

## SPECIAL COLLECTION: INNOVATIONS IN REMOTE INSTRUCTION

# Triggering STEM Interest With Minecraft in a Hybrid Summer Camp

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We investigated the application of Minecraft in the context of both in-person and hybrid summer camps for informal science learning. Our work focuses on determining the ways in which digital game-based learning experiences can act as triggers of interest in science, technology, engineering, and mathematics. Campers were invited to explore simulations of hypothetical versions of Earth (e.g., What if the Moon did not exist?), make observations of how these worlds are different from our own, and build habitats suitable for survival on these and other alien worlds. Multiple forms of data, including field notes, interviews, game log data, and in-game knowledge assessments, suggest that many different aspects of the game and informal learning contributed to interest development. In particular, learners were found to have their interest triggered by various in-game and contextual aspects of the learning experiences, such as instructional conversation, novelty, ownership, and challenge. These interest triggers remained constant across in-person and remote camp settings with no consistent differences emerging between the two settings.

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**Keywords:** interest development, interest triggering, educational games, informal science learning, engagement

The development of interest has repeatedly been shown to positively influence learning behaviors, choices, and outcomes (Renninger & Hidi, 2016). Interest is also well suited to act as a theoretical framework for research on informal learning as it frequently involves self-direction and higher levels of learner autonomy

(Renninger, 2009). In this article, we investigate the role of game-based educational technologies in fostering interest in science, technology, engineering, and mathematics (STEM). We leverage the popular game *Minecraft*, an open-world digital sandbox game, as our primary learning environment and tool for data collection.

The informal learning context for our work is that of a summer camp. Our camps provide a Minecraft-based curriculum that allows learners the chance to explore hypothetical versions of Earth (e.g., What if the Moon did not exist?) and feasible representations of known exoplanets. The curriculum is built around the concept of habitability and the search for a world capable of supporting human life. Camp activities incorporate a range of STEM disciplines, such as Astronomy, Earth Science, Civil Engineering, Plant Biology, and Atmospheric Sciences. Camps typically run for a week, 4 hr a day, and include a combination of interactive presentations on science topics (with discussion), exploration of virtual worlds together on a server, observations about how the various worlds are different from Earth, analysis of the properties of the worlds (e.g., oxygen levels, radiation, temperature), and culminate in a habitat design and construction challenge.

In each of the summers between 2018 and 2020, we held two, 1-week hybrid summer camps for middle school learners hosted at a community center for K-12 children from low-income families and who are historically underrepresented in STEM. In 2018 and 2019, the camps were held fully in-person in a classroom at the community center. Due to the COVID-19 pandemic, the 2020 version of camp was converted to a hybrid format with campers on site (with basic staff supervision) and remote instruction (via videoconference) from the instructional staff and researchers. In this article, we investigate the nature of interest development in both contexts. We explore how the affordances of Minecraft contribute to interest in STEM and identify key contextual factors

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that emerge as important. With a focus on the 2018 and 2020 data sets, we seek to identify similarities and differences between traditional and hybrid formats and assess the utility of Minecraft as an environment for promoting interest in STEM.

## Review of Literature

### Informal STEM Learning

The need to cultivate interest in STEM and the fundamental role it plays for learning is a recurring theme in prominent reports focusing on STEM education in the United States (National Research Council [NRC], 2009a, 2009b, 2011). The NRC (2015) recommends that STEM programs need to “respond to young people’s interests, experiences, and cultural practices” (p. 2-1). More recently, *How People Learn II* (National Academies of Sciences, Engineering, & Medicine, 2018) states “People learn continually through active engagement across many settings in their environments; learning that occurs outside of compulsory educational environments is a function of the learner’s motivation, interests, and opportunities” (p. 8). In addition, many informal contexts (e.g., museums, digital experiences) are designed in specific ways and for specific goals, and therefore suitable for empirical research on the impacts of those designs.

Interviews of adult scientists and engineers and STEM-engaged youth suggest that “interests in science often emerge before high school” and that as interest and engagement build, learners “increasingly seek out and create opportunities to learn,” many of which occur in informal learning contexts (Crowley et al., 2015, p. 297). Relatedly, analysis of school-based factors suggests that interest in STEM is most powerful when established prior to high school (Maltese & Tai, 2011). Establishing early interest in STEM is even more important for girls and minorities, who disproportionately exit from the STEM pipeline (aka, the “leaky pipeline”; Lyon et al., 2012; Wynarczyk et al., 2006). Thus, we focus our attention on middle school learners from audiences who are historically underrepresented in STEM.

### Interest Development

Research has repeatedly demonstrated that interest in a topic has a powerful influence on one’s perceptions, beliefs, attitudes, and willingness to learn more about that topic (Krapp, 1999; Renninger & Hidi, 2016; Silvia, 2006). The presence of interest leads to observable and meaningful differences in behavior. Renninger and Hidi (2016) explain that people who are interested in something “choose to reengage with a particular object/activity/idea, or content, repeatedly” and that their engagement “is distinctive and appears to be self-sustaining” (p. 1). The many positive consequences of establishing interest and its facilitating effect on learning are well documented (Hidi & Harackiewicz, 2000; Renninger et al., 2015b). When a learner is interested, that interest can feed on itself and grow (Barron, 2006). As a result, motivation to learn and attitudes about content improve (Potvin & Hasni, 2014), achievement and performance in school improve (Harackiewicz & Hulleman, 2010), and learners are more prone to establish deep conceptual understanding than are those lacking interest in the subject (Andre & Windschitl, 2003; Renninger et al., 2014).

Researchers typically characterize interest as a complex construct that incorporates cognitive, affective, and temporal components. We

adopt the view of Renninger et al. (2015b) who define interest as (a) referring to *interaction with particular content*, (b) existing as a *relation between the learner and the environment*, and (c) having *affective and cognitive components*. Importantly, interest has also been shown to be malleable and prone to change based on exposure and interaction with content. Hidi and Renninger (2006) proposed a *four-phase model* based on two primary phases: *situational interest*, a product of environmental features, which is followed by *individual interest*, a relatively self-sustaining state marked by reengagement over time and increases in autonomy. In learning contexts, *interest triggers* are defined experiences of high engagement that depend on features of the environment and are necessary for interest to develop over time (Renninger & Bachrach, 2015). Without access to content or reoccurring triggers, interest can become dormant and regress.

How to foster interest is a critical question for parents, educators, researchers, and policymakers, research suggests that the best triggers are novel and attention getting (Harackiewicz et al., 2016; Renninger & Bachrach, 2015) and lead learners to generate questions (Ainley & Ainley, 2015). Effective triggers often vary based on learner characteristics, but certain kinds of triggering events present themselves repeatedly across informal, inquiry-based interventions (Renninger & Bachrach, 2015). Triggering events that emerge from positive affect, challenge, computers and technology, novelty, ownership, character identification, and instructional conversation have been found to broadly strengthen interest in STEM (Renninger et al., 2019). Designing opportunities with such triggers in mind can facilitate the integration of new content with learners’ prior interests (Azevedo, 2018) and result in learners returning to the activities, wanting to know more about the underlying science.

Despite the elaborative body of research on how interest can be triggered, very little of this work has involved the study of interest development with virtual or game-based learning environments. Our work seeks to address this gap by investigating how interest-triggering events emerge in a sandbox-style video game (Minecraft) and by combining digital data (logs) with more traditional qualitative methods (interviews, field notes). We not only focus on triggers from within the game but also incorporate contextual factors to better understand the full scope of interest triggering in our summer camp settings and strengthen its relevance to the extant literature.

### In-Person Versus Hybrid/Remote

The COVID-19 pandemic upended traditional, face-to-face learning in both formal and informal environments, with many in-person environments remaining shuttered or limited in their capacity to reach the public for the duration of 2020 and into 2021. In response to spending more time at home, video game sales exploded among U.S. households and has held steady, with an 18% increase in sales as of April 2021 compared to that point in 2020 (Morris, 2021). Given Minecraft’s ongoing popularity, as well as its inherent collaborative style of play, investigating its suitability for learning during the pandemic was well worth pursuing.

While hybrid-remote learning conditions are less common targets for research, comparisons between online and face-to-face instruction have seen significant attention. For example, in a high school computer science class, students could receive more personalized feedback on code while learning remotely, although immediate and

peer-to-peer interaction was significantly reduced (Jayathirtha et al., 2020). Factors such as feelings of connectedness and community are generally recognized to be deficient for remote learning when compared to in-person. A study comparing graduate students enrolled in one of three modalities of education leadership courses (remote, hybrid, or in-person) found that students in the remote learning group felt a significantly lower “sense of classroom community” (Ritter et al., 2010). A recent study examining graduate student learning in a Public Health program at a university showed similar levels of learning between in-person and hybrid/remote, as well as commensurate levels of satisfaction between the two modalities (Walker et al., 2021). The literature comparing remote/hybrid and in-person learning for adolescent learners in informal learning environments is lacking, and our research helps to fill this gap by proposing that engagement and interest do not necessarily suffer from shifting from in-person to a remote/hybrid modality.

