Persistence in STEAM Activities at the Elementary Level

A Dissertation
Presented in Partial Fulfillment of the Requirements for the
Degree of Doctor of Philosophy
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Major in Curriculum and Instruction
in the
College of Graduate Studies
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by
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Authorization to Submit Dissertation

This dissertation of Luella M. Stelck, submitted for the degree of Doctor of Philosophy with a Major in Curriculum and Instruction and titled "Persistence in STEAM Activities at the Elementary Level," has been reviewed in final form. Permission, as indicated by the signatures and dates below, is now granted to submit final copies to the College of Graduate Studies for approval.

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Abstract

This three-article dissertation presents a perspective of persistence in STEAM learning at the elementary level within the context of a third through fifth-grade elementary school in Northern Idaho. Students at this elementary school were offered extra-curricular opportunities to persist in STEAM learning and while participating in a makerspace type club, self-determined their activity. All three articles discuss aspects of persistence. The first article specifically defines and investigates *macro*-persistence, which means returning to a STEAM activity at one's own discretion, and articles two and three deliberate the constructs of both *macro* and *micro*-persistence, which means continuing an activity at the moment after the allotted time. While the first article investigates the type of activities students choose, the second article takes a closer look at the materials used to teach some computer science lessons, and article three deliberates how teachers might use Minecraft in STEAM education.

Keywords: STEAM education, self-determination theory, computer coding, Minecraft

Acknowledgments

My first acknowledgment goes to my mother who set me on the path to persistence and was a wealth of inspirational sayings. “You will never know unless you try,” she would tell me when I expressed interest in learning something new. Or when she wanted me to reach my potential she would often say, “When there’s a will, there’s a way.” Even though she is no longer physically present on the Earth, I can still hear her voice encouraging me to persist. Her words have kept me going when I might have quit. Mom, I am forever grateful for your belief in me. Your ideals helped shape me into the person I am today, and sound similar to some of the advice I receive from my major professor.

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Dedication

My life verse from the Bible reads: “The Lord himself is my inheritance, my prize. He is my food and drink, my highest joy! He guards all that is mine. He sees that I am given pleasant brooks and meadows as my share! What a wonderful inheritance! I will bless the Lord who counsels me; he gives me wisdom in the night. He tells me what to do (Psalm 16:5-7).” Thank you, Lord Jesus, for your counsel and wisdom, and for giving me, Dan.

Dan, God’s right-hand man, in my opinion, thank you for sharpening my thinking and enveloping me with your love and understanding while I reached this goal. I appreciate your willing, but not always easy, sacrifices you made through this process. You are my best friend and I admire you. I am grateful God gave us to each other as we journey through life.

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Chapter 1: Introduction

These three manuscripts represent the beginning of my contribution to research regarding science, technology, engineering, art, and mathematics (STEAM) education. I have worked with kindergarten through 10th-grade students over the last 25 years teaching science, math, and integrated STEAM. In my early years as an educator, I worked at a private school where students had access to resources after school hours. These students worked with volunteer adults to create networks with computers, operate soundboards, and make videos. Many of these students later pursued degrees in computer science and engineering and are now successful in their chosen careers. Their stories are similar to the account told of Bill Gates, who spent hours after school learning how to use technology (Influential Individuals, 2017). Both cases, my students and Bill Gates, demonstrate the power of access on persistence in STEAM learning, autonomously and repeatedly over time.

Now an integrated STEAM educator to third through fifth-grade students in Moscow, Idaho, 55% of our students come from low-income homes, as measured by the number of students who qualify for free/reduced lunch. Most of these students have limited access to resources, including STEAM materials. Thus, my responsibilities include making resources available to students outside school hours to enhance access and support interests in STEAM learning. As the provider of these opportunities, I am particularly interested in discovering why some students persist in STEAM activities.

