (wolf)

h. Building a recreational structure (fountain, library, roller coaster)

7. Please rate how much you agree with the following statements. If you have an example, we would love to know more under ‘Additional comments’ about something you really liked or did not like! (new 2020 additional section)

    a. I like telling and sharing with my teacher about what I did in Minecraft.

    b. I like telling and sharing with my parental guardians about what I did in Minecraft.

    c. I like getting feedback from my friends on something I’m working on.

    d. The camp instructors helped me learn throughout the camp.

    e. I liked hearing my friends’ thoughts and opinions about me during camp.

    f. I enjoyed exploring each map during camp.

    g. I think science is interesting.

    h. I think astronomy is interesting.

    i. I relied on other peers’ help during the camp.

    j. I relied on the instructors’ help during the camp.

    k. I liked working with my friends during the camp.

    l. I competed with my friends a lot during the camp.

    m. The camp experience was similar to what it would actually be like in outer space.

    n. I lost track of time during camp easily.

    o. I liked being able to ask the instructors and/or NPC’s science questions.

Demographics

8. Which best describes your experience with Minecraft?

    a. I am still new at it.

    b. I have played a fair amount and have nailed down the basics.

    c. I play often - even hours at a time sometimes - and can do quite a lot in the game.

d. I play a lot (or used to) and consider myself an expert. I use advanced features regularly.

e. I play way too much and all my friends ask me Minecraft questions (that I can answer). I use mods, set up servers, and more.

9. What is your age?

   a. 9 or younger

   b. 10

   c. 11

   d. 12

   e. 13

   f. 14

   g. 15

10. What is your gender?

    a. Female

    b. Male

    c. Prefer not to answer

    d. Other (option to specify)

11. What is your ethnicity?

    a. American Indian or Alaskan Native

    b. Asian or Pacific Islander

    c. Black or African American

    d. Hispanic or Latino

    e. White or Caucasian

    f. Prefer not to answer

APPENDIX G: SELECTION OF CASES (PARTICIPANT SCORES)

Cases that have been chosen are highlighted below.

STEM Interest Scores and Minecraft Mastery, Pre-intervention 2018

	Total Score (Out of 160)	Minecraft Mastery (Out of 5)
401	70	4
403	55	1
404	92	1
405	84	2
406	89	N/A
407	116	1
408	44	4
Case 3	70	5
411	80	3
412	59	2
413	67	N/A
Case 2	92	1
415	78	2

STEM Interest Scores and Minecraft Mastery, Pre-intervention 2020

	Total Score (Out of 130)	Minecraft Mastery (Out of 5)
Case 4	52	1
703	83	3
704	76	3
Case 1	108	4
708	70	1