## **Virtual Environments and Educational Games for STEM Learning**

Virtual environments, simulations, and game-based environments for STEM learning have been a popular focus of educational technology research (Dede & Barab, 2009; National Research Council, 2011; Potkonjak et al., 2016). Although some reviews of game-based environments have produced mixed results (Honey & Hilton, 2011; Mayer, 2014; Wouters et al., 2013), many others have shown substantial promise for learning (Blumberg, 2014; De Freitas, 2018; Granic et al., 2014; Shute et al., 2013). Very little of this work has focused on whether, how, and to what extent digital environments can be used to influence interest in STEM. Some positive links have been found between situational interest and computer simulation use (Clapper, 2014), with pervasive technologies in promoting curiosity and interest (Arnone et al., 2011), and the use of technology to reveal interesting hidden phenomena (MacDonald & Bean, 2011); however, no research that we are aware of has investigated the relationship between learner behaviors in a digital or virtual environment and interest development. Identifying patterns of interaction and contextual factors in such environments, therefore, has the potential to expand our understanding of interest development in important ways.

## **Minecraft and Its Suitability as an STEM Learning Environment**

Our research uses *Minecraft* (Java Edition) as an STEM learning environment (Lane & Yi, 2017). Categorized as a *sandbox* game, *Minecraft* allows players to interact freely to explore and modify worlds as they wish. The basic unit of interaction is a *block*, which includes an enormous range of types such as stone, iron, dirt, oak, water, lava, slime, honeycombs, and hundreds more. Generated worlds consist of multiple biomes and terrain types and are populated by a range of animals and creatures. There are three primary forms of the game:

1. Survival mode involves exploration, gathering of resources, creating tools, combining materials (referred to as “crafting”), finding food, and building shelters to survive in a world full of zombies, skeletons, and “Creeper” monsters.

2. Creative mode empowers learners to by unlocking all block types and items and allowing players to fly and build as they please without fear of damage or monsters. In this mode, they may work with advanced tools like command blocks (that use code to control the world) or redstone (*Minecraft*’s version of electricity for building circuits and machines).
3. Adventure mode places players in a predesigned experience which may range from a puzzle-solving mystery, to Hunger Games-style combat arenas, or to astronomy science simulations like our server.

We primarily utilize Adventure mode in our study, as it is the most conducive mode to providing curated experiences. Learners explore worlds, talk to characters who provide objectives and science information, and then build their own space survival habitats based on relevant science characteristics of the worlds.

Since its release in 2009, *Minecraft*’s popularity has exploded with over 140M monthly players (McNulty, 2021), 241M logins per month, 231M copies sold (Microsoft, 2021), 2B+ hours played on Xbox alone (Fallon, 2015). The original company, Mojang, was purchased by Microsoft in 2014. Teacher use of *Minecraft* in schools and afterschool programs enjoys great popularity (Groden, 2015) for topics as diverse as history, foreign languages, social studies, and mathematics (Bos et al., 2014; Schwartz, 2015). *Minecraft: Education Edition* has been used by over 31M students worldwide (Microsoft, 2021). *Minecraft* has grown into three platforms and versions, including a simpler, monetized variation for mobile devices targeted at young children, a dedicated education edition with curricular tie-ins and the hugely modular long-standing community-driven Java Edition that we have leveraged for our project.

Because *Minecraft* can be considered a simulation of the natural world, it provides numerous direct links to STEM (Lane & Yi, 2017). Soon after its 2009 release, Short (2012) summarized *Minecraft*’s suitability for science learning as follows: “*Minecraft* also has a functioning ecology, with chemistry and physics aspects interwoven within the game that can be used to develop the scientific literacy of players.” It has also been used as a tool for engaging struggling math learners (Parrilla, 2012) and as a research context for understanding collaboration (Davis et al., 2018). Empirical research with *Minecraft* demonstrating its suitability for knowledge and skill acquisition is increasing (Baek et al., 2020) and it has been shown to be well suited for summer camp formats and broadening participation in STEM (Ames & Burrell, 2017).

## **Research Questions**

We are broadly interested in understanding how interest develops in digital learning environments, specifically educational games. In this study, we investigate interest-triggering events that emerge while children are interacting with virtual worlds that represent scientifically plausible alternative versions of Earth and known exoplanets in *Minecraft*. Our two primary research questions and hypotheses are:

1. In what ways does a *Minecraft*-based informal learning experience trigger interest in STEM?

*Hypothesis 1:* Learner interest will be triggered by features such as novelty, personal relevance, and autonomy during *Minecraft*

play. Additionally, having instructional support available to offer guidance and answer content questions will provide further opportunities for interest triggering.

2. What limitations and/or benefits does a hybrid/remote learning context have on interest development?

*Hypothesis 2:* We hypothesize Minecraft-related triggering events will occur in both research contexts given the existing appeal of the game and ability to virtually be together on the server.

Below, we describe four different sources of data that we collected to help answer these questions. We hope that addressing such questions advance our understanding of what aspects of both learning environments are most important for interest triggering to occur. Connecting game play data with expressions of interest through interviews and actions could provide insight into how learners reveal and develop their interests in digital environments.

## Method

Assessing and measuring the development of interest is methodologically challenging (Linnenbrink-Garcia et al., 2010; Renninger & Hidi, 2011). In following best practices, we adopted a mixed-methods approach by collecting data in various forms to better understand the richness and complexity of potential interest-triggering events. Our data include (a) behavioral logs from our server, (b) field notes, and (c) interviews. Behavioral data captured how students played Minecraft, where and how they explored, what observations they made, how they went about building, and off-task behaviors. Field notes captured what students talk about, their affect during play, their participation in discussion, and any notable behaviors or activities that were unlikely to be captured automatically. Finally, interviews included questions about their feelings about STEM generally (e.g., classes) as well as how they felt about the content of the camp.

## “What-If” Minecraft Server and Supporting Materials

One key element behind the success of Minecraft is how easy it is to set up and host a server to enable groups of players to inhabit the same map. Unlike many popular games, where players connect to

company-controlled servers to play with others online, Minecraft provides participants with the option to create their own personalized server to play with just their friends. For some, this may mean a server with a focus on creative building elements, for others it may be more about violent or competitive outlets, and for others still it could be a social gathering grounds and associated community. Ultimately, playing on a Minecraft server is second nature for most players, thus making the decision very easy for us to configure one for our project.

Our server emerged out of a summer camp series and collaboration with teen interns as an experiment in modeling alien worlds. Our project, *What-If Hypothetical Implementations in Minecraft* (WHIMC) was based on these early prototypes and evolved into an environment that allows kids to explore a range of hypothetical versions of Earth and known exoplanets. We currently use a web-hosting company for our game server which is comprised of world files like “Earth with No Moon.” Content is created with a combination of third-party design software and in-game extensions like datapacks and plugins.

We use a database to keep track of participant engagement with commands (actions), quests (tasks), and exploration, which in turn allows our team of designers and developers to shape the server experience and learning opportunities based on what participants do. We intentionally chose Java Edition over Education Edition because it allows us the ability to create more realistic and interesting astronomy simulations, and, more importantly, automate parts of our data collection to create a learning system that is responsive to player actions.

Our Minecraft server is home to most of the learner activities in the camp. When a learner logs on to the server, they begin on a “Hub” world that uses an airport (or “spaceport”) metaphor to help the navigate all worlds and resources (Figure 1). A learner can move around to speak with any number of nonplayer characters (NPCs) who have relevant knowledge or guidance for the visitor (e.g., offering quests to accomplish, explanations about the worlds). The hub is broken up into several areas providing access to and information about our solar system such as a Moon base (Figure 2, left) and Mars. Other sections of the hub give access to hypothetical versions of Earth (“What-if” worlds) and several known exoplanets. While visiting these worlds, learners have access to a suite of science tools that enable them to measure temperature, radiation levels, oxygen, airflow, and other variables relevant to habitability. Also,

**Figure 1**  
*The Hub of Our Minecraft Server*



*Note.* From here, learners can explore a variety of rooms, take on missions (left), learn about resources and science, and take portals to visit other worlds (right).

**Figure 2**

*A Model of a Moon Base That Includes a Nursery, Living Quarters, Research Facilities, Ice Mining, Solar Power Station, and More*



*Note.* Gravity is 1/6 that of Earth allowing learners to experience low gravity (left). A scene from the “What if the Moon did not exist?” map displaying short, sturdy trees (right) that are able to withstand the intense winds that would exist on such a version of Earth (without the Moon’s gravitational pull to slow down Earth’s spin).

on the worlds learners are invited to make observations of what is different or unique (Figure 2, right). Finally, in the camps, learners are invited to build habitats for survival on these often-inhospitable worlds, which encourages them to apply their understanding of habitability and use engineering principles to build habitats that address the unique features of the worlds (e.g., slanted roofs to protect against fierce winds, underground rooms to protect against radiation).