Persistence is measured in various ways throughout research but not consistently defined. In an attempt to clarify this area of study, I draw upon definitions that characterize persistence in learning as the non-cognitive trait of autonomously extending determination and exertion through the barriers of time, context, and difficulty. To measure persistence, some researchers use a free-choice method to measure persistence, as discussed by Deci, Koestner, and Ryan (2001), as an indicator of intrinsic motivation. Researchers using this method develop an intervention and implement a free-choice period immediately following the activity. The amount of time the participant persists in completing the intervention indicates the level of intrinsic motivation that a person has toward the activity. Based on this description, I have termed autonomous continuance of the immediate activity as micro-persistence. Other researchers use persistence to refer to a person autonomously returning to an activity repeatedly over time, such as the study that introduced the trans-contextual model (Hagger, Chatzisarantis, Culverhouse, & Biddle, 2003). Through the trans-contextual model, Hagger and Chatzisarantis (2016) suggested that students demonstrate intrinsic motivation when they intend to persist in school-related activities during their leisure time. Based on this description, I have termed the behavior of autonomously participating in an activity repeatedly over time as macro-persistence. Defining persistence in these ways helps clarify the two aspects of persistence under investigation in these studies. Combined, these terms establish guiding definitions to explore persistence in STEAM learning through an integrated research study that results in three separate manuscripts to fulfill doctoral research requirements at the University of Idaho. The three manuscripts that comprise my dissertation focus on specific research questions and methodologies.

Setting

The research took place in *the STEAM Room*, which is also my classroom. This room serves as an enrichment classroom for approximately 180 third through fifth-grade students in the Moscow School District. Students attend STEAM class for 45 minutes once every three school days. *The STEAM Room* also hosts many clubs and activities outside school hours, such as Chess Club and Minecraft Club.

The research was conducted throughout the second semester of the 2017-18 school year. Except for a Spring Break Minecraft camp, all activities were typical of what normally takes place surrounding *the STEAM Room*. The following three manuscripts describe factors in *the STEAM Room* supporting persistence using the theoretical framework of self-determination theory (Ryan & Deci, 2017).

Manuscripts

Persistence in STEAM activities at the elementary level.

The first manuscript describes the context of the study and demographics regarding student participants who demonstrated *macro-persistence* by their participation in extra-curricular STEAM opportunities, including the types of activities chosen by each student, through the lens of self-determination theory. In this study, students participated in three scheduled units during school hours, coding, 3D design, and constructing a chain reaction machine. These units took place during the second semester of the school year in the months of February through May. To measure the construct of macro-persistence, I opened *the STEAM Room* to host before and after school clubs. In addition, I also allowed students to return to *the STEAM Room* during their lunch break to continue working on unit related activities. These club and recess opportunities were available for any student interested in participating, students could choose to participate in as many or as few of the different clubs as they determined, attendance at each club event was optional, and the club opportunities were free of charge. This exploration study focused on answering these two questions:

1. Based on student demographics of SES, gender, achievement, and grade level, which students demonstrate *macro*-persistence when given access to STEAM materials?

2. When students demonstrate *macro*-persistence using STEAM materials, what activities do students choose?

Multiple sources of data were collected and examined to find patterns among students demonstrating *macro-persistence*, including student demographics, attendance at extra-curricular opportunities, and records of student activity. Parental consent and student assent (N=129) to participate in this study was granted.

Table 1.1
Summary of data sources for persistence in STEAM activities

Data	Type	Analysis	Outcome
Student *macro-persistence*	Quantitative	Discrete categories	Percent
Demographics (gender, SES, achievement, grade-level)	Quantitative	Nonparametric test to determine differences between two groups	Comparison of mean rank between independent groups

I hypothesized that the activity of Minecraft would show the highest amount of *macro-persistence*. I further hypothesized that more males would participate than females, students from not-low SES would participate than those from low SES, and that students from not-low math achievement would participate than those from low math achievement. Reports on STEM attrition, such as the one by Chen and Soldner (2014), frequently find that females and low SES students do not persist in STEM subjects. Finally, I hypothesized that there would be no difference between the grade levels. Aside from Minecraft, the results proved different than I expected. These differences are explored in Chapter 5.