Over the past several years, we provided three principal What-if worlds for exploration on our server: No Moon, Colder Sun, and Tilted Earth. Each world represents a feasible alternative for how Earth could have evolved. In Earth without a Moon, learners experience high winds and a unique landscape resulting from strong, constant winds, as well as a much faster day/night cycle (note: this would be a result of not having the Moon’s gravitational pull to slow down Earth’s spin). In our second world, Earth with a Colder Sun, the Earth would need to be much closer to that Sun and would lock in orbit, exposing one side of the Earth to constant heat, the back side to cold darkness, and a “habitable” strip along the boundary. We use three maps to represent different areas on the planet (desert, tundra, habitable zone). Finally, our third world reflects the possibility that Earth’s rotational axis was 90 degrees rather than 23.5. With such a massive tilt, Earth’s seasons would be radically different producing a long frozen and thawing cycle having major impacts on the surface. We also used three maps to represent these changes based on time for Earth titled 90 degrees (Winter, Spring, Summer). Together, these fantasy worlds seek to help the learner reflect on our own Earth and imagine what it would be to live on these alternate versions of Earth.

Feedback from summer camp participants and online players has contributed to improvements in server design. First, we have added several tutorials and spaces to kickstart interest, including a rocket launch facility and Earth and lunar-based scenarios to teach what scientists look for and how they make observations. Several exoplanets, including Gliese 436b, Cancri 55e, and Trappist 1e are presented as examples of extreme (but observable) conditions where humans could not exist. A conceptual diagram of overall user experience and learning pathways on the server, as tied to standards-based and social-emotional learning objectives (as of summer 2021) is provided for reference (Figure 3).

## Technology

In-person camps make use of classroom facilities with ample power, internet, wall-mounted displays, and writing spaces as well as laptops for each participant. The software is configured in advance by staff using premade installation packages in combination with loaner accounts provided to participants for free and each tied to data collection protocols. Hybrid camps made additional use of video conferencing and headsets, and all forms of our camps or workshops include a variety of instructors, supporting staff or interns, as well as additional activities like recess and snacks, or complementary learning programs such as the Public Broadcasting System (PBS) NOVA Exoplanet lab or Worldpainter Minecraft map design tool. Other traditional teaching resources and techniques, such as lectures and slides, worksheets or handouts and ball-based planetary relationship demos are included either live in camps or as online resources for independent learners.

## Context

### *In-Person Summer Camp*

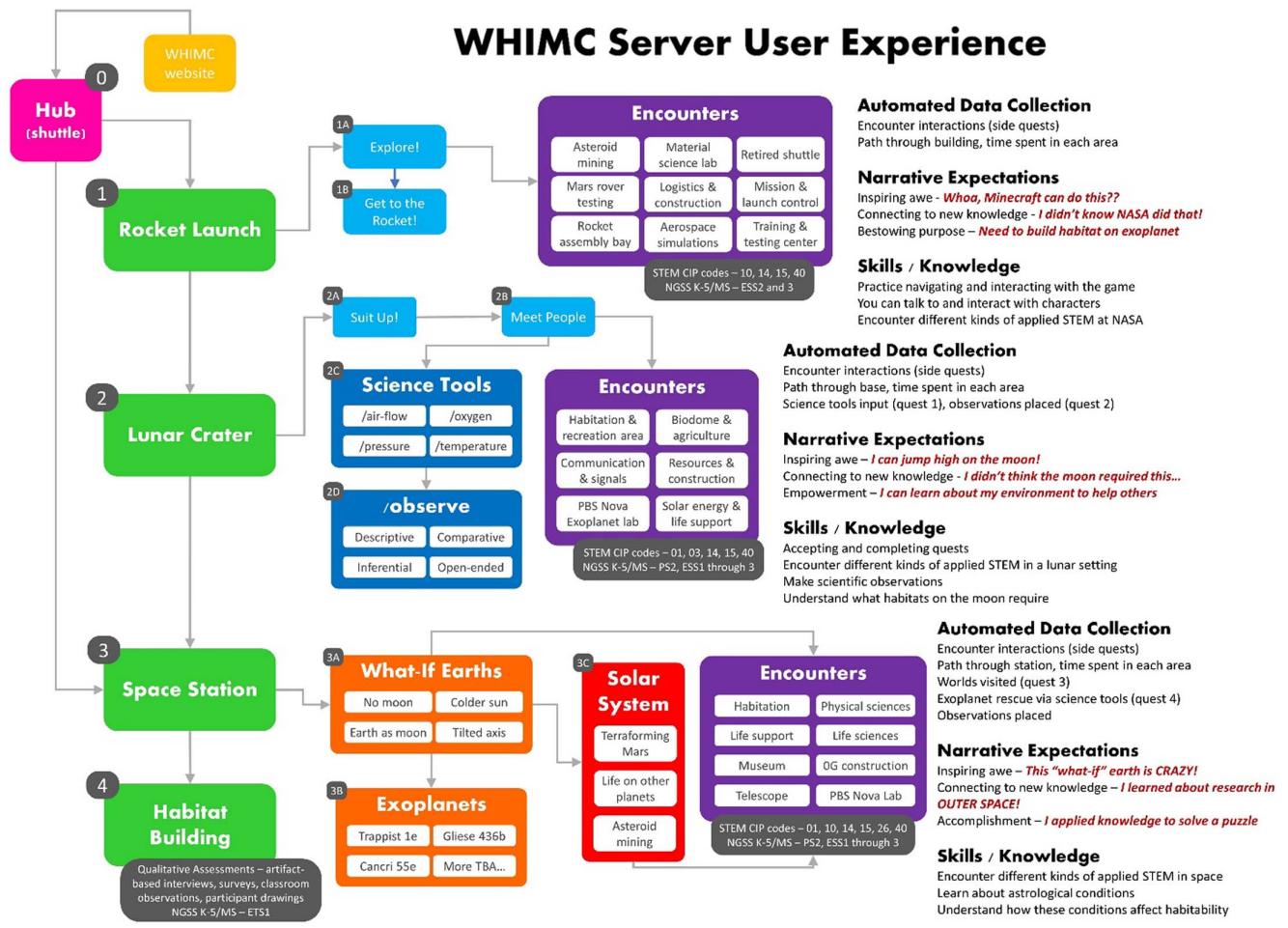
Conducted in summers 2018 and 2019, 1-week camps were held in the afternoons for 4 hr each day and consisted of learning activities including technical tutorials, lecture, discussion, guided explorations within the game, and free time to work on individual or group projects. No grades were assigned for these activities. We partnered with a nonprofit community center serving underrepresented populations in a small Midwestern city to run the camps. Researchers and instructors were onsite, along with center staff, to guide the camps. Figure 4 (upper left) shows a typical day in the in-person camp.

### *Hybrid Summer Camp*

Implemented during summer 2020, we partnered with the same community center as in 2018 and 2019. However, due to concerns regarding the COVID-19 pandemic, no research team members were onsite with the learners. Interaction occurred through videoconferencing software and in *Minecraft* on the same laptops (one per student). Community center staff were on-site to chaperone participants and

**Figure 3**

A Snapshot of Overall User Experience and Learning Pathways as Tied to Standards-Based and Social–Emotional Learning Objectives (as of Summer 2021)



**Note.** WHIMC = What-If Hypothetical Implementations in Minecraft; STEM = science, technology, engineering, and mathematics; NGSS = Next Generation Science Standards; MC = Minecraft; CIP = Classification of Instructional Programs; ESS = Earth & Space Science; NASA = National Aeronautics and Space Administration; PS2 = physical sciences 2.

monitor behavior. Participants were required to wear masks while indoors and were distanced as close to 6 ft apart as possible in the community center. Content-wise, while structurally the same as 2018 with the same basic activities, a few additional components were offered including a Moon base and an online PBS NOVA Lab focused on exoplanet detection (non-Minecraft related). Images of the camp are shown in Figure 4 (upper right and lower half).

## Participants

In 2018, participants ranged from 10 years to 13 years old, ( $n = 22$ , 59% female,  $M_{age} = 11.5$ ,  $SD = 0.910$ ). None of the participants previously participated in one of our summer camps. Of the 22 participants, 14 identified as Black/African American, two as biracial, and six declined to respond. All participants qualified for free and reduced lunch. Consent was received from the parent or guardian of the participant and the participant. Each child was

informed their participation was voluntary, and they could withdraw from the camp at any time.

In 2020, participants ranged from 10 years to 15 years old ( $n = 13$ , 62% female,  $M_{age} = 13$ ,  $SD = 1.256$ ), with five participants having previously participated in our camps: one in 2018 only, one in 2019 only, and three in both 2018 and 2019. Of the participants, 10 identified as Black/African American, two as biracial, and one declined to respond. All participants qualified for free and reduced lunch. Consent was received remotely, through an institutional review board-approved platform, from the parent or guardian of the participant and the participant. Each child was informed their participant was voluntary, and they could withdraw from the camp at any time.