The Hour of Code: Impact of materials on persistence in computational thinking.

The second manuscript focuses on two different modes of game-based skill development that support intrinsic motivation and *micro-persistence* through the lens of self-determination theory. A convenience sample of students (N =144) participated in two iterations of a coding lesson using different materials, tabletop and digital. Applying a free-choice method of understanding the intrinsic motivation construct used in self-determination theory research (Deci, Koestner, & Ryan, 2001), I recorded the time students spent autonomously continuing the lesson activity, or *micro-persistence,* after I asked the students to clean-up and announced a 10-minute break. Break time consisted of students using their discretion to choose an activity of interest and available in *the STEAM Room.* Students also shared their perceptions of each activity through a modified IMI (McAuley, Duncan, & Tammen, 1989), an adaptable instrument used to measure students' intrinsic motivation toward an activity. The findings helped answer two questions:

1. What is the difference in persistence toward computer coding when students use tabletop or virtual materials during a computational thinking unit at the third through fifth-grade level?
2. What is the difference in intrinsic motivation toward computer coding when students use tabletop or virtual materials during a computational thinking unit at the third through fifth-grade level?

Table 1.2
Summary of data sources for the Hour of Code

Data	Type	Analysis	Outcome
Intrinsic Motivation Inventory	Quantitative	Mean differences between paired observations	Measure of student perceptions of intrinsic motivation
Student activity choice	Quantitative	Differences on a dichotomous dependent variable between two related groups	Measure of *micro* and *macro-persistence*

I hypothesized that students would demonstrate *micro* and *macro-persistence* toward the digital materials. This assumption may seem obvious, due to the general preference for digital gaming exhibited by many children, yet it sets the stage for further investigation, especially when considering the need to fund digital materials for the classroom and the results of student's *micro-* and *macro-persistence* toward either material.

Minecraft in education: Impact of external directives on an intrinsically motivating activity.

The third manuscript focuses on student perceptions of teacher directives while participating in a week-long Spring Break camp themed around the Minecraft game. Minecraft was selected because students demonstrate intrinsic motivation in the classroom toward this activity through conversations and free choice activities. During the camp, students received two types of teacher directives, one in the form of a problem and the other in the form of a science standard. Students received a directive once each morning, from Monday through Thursday, so each student encountered each type of directive twice. Immediately following the time allotted for completing the teacher-directed activity, students were asked to share how they answered the prompt in their digital journal followed by a group sharing time. *Micro-persistence* in this situation consisted of students who continued to work on their project at least two minutes after allotted time. In addition to measuring *micro*-persistence, I measured each student's perceptions of both types of directives using a modified IMI regarding the activity. These components of the study compared the difference between two type of external directives, standards-based and problem-based, given by the teacher while students engaged in Minecraft. I hypothesized that students would perceive and demonstrate more intrinsic motivation toward the problem-based directives than the standards-based directives because of the open-ended nature of the problem-based prompts compared to the narrow focus of the standards-based prompts.

Table 1.3
Summary of data sources for Minecraft in education

Data	Type	Analysis	Outcome
Intrinsic Motivation Inventory	Quantitative	Median differences between paired observations	Measure of differences in student perceptions of intrinsic motivation between two conditions
Students activity choice	Quantitative	Differences on a dichotomous dependent variable between two related groups	Measure of *micro* and *macro-persistence* between two conditions

Eseryl, Law, Ifenthaler, Ge, and Miller (2014) report that problem-based learning situations better support student motivation and facilitate engagement over traditional classroom strategies. Therefore, I hypothesized that students would perceive more intrinsic motivation toward the project-based lessons. I also hypothesized that students would demonstrate more *micro* and *macro-persistence* toward the project-based lessons.

Chapter 5 provides a brief conclusion explaining how these three articles fit together. While specific findings for each study are discussed within each manuscript, the conclusion collectively addresses the findings and broader implications, including practical applications, empirical contributions, and future directions for research.