We note that while we did hold the camp in 2019, we are not including this data set in our analysis because of some inconsistencies with respect to participation, different interviewers, and staggered participation of campers that week. We will continue to investigate these differences for future research.

**Figure 4**  
*Summer Camp Physical Space*



*Note.* Prepandemic conditions allowed for fully in-person instruction and discussion (upper left); while in a hybrid format, instruction and discussion occurred over videoconferencing during the pandemic (upper right), with campers socially distanced and masked at the community center (lower half).

## Measures (Table 1)

### *In-Game Data*

**Observations.** Campers were asked to explore our different worlds and make in-game observations about things that look different or “weird” to them with a custom-made plugin that drops floating signs with observation text in-game (Figure 2, right side). A camper might observe an area of a map in Minecraft covered in snow and record an observation by typing “/observe” in the in-game command bar followed by the observation, such as, “This area gets no sun so it is frozen and too cold for humans.” Campers are all encouraged to type such observations in-game as they explore the variety of maps on the server. Early piloting revealed that campers were found to be comfortable entering observations on the command-line of the game (Yi et al., 2020). Each in-game observation made by campers is recorded and saved in a database where we can extract all observations for analysis.

Using in-game observations made by participants in the 2018 summer camp, we initially developed five codes to capture the nature of the scientific observations (Yi et al., 2020), but soon-after extended the scheme to six codes to capture additional nuances discovered in the data. We also added an evaluation component to assess the quality of observations (i.e., whether the connection between the scientific observation and category was clear or ambiguous). Table 2 lists all codes, definitions, and examples. We organized categories by their level of sensemaking and reliance on external knowledge: Factual observations and off-topic comments are the lowest level (i.e., “I see pigs”), followed by descriptive and comparative as mid level (i.e., “This area is entirely dirt compared to the area on the other side of the mountain”), and inference and analogy as the highest level of sensemaking (i.e., “A tsunami must have hit this coast because it looks destroyed”; Yi et al., 2020). Two graduate students on the project applied the coding scheme to 200 observations from the 2019 camp using Microsoft Excel, achieving an interrater reliability of  $\kappa = .87$ , indicating strong agreement.

**Table 1**  
*Comparison of Context and Measures Between 2018 and 2020*

Year	Context	Field notes	In-game observations	ICANs	Exploration logs	Interviews
2018	In-person	Recorded by two researchers in-person	Yes	No	Yes	In-person
2020	Hybrid/remote	Recorded by two researchers via Zoom	Yes	Yes	Yes	Via Zoom

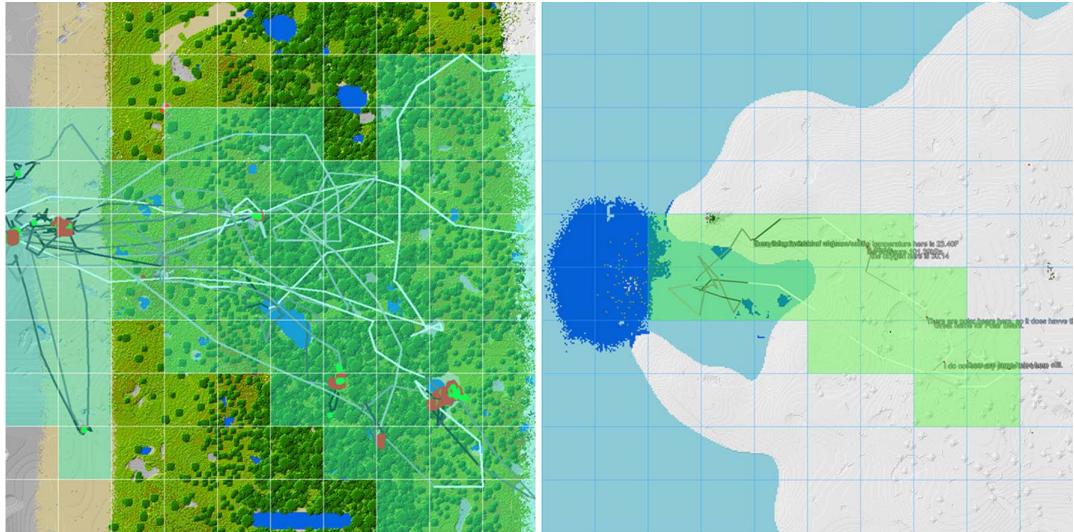
**Table 2***Codes Used to Describe Scientific Observations Made by Participants in Minecraft*

Category	Definition	Quality
Factual Off-topic	Stating nouns without any elaborations Technology related, conversational	Direct observations (“carrots,” “pigs,” “I see flowers”) Irrelevant to task (“smoking is good,” “I was here,” “Participant 2’s Place”)
Descriptive	Related to color, temperature, quantity, and other physical attributes such as weight or size	Clear (“lots of coral,” the temperature is 200 F) Ambiguous (“the water is very nice”)
Comparative	Comparing one natural phenomenon to another; expectations are violated	Clear (“the grass is greener in the habitable strip”) Ambiguous (“the trees are different,” “I haven’t seen no animals”)
Analogy	Comparing natural phenomena with another similar structure or object; an advanced form of comparative	Clear (“tumble weed looking plant,” “the wind blows fast like a tornado’s here”) Ambiguous (“the trees look like animals”)
Inference	A hypothesis or explanation is proposed	Clear (“trees grow because probably facing the sun a lot,” “I assume the stone is here because the water tide moved it”) Ambiguous (“climate change,” “it’s livable here”)

## Exploration Logs

Positional data for each participant are recorded on our server every 3 s. This enables us to create detailed maps of exploration behavior and unpack the depth of engagement learners have with our maps. Participants are encouraged to explore and make scientific observations based on variables represented in-game, such as pressure or temperature, as well as those they can readily see, such as the presence of the Moon, shape of the terrain, or effects on plant and animal life. Exploration logs were extracted for seven maps on our server (discussed above: one for No-Moon, three for Colder Sun, and three for Tilted Earth) and only included days where participants were asked to explore and make observations.

To score the quality of exploration, each map is divided into a  $10 \times 10$  grid and if a player occupies a cell on the grid at some point, we record that the cell was visited. Exploration is then scored as the sum of all cells visited while on the map; a higher number of squares visited indicates a player with a high level of exploration (maximum = 100). The quantity of exploration may not denote quality, however, which is why we also examined observations made, science variables measured, and quests encountered as additional metrics to determine engagement. Figure 5 provides two examples of exploration paths and scoring (shaded boxes represent areas of the map counted in the exploration scoring algorithm).

**Figure 5***Exploration Maps From Learners Investigating Hypothetical Worlds*

*Note.* Dark lines represent walking while lighter colors indicate flying/elevation. Our exploration counting algorithm carves up the space in a  $10 \times 10$  grid and counts the number of cells that are visited along a path (depicted by shaded cells in the images).

## Nongame Data

### Interviews

In 2018, semistructured interviews were conducted with each participant and two researchers present. Interviews were conducted on the last day of camp and took approximately 10–15 min per session. The interview protocol consisted of 14 questions and covered topics on home and school life, Minecraft play preferences, and astronomy knowledge. For example, participants were asked, “How do you like school? Which class is your favorite and why?” “How does MC resemble real life for you or how does it not? Could you provide an example?” And “Can you tell me about the Moon? How does it affect us here on Earth?” See Appendix, for 2018 interview protocol.

In 2020, one-on-one semistructured interviews were conducted over videoconference in 1-1 breakout rooms, and again on the last day of the camp. Interviews took approximately 10–15 min per session. The interview protocol for middle school students consisted of 16 questions and covered topics on home and school life, long-term interest, Minecraft play preferences, astronomy knowledge, and camp feedback. The 2020 protocol was similar to the one used in 2018; however, questions were added to understand participant interest in astronomy as a result of the camp context, such as “Has WHIMC camp helped answer any questions you have about space? Has camp prompted you to think of a question about space you would like to answer?” and “Have you read any books or comics, television shows, or movies about space after enrolling in our camp?” Additionally, questions were added to gauge how participants identify with science, such as “What does science mean to you?” And “Do you see yourself as a science person?” Our 2020 interview protocol can be found in the Appendix.

The 2020 interviews were coded in Microsoft Excel for specific interest triggers by two graduate researchers using codes developed by Renninger and Bachrach (2015), such as novelty, autonomy,

challenge, instructional conversation, or computers/technology. For example, a learner might state in their interview that they liked the habitat-building challenge because it required them to think creatively. Such a statement would indicate interest in an activity, and “challenge” would be the appropriate trigger, based on their statement. Interest-trigger definitions can be found in Table 2. All interest triggers were based on participant responses to interview questions and coded from individual interview transcriptions. Cohen’s  $\kappa$  was used to determine the agreement between the two researchers on interest-triggering episodes. There was a substantial agreement between the two researchers’ initial coding on interest-triggering episodes,  $\kappa = .73$ . All disagreements were resolved in conference.