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Chapter 2: Persistence in steam activities at the elementary level

Abstract

During a spring semester, third through fifth-grade students participated in some extra-curricular STEAM activities provided by a teacher at a local elementary school. The activities ranged from pre-determined club activities, such as chess, to the free use of STEAM materials during an afternoon club. The students responded with distinct preferences for the club that allowed activity choice. Of all the available materials and activities in the STEAM classroom at the school, students chose to use Minecraft Pocket Edition. In addition, few significant differences in preferences were found based on socioeconomic level, gender, and academic ability differences between students. A surprising difference was found in participation between the fourth-grade students and each of the other grade levels, third and fifth. Fourth graders attended club activities more than students at the other two grades. Understanding the factors that support persistence offers valuable insight to improve how, when, and what extra-curricular STEAM activities schools might offer elementary students.

Introduction

“Can we stay longer?” “I don’t want to leave.” “It can’t be time to go.” These are the statements some teachers hear from students when announcing the end of class. The comments are those heard in a science, technology, engineering, art, and math (STEAM) classroom that serves approximately 180 students at a rural elementary school in northern Idaho. In this Title 1 school, where a high percentage (55%) of students come from low-income families, students can use a variety of tools and technologies; e.g., LEGO MINDSTORMS and WeDo, iPads, Piper Computer kits, and 3D printers, purchased through grants and local fundraising. Unfortunately, students have minimal time available during school hours to use the equipment. For most students, STEAM class activities take place during one, 45-minute period once every three days. This limited class time hinders developing interest and encouraging exploration for all students, but especially for those students without the means to access the materials outside of a school setting.

Based off of this observation, a teacher/researcher decided to investigate motivation behind comments made by students expressing a desire to continue working in the STEAM classroom, thus setting-up an open-ended inquiry about student persistence through exploring the relationship between activity choice and student demographics. In particular, the teacher/researcher wanted to understand the phenomenon of students, especially those from low-income families, returning to the STEAM room and persisting in STEAM activities.

The interest in socio-economic status differences emanates from the growing body of research on factors that impact education. Notably, students from low-income families show a lower performance in cognitive performance and non-cognitive traits, over their more affluent peers. Socioeconomic status (SES) contributes to differences in cognitive development (Morgan, Farkas, Hillemeier, & Maczuga, 2016), non-cognitive development (Heckman & Kautz, 2012), exposure to new learning situations (Garcia & Weiss, 2015), and skill (Chudgar & Luschei, 2009) between affluent and low-income households. Consider the following situated example from the teacher/researcher's classroom. Shortly after purchasing a 3D printer with grant funds for the classroom, one student received a 3D printer as a birthday present. Simultaneously, multiple other students in the same class rely on the school's backpack program to supply them with food over the weekend. While some students with access to STEAM materials at home can afford the time to play and explore the equipment, others do not have that liberty and are instead concerned about their next meal. Situations like the one mentioned above impact student learning and development. Providing access to STEAM tools and activities during school can foster excitement and engagement, as illustrated by the comments noted earlier. However, limited access to such materials, regardless of SES, restricts students' exploration and growth. Attainable outside-of-school opportunities support students' desire to access materials (Chudgar & Luschei, 2009) and encourage the development of non-cognitive skills (Garcia & Weiss, 2015), such as persistence. Research is only beginning to explore and explain the nuances of non-cognitive factors and how they directly impact learning. Thus, the teacher/researcher sought to examine student persistence in the STEAM enrichment classroom, between in-school and outside-school events in an exploratory case study. The focus of the case centers on activities students chose when given multiple opportunities throughout a spring semester and takes into consideration learner demographics.

STEAM learning

The educational focus of this research centers on STEM learning because of the continued need for STEM workers. STEM occupations have the potential to produce economic mobility, lifting low-income children who pursue a STEM field out of poverty (Corak, 2012). The U.S. Department of Education (Chen & Soldner, 2013) identified two factors influencing this demand in the workforce, the fast expansion of STEM occupations and a lack of students persisting in STEM fields during college.