### Field Notes

In 2018, field notes were collected by two researchers on location. Field notes in 2020 were collected remotely by two researchers using both videoconference and Minecraft. Observations were coded using interest triggers developed by Renninger and Bachrach (2015) and modified by two researchers from our lab to capture observations specifically related to digital environments. These are the same interest triggers used to analyze the interview responses (see Table 3). In total, thirteen interest triggers were implemented to capture interest-triggering episodes related to camp sessions in 2018 and 2020. The two graduate students who did the coding were the researchers collecting field notes in 2020, one of the graduate students collected field notes in 2018 and the other researcher collecting field notes was a visiting scholar. All coding was done using Microsoft Excel. The researchers primarily looked for instances where participants expressed excitement about an activity, asked questions, displayed focused attention on their task, and instances where learners disengaged or became disruptive.

**Table 3**  
*Interest Triggers Definitions*

Codes	Triggers for STEM interest	Elaboration
AFF	Affect	Participant experiences joy or frustration; usually coincides with hands-on activity.
CI	Character identification	Seeing oneself as a scientist (or other relevant character)
O	Ownership	Feeling that an output of an activity belongs to or is an extension of the learner.
A	Autonomy	Learner-directed activity, often involving answering a personal question
C	Challenge	Content or activity that is difficult for the learner, including problem-solving
COM	Computers/tech	Work with computers or another form of technology
COM-P	Popular media	Cultural references to movies, TV shows, games (non-MC), books
COM-MCL	Minecraft learning	Play preferences; in-game interactions that lead to new knowledge or understanding; builds on prior knowledge
COM-MC	Minecraft play	Play preferences or interactions with Minecraft that do not result in learning of the content
GW	Group work	Work with others, where others are peers and not the instructor
H	Hands-on activity	An activity that is interactive or involves the use of one’s hands
I	Instructional conversation	A conversation that engages content and enables a learner to reach a new understanding
N	Novelty	Anything that is new or arouses curiosity, including new insight about something that is familiar
PR	Personal relevance	A connection between an activity and a learner’s past experience, plus attempt to build on prior knowledge
PR-F	Family influence	Interaction with family members that engages content and influences engagement with content
UNK	Does not fall under the above	An interest trigger that does not fall under any known categories; any interest that is non-STEM related
E	Intent to reengage	Willingness to reengage in a learning activity in the future

*Note.* STEM = science, technology, engineering, and mathematics; UNK = unknown.

## Data Analysis

We rely on mostly qualitative data to answer research question 1 (RQ1; triggering of interest in camp). Because of small sample sizes in our camps, we are unable to achieve statistical power to make significant claims about how the experience triggers, or contributes to the development of, STEM interest in adolescents. However, a small sample size does allow us to closely examine field notes and interviews with participants to draw case studies answering our research questions. We take a contextual inquiry approach to human-computer interaction research (Blandford et al., 2016), which interleaves interviews and field notes to examine how participants' interest in STEM influences how they interact with STEM content in Minecraft, and how their interactions in Minecraft influence their statements about STEM in interviews. We do include some simple descriptive analyses, such as most in-game observations made or highest mean exploration score, to support our qualitative data.

To answer research question 2 (RQ2) about the limitations of hybrid versus in-person experiences using Minecraft to develop STEM interest, we incorporate more quantitative methods through comparisons of proportions of interest triggers present, mean exploration scores, as well as quantity of in-game observations made across contexts. Because of incomplete exploration data from our server in 2018, the exploration patterns could only be gathered for 1 week of participants ( $n = 8$ ). A Mann-Whitney  $U$  test was used to examine mean differences in exploration patterns at both participant and worlds explored levels, as well as overall observations by participants, in hybrid versus in-person contexts. Nonparametric tests were used because of the small sample size, nonnormal distribution of the exploration patterns and observations, and robustness against outliers. Finally, we do incorporate our own qualitative reflections on the experience and consider usability improvements for future iterations of the informal learning experience.

## Data Availability Statement

Digital log files, including information about exploration and observations, are available through our website (<http://whimc.education.illinois.edu/>) and other materials (interview transcripts, field notes, ICANs) are available upon request. Additional materials are also available on our website describing camp materials and required software downloads.

## Results

### STEM Interest Triggering (RQ1)

Field note observations from 2018 and 2020 were used to examine the camp activities that triggered interest in STEM and what aspect of each instance served as the best candidate for an interest trigger. Field note observations were coded using interest triggers described in Table 3, revealing several interest triggers present throughout camp activities. Table 4 provides details about the proportion of each trigger's occurrence throughout camps in 2018 and 2020, respectively. A total of 11 distinct interest triggers were present throughout the camp in 2018, and a total of 12 distinct interest triggers were present in 2020. These codes are based upon the work of Renninger and Bachrach (2015) and reflect how activities prompt learners to behave in ways consistent with interest

**Table 4**

*Interest Triggers as a Proportion of All Triggers Present in 2018 and 2020*

Interest triggers	Proportion of all triggers present in 2018 <sup>a</sup>	Proportion of all triggers present in 2020 <sup>a</sup>
Affect	0.0345	0.088
Autonomy	0.069	0.0889
Char Ident.	0	0.0444
Challenge	0.069	0.0444
Computers/tech	0.069	0
Minecraft learning	0.0345	0.1111
Minecraft play	0.1724	0.1111
Group work	0.1034	0.1111
Instr Conv.	0.2069	0.1778
Novelty	0	0.0889
Ownership	0.069	0.0667
Personal relevance	0.0345	0.0444
Intent to reengage	0.1379	0.0222
Total triggers present	28	40

*Note.* Char Ident = "character identification"; Instr Conv. = instructional conversation.

<sup>a</sup> Based on observational field notes recorded by graduate researchers.

development, outlined in the four-phase model of interest development (Hidi & Renninger, 2006). We acknowledge that these are estimations of what interest in science-based activities looks like to an observer; yet, observations of heightened affect and focused attention on content are known to be indicative of interest triggering (Renninger & Hidi, 2011).

Instructional conversation (I) was the most frequently observed interest trigger for both years, with it being observed across 18% of camp activities in 2020 and 20% of camp activities in 2018. This could indicate the importance of approachable instructors as an antecedent for triggering interest (Linnenbrink-Garcia et al., 2013), a desire to learn more by actively seeking information related to oneself (Renninger & Hidi, 2021), or reflect a potential limitation of conveying content through Minecraft, where the instructor is needed to point out, explain, or clarify concepts.

The next most frequently observed interest trigger was a customized category for our context: Minecraft Play (COM-MC). This code reflects participants making statements about liking the use of Minecraft to explore astronomy concepts or play preferences in Minecraft, such as expressing excitement at being able to jump higher on the Lunar Crater map, or asking for assistance to finish a Redstone circuit (Minecraft's version of electricity that allows construction of machines with moving parts, lights, automatic doors, rails, and more). Minecraft Play accounted for 11% of interest triggering in 2020 and 17% of all interest triggers in 2018. These recorded interactions and preferences are not evidence of learning alone (although the interactions may result in learning), but they do reflect interest in playing the game and a desire to engage the content embedded in the game. Minecraft is a platform most participants were familiar with, and therefore they approach the experience bearing a shared familiarity and expertise they can put into practice.

Surprisingly, there were no instances of character identification (CI) or Novelty (N) in the 2018 camp. The camp evolves each year to address feedback from campers and incorporate new means for triggering interest. Some of the activities present in 2020 that led

to CI and N interest triggering were not present in 2018, such as the introduction of the PBS NOVA Exoplanet Lab. Additionally, questions regarding the relevance of astronomy content to everyday life are occasionally raised by participants, some of whom do not identify with STEM or aspire to STEM careers. As such, an emphasis is placed on personal relevance as an interest trigger and using participant Minecraft experiences to connect the abstract forms of STEM with applied and relevant instances. For example, the Lunar Crater map simulates what a habitat on the Moon could look like, and participants can discover NPCs on the Moon who champion roles such as a psychologist, medical doctors, critical maintenance crew, and even exercising to ward off the negative effects of low gravity. Finding relevant connections to their own domain interests coincides with the desire for autonomy in Minecraft and the opportunity to build habitats.

The question of “What is your favorite thing to do/build in Minecraft?” asked during interviews, resulted in 76% of participants from combined 2020 camps saying they like building habitats most. Drawing upon current events and global challenges, we include a habitat-building activity on Mars as an overarching aspect of the camps. This requires learners to explore and learn about the extreme conditions on Mars and other worlds that make it difficult to build a successful habitat there, informing how they can build a sustainable habitat for human life. Habitat building to address habitability concerns allows participants to integrate knowledge from camp into a collaborative exercise with peers, targeting interest triggers of hands-on, group work, ownership, and autonomy. Furthermore, this nudges learners to develop their own hypotheses and questions as to whether or not a potential solution to living in an inhospitable environment could work.

### Interest-Triggering Case Examples

The primary platform of our summer camps, Minecraft, plays an integral role in triggering STEM interest for adolescent learners. Camp participants were shown to develop STEM interests, regardless of their prior Minecraft experience entering the camp. To further

illustrate the richness of interest triggering that occurred in the camp, we provide a summary of three individual learner case studies that demonstrate the appeal of Minecraft to a variety of learners. Data for these case studies are pulled from field notes, interview transcriptions, and a combination of logs, including exploration patterns and paths and location-specific observations made in-game.

#### Case 1

In the hybrid 2020 context, a 14-year-old female stated this was the first time she had ever played Minecraft. She received one-on-one tutorials on how to play to elevate her to a level that she could engage the STEM content embedded in the game. She scored a  $.5 SD$  below the mean for exploration during her week, likely because of inexperience with the game and needing time to master controls. She also recorded 21 in-game observations, accounting for 22% of all in-game observations made during the first week of camp in 2020, placing her second in her cohort for most observations (P6 in Table 5). In her interview, she discussed being interested in STEM previously, but her interest faded as she observed her mother, a health care worker, become displeased with her work. In interviews, she expressed a dislike for her current science classes in school. However, when talking about the camp she expressed mild interest in Astronomy, stating “I don’t know, just, I sometimes like the planets and stuff like that,” and when asked what hypothetical world she would most like to learn about she said,

What if the Earth was a Moon. What, would be rotating around, you know, how the Moon rotates around the Earth? What would we be rotating around and how would it be? So I don’t know. Seems cool.

Minecraft, and the camp experience, was able to bring out and engage a prior interest in STEM that had seemingly gone dormant because of other social factors in her life, prompting her to come up with new interest questions and offering an expression of enjoyment when thinking about the possible answers. Her lack of Minecraft play experience may have inhibited her ability to explore the server

**Table 5**  
*Total Observations and Proportions for Participants in 2018 and 2020*

2018						2020					
Week 1			Week 2			Week 1			Week 2		
ID no.	Observations	Proportion	ID no.	Observations	Proportion	ID no.	Observations	Proportion	ID no.	Observations	Proportion
P1 <sup>a</sup>	8	0.04	P1	17	0.10	P1 <sup>a</sup>	12	0.13	P1	9	0.05
P2	12	0.06	P2 <sup>c</sup>	58	0.34	P2 <sup>c</sup>	11	0.12	P2	3	0.02
P3 <sup>c</sup>	30	0.14	P3	15	0.09	P3 <sup>c</sup>	6	0.06	P3	31	0.17
P4	13	0.06	P4	9	0.05	P4 <sup>b</sup>	13	0.14	P4	7	0.04
P5 <sup>c</sup>	39	0.18	P5	5	0.03	P5 <sup>c</sup>	32	0.34	P5	27	0.15
P6	10	0.05	P6	20	0.12	P6	21	0.22	P6	93	0.51
P7	16	0.08	P7	16	0.09				P7	11	0.06
P8	22	0.10	P8	11	0.06						
P9	9	0.04	P9	9	0.05						
P10	11	0.05	P10	11	0.06						
P11	26	0.12									
P12	17	0.08									
<i>M</i>	17.75			12.00			15.83			14.67	
<i>SD</i>	9.65			4.75			9.28			11.48	

*Note.* P2 in 2018 Week 2 and P6 in 2020 Week 2 were removed from *M* and *SD* for being extreme outliers.

<sup>a</sup>Participated in both 2018 and 2020 camps. <sup>b</sup>Participated in both 2019 and 2020 camps. <sup>c</sup>Participated in 2018, 2019, and 2020 camps.

initially but did not adversely affect her ability to engage with STEM content.

### Case 2

In the second week of the hybrid 2020 context, a 13-year-old male entered the summer camp with a lot of experience playing Minecraft, and a prior interest in STEM. This participant explored the maps more than any other, averaging 25.44 squares out of 100 visited per map and a total of 229 visited squares, over 1 *SD* above the average across all participants from his week. He made 27 total in-game observations during the week, accounting for 15% of all observations made during Week 2 of 2020, placing in third for most observations (P5 in Table 5). When given time to build a habitat that could be sustained on our “No Moon” map, he focused his efforts on the task, staying late and returning early from break to work on his habitat. He also wanted to show his project to all camp instructors at the end of the week. During the interview when asked if he sees himself as a “science person” he stated his desire to be an engineer, saying “I like to fix and improve things, like items, simple objects.” When asked if there is anything about space that interests him, he said, “That suns can turn into black holes,” which was not a topic covered in camp, indicating an interest in astronomy beyond the context we provided. When asked about a hypothetical world he finds interesting, he explained,

I would go to [No Moon]. The one we’ve been working on. I’ve been working on it because the trees. Since the world’s spinning faster, the trees would look so weird. They’ll be like, kind of like bushes. And the wind, it kind of sounds like a helicopter when it comes by when you hear it.

With a strong interest in STEM, and experience playing Minecraft, this participant showed Minecraft can provide an environment for advanced players to engage STEM content. It is likely that the experience strengthened his individual interest. He was able to link his existing interest in astronomy with content available on the server, making inferential connections between the features of the hypothetical world and the reasons why these features are different from physical Earth phenomena.

### Case 3

Two females, ages 12 and 13, worked very closely together throughout the course of the in-person 2018 camp. They were observed having discussions with each other about the differences they noticed on the Colder Sun map, observing the sun was shaped oddly and was a different color than they expected. When given the opportunity to stay indoors and explore and build on the server or go outside, they remained inside to continue playing Minecraft (we later withdrew this option, but noted when students asked to stay). The 13-year-old participant was the second most active explorer during her week of camp with an average of 13.75 squares out of 100 visited per world. She totaled 55 squares across four worlds, .5 *SD* above the average exploration total across other participants. The 12-year-old made 39 observations during the first week of camp in 2018, accounting for 18% of all in-game observations that week, the most in her cohort (P5<sup>c</sup> in Table 5).

In their free time to play, they collaborated on building a roller-coaster. They also were two of the most involved participants during a team quiz activity. Both used concrete examples from camp

discussions for their answers to knowledge questions during a joint interview, such as the answer to “What is a habitable zone,” with the 12-year-old stating, “You’re able to live there and receive all the resources you need for life, like water, animals to eat, wood for building, like iron and trees.” Both participants displayed a high degree of knowledge regarding the astronomy questions related to concepts from camp, and this could be a result of them engaging the content in camp or a previous interest in astronomy that they can build upon in the camp. When asked if there are any hypothetical worlds they thought might be more fun to explore, they said, “No, cause the ones we visited were really cool.” The 12-year-old participant attended the camp again in 2019 and 2020, reflecting an enduring individual interest in STEM.

Looking across the case studies, learners of varying interest levels in STEM engage the server in similar ways through exploration and observations. Prior interest, experiences, and knowledge may affect how learners process the information and make connections between what they observe on the server and the reasons as to why certain phenomena are happening on hypothetical worlds, but this does not preclude them from asking questions and having their interest triggered. The hypothetical worlds provide an opportunity to interactively explore novel environments that are otherwise inaccessible to humans. Regardless of experience with Minecraft, participants found varying aspects of the server interesting and thought more deeply about them through questions and conceptual connections. In this way, we propose the novelty of the server, combined with the popularity of an open-world, popular, and creation-oriented game like Minecraft, provides an accessible environment for interest development that can further be shaped to respond to participant interests.

### Differences Between Formats (RQ2)

A combination of field notes, exploration patterns, and in-game observations highlight the differences between in-person and hybrid/remote formats. Minecraft is central in both camps as learners use it for exploration and interactions with our simulated worlds, so this key feature remained consistent from 2018 to 2020. However, a major difference emerged from the inability to control distractions and minimize off-task behaviors in the remote setting. In-person we usually have a team of four or five staff present each day to instruct, help with technical issues, and to engage with and keep participants focused on task goals. The remote setting resulted in laptops suddenly dying because they were not being charged, videoconference disconnections, students unwilling to speak up if they needed assistance learning to play Minecraft, and a reliance on students to keep each other accountable and on task. Adding more responsibility to the participants may have negatively impacted their experience in the camp and we decided to offer a greater amount of autonomy in how participants interact with camp goals, such as the allowance of personal projects. Defining engagement in this setting remained a challenge.

Exploring what-if worlds in Minecraft, the central activity of the camps, did not drastically change between formats, except for having more worlds to explore in 2020 than in 2018. Looking at the mean exploration patterns of all participants across the five core worlds visited between 2018 (2018 Week 1 missing due to exploration patterns not being recorded for most worlds explored) and 2020 (see Table 6), the means are not drastically different. However, the large standard deviations present from camp to camp suggest the

**Table 6**  
*Mean Exploration Values by Week for 2018 and 2020*

Camp	NM	CS:HS	CS:Cold	CS:Hot	TE: Frozen	TE: Jungle	Total
2018 Week 2 ( <i>n</i> = 8)							
<i>M</i>	24.25	17.75	12.88	15.89	10.89	19.75	93.11
<i>SD</i>	14.37	19.08	13.08	12.46	10.12	12.19	63.88
2020 Week 1 ( <i>n</i> = 7)							
<i>M</i>	28.63	13.38	9.88	5.75	25	12	80.75
<i>SD</i>	13.84	6.63	10.52	3.06	8.51	4.85	37.96
2020 Week 2 ( <i>n</i> = 6)							
<i>M</i>	36.71	19	9.5	7.43	9.17	24.67	100.29
<i>SD</i>	15.97	14.87	4.04	6.11	5.49	10.56	41.99

*Note.* NM = No Moon; CS:HS = Colder Sun:Habitable Strip; CS:Cold = Colder Sun:Cold; CS:Hot = Colder Sun:Hot; TE:Frozen = Tilted Earth:Frozen; TE:Jungle = Tilted Earth:Jungle. Total is the mean of the total number of squares explored across participants. 2018 Week 1 was not included because exploration was only captured on three maps.

amount of exploration varies by participant. Some participants have their interest triggered by the environments and want to learn more about the worlds, while others do not have their interest triggered and explore very little of the environments. A Mann–Whitney *U* test conducted between contexts revealed a nonsignificant relationship between exploration patterns between in-person and both hybrid camps: 2020 Week 1 ( $U = 21, p = .699$ ), 2020 Week 2 ( $U = 20, p = .818$ ). To examine if mean exploration patterns for each participant differed across contexts we conducted another Mann–Whitney *U* test accounting for individual means, revealing a nonsignificant difference in mean exploration patterns between hybrid and in-person participants (In-person<sub>mean</sub> = 16.8, Hybrid<sub>mean</sub> = 16.6,  $U = 47.5, p = .772$ ). Regardless of camp format, participants are consistently exploring rich Minecraft environments and engaging the science built into them. In-game observations made by participants showed a similar pattern. The in-game observations show that the average number of observations made each week between 2018 and 2020 did not vary much (see Table 5), and the standard deviations remained relatively consistent, after removing extreme outliers. Week 2 in 2018 had one participant make 58 in-game observations, accounting for 34% of all in-game observations that week, while Week 2 in 2020 had one participant make 93 in-game observations, accounting for 51% of all in-game observations that week. Regardless of being in-person or hybrid, interested and motivated participants are still able to and interested in engaging the content on the server. A Mann–Whitney *U* test conducted on the count of participant observations between in-person and hybrid revealed a nonsignificant difference in observation behaviors ( $U = 147.5, p = .89$ ). The median in-person observations made was 14, and the median hybrid observations made was 12. This suggests that hybrid versus in-person contexts have little to no effect on how much learners engage STEM content in a digital game format, where the context does not seem to matter as much as the prior knowledge and existing interest participants bring with them to the camp experience.

Looking at the number of interest triggers present across camp activities, recorded through field notes, activities in 2018 resulted in 28 interest triggers, while 2020 resulted in 40 interest triggers (Table 4). Proportions of interest triggers across all camp activities were calculated and Spearman's  $\rho$  was conducted to look for a rank-order correlation between the 2 years ( $r_s = .28, p = .38$ ),

which resulted in a nonsignificant correlation in interest triggers between 2018 and 2020. This could be due to interest being triggered in different ways between the hybrid and in-person contexts, with instructional conversation feeling more accessible when everyone is on a screen instead of the instructor facing the campers. Additionally, with 2020 being the third iteration of the informal experience in this location, we have improved design to optimize interaction and promote greater interest triggering.

One positive aspect of the remote environment was the presence of all instructors and staff in the Minecraft environment with the campers. Being together on the server may have minimized the student–teacher power difference, making instructors less authority figures and instead collaborators or fellow players. There were also no physical reminders of the difference (e.g., no one sitting at the front of the room presenting), but instead everyone navigated the digital space in their own way. Participants who wanted to showcase their designs and ideas had the opportunity to do so immediately by calling attention to their builds. In-person, a research team member may or may not be on the server interacting with the camp participants. Having time to explore participant builds and hear how the participant describes and explains his/her creation reflects interest triggers of ownership and autonomy. Additionally, an inspection of the artifact could yield further evidence as to the nature of the participant's individual interests.

Disengagement in the hybrid context, evidenced through field notes, was uncovered primarily by participants informing the instructor that another student was playing other computer games, watching videos, or engaging in other activities not related to the camp. When in-person with the students, such disengagement could be noticed by staff and addressed swiftly; however, the remote setting relied on communicating with Center staff and having a staff member ask the participants to reengage. This sometimes proved to be a slow process and dramatically interrupted the flow of the lessons. Despite difficulties, engagement on the server, through observations and exploration, remained consistent across years.

Ultimately, the results of exploration, observations, and interest triggers presently indicate that participation patterns do not vary greatly between in-person and hybrid/remote contexts. Minecraft is an environment well suited to engage students in either context, positioning our informal camp experiences as capable of developing STEM interest in adolescents regardless of context.

## Discussion

Because health safety concerns required a move to distance learning, our research team conducted our informal STEM summer camp remotely. Participants remained in-person at the Community Center. We first wanted to explore how an informal STEM camp centered around the use of Minecraft triggers interest in STEM for adolescent learners (RQ1). We also sought to understand if there were major differences in engagement (in-game and out) and interest triggering, between the in-person and hybrid contexts (RQ2).

### Minecraft as an STEM Learning Environment

Minecraft has now been used extensively for learners to learn and explore science content (Baek et al., 2020; Pusey & Pusey, 2015). Games offer an opportunity to explore and interact with environments otherwise inaccessible to learners, such as our hypothetical worlds and exoplanets. On Earth without a Moon, for example, learners can hear the extreme winds, see a night sky more brightly lit by the stars, and stand next to short trees with wide bases. They experience 1/6th of gravity on the Moon by “floating” when they walk and jumping longer distances. Besides hearing or reading about such concepts, Minecraft allows players to have an interactive experience in a familiar digital environment. Further, we ask them to consider the conditions on the various what-if worlds and think about how a habitat for humans might be constructed, given the adverse conditions for survival. We have connected these activities to national science standards, such as the Next Generation Science Standards (NGSS), to promote understanding of cause and effect and the interactions between sunlight, the oceans, living organisms, and landforms (MS-Earth and Space Science [ESS]2.D, for example). Through exploration and building, learners can ask questions and develop knowledge surrounding complex systems of natural science.

The informal camp experience, including the predominant use of Minecraft, harnesses many points of entry, in terms of how interest can be triggered and maintained. Without staking a claim on the directionality of causation, interest development and learning are intertwined and co-occur (Renninger & Hidi, 2016; Rotgans & Schmidt, 2017). Learner interest can be triggered by the novelty of seeing a giant planet on Earth’s horizon, by asking questions and conversing with instructors in-game, or by being challenged to address adverse conditions in building a settlement. Through all these triggers, campers are learning about how different lived experiences would be if Earth had developed any differently. Campers expressed interest in continuing to learn more about the worlds on the server, sometimes thinking of new hypothetical scenarios they would like to explore.

Further, most research on interest development has focused on nondigital settings, and so our work begins to fill a gap in understanding how in-game experiences, such as habitat building and exploration, relate to interest development more broadly. In future work, we will explore in-game behaviors (e.g., such as quality of exploration of a map or depth of observations made) and correlations they may or may not have with survey- and interview-based responses. Behavioral data offer substantial opportunity to gain insights into “what interest looks like” during game play. We have only scratched the surface in this work to understand the richness and potential of such data and anticipate leveraging techniques from

artificial intelligence to assess learner habitats and provide automated guidance while learners are working on the server.

### Individual Differences

Participants approach the camp with varying levels of interest, from no interest to dormant interest to well-developed individual interest. The camp experience must be suited to accommodate learners at all phases of interest development. Minecraft is a game familiar to most participants; however, for those with no Minecraft play experience, we devote time to ensuring those participants reach a level of competency where they can collaborate with peers and access the science content in the game. Establishing this level of competency is critical for any intervention involving a digital environment. The degree of interest the learner has in the subject, or science more broadly, seems to strongly indicate how the learner engages the camp. Still, the experiences are an evolving process and making them relevant to individual learners is of great importance.

### In-Person Versus Hybrid Format

While developing a server accessible to the public has always been part of our plan, we did not envision running our camps remotely. With Minecraft being a digital environment potentially conducive to remote experiences, we decided to run camps with research staff remote and learners in-person at their regular summer program location. Many participants would not have been otherwise able to participate at home, where computer and internet access are not assured, and the camp location offered them the chance to be around friends (following safety guidelines).

Each camp format has different affordances. The in-person camps allowed for more situational awareness and direct intervention by instructors, as well as opportunities for gesture-based or worksheet-type teaching aides, such as showing balls orbiting one another or campers drawing out plans for space habitats. The hybrid camps, by contrast, may have offered a more “pure” view into participant interests in STEM, as there was less direct encouragement and support and considerably more reliance on self-driven engagement. The influence of instructors as role models was likely reduced and they were less able to actively shape peer learning interactions between participants. The hybrid camp and daunting COVID conditions contributed to activities taking longer, which may have resulted in fewer learning opportunities but also a less stressful pace. Overall, our results showed minimal differences in how learners engaged the camp experience between contexts (see Tables 5 and 6), with the overall quality of instruction, immersive simulation, and data collection improving with each year.

Consistency across contexts could be a result of the same instructors being present for multiple years, a few campers returning for multiple years, and improved camp design. Experienced instructors build on previous camps and can anticipate what features of the camp are engaging and how long is adequate for each world or experience before moving to another activity. Knowledge of how campers engaged the variety of worlds has provided our own instructors with valuable knowledge of how to successfully run a camp using the server, whether that be in person or remotely. This could be one of the reasons more instances of interest being triggered were observed through field notes in 2020 than in 2018. Between hybrid and in-person contexts we did not have to remove any hypothetical worlds,

rather we continued to add worlds, offering more opportunities for exploration and observations. Quests and points of interest are continuously added to improve the experience. Also, as evidenced by a total number of individual observations in Table 5, a highly motivated camper attended each year, and highly motivated behavior could have motivated some of the other campers to engage the experience at a higher level.

While there were several positive aspects of the remote format, we still confronted several challenges, including off-task behaviors, students removing headphones, playing other games besides Minecraft, and diminished attention during discussion times. Having the children in the same physical room led to numerous challenges, such as off-topic chat and a lack of consistently enforced rules by in-person community center staff. However, the inclusion of Minecraft in the experience mostly engaged students and kept them interested in the incorporated science concepts. Some campers even asked their fellow campers to calm down and get back to the game, which happened several times throughout our hybrid camps. Without instructors present in-person, some campers placed themselves positions of encouraging engagement and enforcing codes of conduct expected at the center. Motivated and interested students lead through example and expend effort trying to keep the integrity of the experience intact.

### Limitations and Future Research

Our work has several limitations worth consideration. First, and most obviously, our data were collected in a noisy and often chaotic environment which means that there are many aspects of the environment that potentially influenced interest for which we were likely unable to capture. For example, campers at our community center participated in a variety of different activities, both in the mornings before our camp and before and after the rest of the summer. A second limitation relates to the changes between both the content of our 2018 and 2020 camps as well as our data collection. In the 2 years between camps, our server and maps were all improved with additional content and an improved user experience. As mentioned, camps in 2020 saw more content including a Moon base, Mars, and some exoplanets. We also added the PBS Exoplanet Lab which could have potential additional influences on emerging interests.

Since conducting our hybrid 2020 camp, our work has focused on integrating more instructional content into the server and enabling independent visitors to engage with the server who are not necessarily part of camps. The Moon base has evolved into a tutorial map for first-time visitors to learn the science tools (to measure temperature, radiation, and more) and learn about the concept of habitability. We have integrated quests and associated promotions that unlock additional content and rights on the server, added a substantial number of additional nonplayer characters to capture diversity and varying roles in STEM, and incorporated science videos and activities in-world. Our ongoing research emphasizes how interest might be triggered and sustained over multiple visits to the server and over time, with tracking tools looking at interactions, exploration, and (when unlocked) habitats that visitors build for survival. As discussed in our introduction, research on the science of interest has yet to take full advantage of digital tools, and so we seek to develop a more intelligent analysis of learner behaviors and relate them to STEM interests (Lane et al., 2017).

Many additional analyses are possible using our data which would enable triangulation beyond what we have been able to complete thus

far. Our initial algorithm for assessing the quality of exploration (counting visited cells in a grid) is informative but could be enriched by including observation data and detection of patterns that are associated with engagement versus off-task behavior. We also have substantial data that we were not able to incorporate into the analyses reported here that capture more active activities such as building habitats, roads, and other structures related to civil infrastructure. In some of these instances, campers slipped into goals less directly related to STEM, such as building “dream homes” (e.g., with swimming pools), while others stayed directly on task taking on considerations of protection from radiation, access to food and heat, and other important aspects of survival. Automatic detection and assessment of these activities would significantly enhance our approach to measuring engagement and detecting interest.

Last, an important issue we intend to address is to better understand how such interest-inducing activities might frame formal learning of STEM. Research has demonstrated that when interest is effectively triggered, learning and engagement with academic activities can be greatly enhanced (Renninger et al., 2015a). We hope to explore this relationship more thoroughly and investigate to what extent Minecraft-based learning leads to (a) increased motivation for academic learning of related content, and (b) transfer of skills and knowledge to more traditional learning contexts (labs, discussion, exams).

### Conclusion

We described a Minecraft-based summer camp designed to trigger interest in STEM and encourage exploration of hypothetical versions of Earth, the Moon, and known exoplanets. We found that interest-triggering events related to a range of sources, including social interaction and the use of Minecraft. While many important differences emerged between the in-person and hybrid formats, such as our ability to monitor off-task behaviors and help children with technical issues, ultimately our data suggest that interest triggering occurred in both contexts relatively reliably. It is possible that virtual colocation in Minecraft acted as a buffer on potential limitations of the hybrid format, and also that preexisting interest in Minecraft was sufficient to maintain engagement over the full period. We hope that our work opens up new possibilities for the design of virtual learning experiences focused on interest development, and potentially lays the groundwork for deeper automated analysis of interest development over time.

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## Appendix

### Interview Protocol 2018

#### Home and School Life

- How do you like school? Which class is your favorite and why?
- How often do you play video games? Tell me three games that you like the most and three you don’t like.
- Do you like playing video games? Where do you play them mostly? Do you have to follow any special rules? Ex: you can only play for an hour on the computer.

#### Minecraft Play

- How often do you play Minecraft (MC)? About how long do you play each time? Where and how do you play it? Do you play alone, or with friends?

- Walk me through the first steps of how you’d play in your favorite mode (creative or survival).
- What’s your favorite thing to build in MC in either mode? How do you plan on building it?
- Which mode of the game do you like to play the most? Why do you like it best?

#### Minecraft and the Real World

- Was there anything cool you saw in MC 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?
- How does MC resemble real life for you or how does it not? Could you provide an example?

(Appendix continues)

- 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

- 10. Can you tell me about the Moon? How does it affect us here on Earth?
  - a. TRANSFER: What do you think Earth would be like if the Moon were twice as large as it is now?
- 11. Can you tell me what the Earth's axis of rotation is? Why is it important?
  - a. TRANSFER: What do you think Earth would be like if it didn't rotate?
- 12. Can you describe what a "habitable zone" is?
  - a. TRANSFER: 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?
- 13. Are there any topics from any of your classes that came into your mind while playing MC? Could you give me an example?
- 14. Is there anything that can be built in MC that would not be possible in the real world?
- 15. Could you make some comparisons between scientific attributes between the MC and the real world (e.g., temperature, gravity, physical and chemical rules).

### Interview Protocol 2020

#### Home and School Life

- 1. How do you like school? Which class is your favorite and why?
- 2. How do you feel about online learning? Compared to in-person?

#### Interest Behaviors

- 3. Has WHIMC camp helped answer any questions you have about space? Has camp prompted you to think of a question about space you would like to answer?
- 4. Have you read any books or comics, television shows, or movies about space after enrolling in our camp?
- 5. Could you give me an example of where you've talked about WHIMC camp with your family or friends?

#### Minecraft Play

- 6. How often do you play Minecraft? About how long do you play each time? Where and how do you play it? Why? Do you play alone, or with friends?
- 7. What's your favorite thing to build in Minecraft in either mode? What is your process for building it?

#### Astronomy Knowledge

- 8. Can you tell me about the Moon? How does it affect us here on Earth?
  - a. TRANSFER: What do you think Earth would be like if the Moon were twice as large as it is now?
- 9. Can you tell me what the Earth's axis of rotation is? Why is it important?
  - a. TRANSFER: 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.
  - a. TRANSFER: 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?
- 11. What does science mean to you?
- 12. Do you see yourself as a science person? Why or why not?
- 13. Is there anything that interests you about space?
- 14. What are the "must have's" you'll need to survive on the moon?

#### Camp Feedback/Situational Interest

- 15. (For those applicable): You've enrolled in this camp for several times now. What drew you to return to our camp? If needed: Minecraft the game, science content, their friends, or seeing the team again?
- 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. Would you want to join our Minecraft camp again if we offer it next summer?