STEM education integrates the four subjects with the language of math tying them together (Sanders, 2009). The idea of including art in the mix, making the acronym STEAM, was introduced by the Rhode Island School of Design. Dousay (2018) posited that integrating STEAM provides space for students to apply academic knowledge and develop skills such as creativity and persistence.

A quality STEAM program in school, therefore, should provide contemporary materials that engage students in real-world applications, contextualizing content. In addition, the teacher in a STEAM classroom should create a working environment similar to STEAM industry, using student-centered and inquiry-based teaching methods, similar to the practice Pink (2011) shared about Google's 20% time. Industry organizations like Google offer employees 20% of their work time to pursue projects of interest. Leaders feel that scheduling time for workers to explore personal interests helps their companies produce new and innovative technology not previously imagined. Likewise, students need time to explore STEAM ideas and materials, but little opportunity for exploration exists during school hours.

Current trends encourage STEAM learning outside school hours. An underlying concern about the disparity of opportunity between our country's children (Corak, 2012) suggests the need for changing how young students can access learning materials. Community centers/makerspaces, libraries, and other organizations support STEAM pursuits by offering events, facilities, materials, and information (Kurti, Kurti, & Fleming, 2014). These optional, and often nonformal, places of learning offer unique experiences allowing participants to autonomously engage in an activity, with a small group or individually. The casual environment encourages exploration, innovation, and safe opportunities to fail and try again. However, young students wanting to participate often face barriers like parental permission, attendance fees, and transportation to these additional learning events. Non-cognitive factors of motivation and persistence play an important role in overcoming some of these barriers. While more affluent children typically find resources, such as money or transportation, from family members to attend extra-curricular STEAM activities, those with lesser means must find others willing to contribute to their developing interests. Because 89.6% of students in the United States (U.S. Department of Education, 2018), regardless of their economic status, attend a public school, studying motivation and persistence within the context of a STEAM classroom may produce a better understanding of the factors that support persistence and the motivation to seek related activities in a broader context.

Persistence in STEAM

In tandem with rising opportunities to engage in STEAM learning, governmental support of these programs seeks to increase the number of people pursuing STEAM careers (Chen & Soldner, 2013). Recent workforce trends in the United States show a continued expansion in need of STEM workers (Fayer, Lacey, & Watson, 2017). This increased demand facilitates the need for educational programs that support the development of student persistence toward STEAM subjects and activities at a young age. Chen and Soldner (2013) reported that about 28% of college students seeking a bachelor's degree chose a STEM field but 48% of these students leave the major prior to graduation. Further, the National Research Council (2011) indicates K-12 STEM education lacks student preparation citing deficient eighth-grade mathematics performance, especially among low-income students. Garcia and Weiss (2015) also include deficiencies in non-cognitive skills, such as persistence, toward STEM attrition, among low-income students.

Researchers have used persistence to describe different behavioral characteristics, such as overcoming obstacles to pursue an activity of interest at the moment (Deci, 1970) and after a period of time (Maehr, 1976). These two examples demonstrate a need for a common definition of persistence and additional terminology to clarify some different barriers represented by the timing of the behavior. Thus, I define persistence in learning as the non-cognitive trait of autonomously extending determination and exertion through the barriers of time, context, and difficulty. To distinguish between the timing of behavior, micro-persistence means an autonomous continuation of an immediate activity while macro-persistence indicates persistence shown when a person autonomously returns to an activity at a later time.

Theories of Motivation and Persistence

To set the context for the current case exploration, I review two mini-theories within self-determination theory, cognitive evaluation theory and organismic integration theory. As I describe these theories of motivation, I also discuss how they contributed to the circumstances which allowed us to observe persistence among elementary students in this study.

Self-Determination Theory.

Exploring factors that support persistence in STEAM requires applying a framework that promotes student curiosity and interest. Self-determination theory explains how social-contextual factors affect people's psychological health through their basic needs for competence, relatedness, and autonomy (Ryan & Deci, 2017). Examples of relevant social-contextual factors include support for autonomy given by the teacher or the safety one feels toward taking risks in front of peers. The theory posits different types of motivation and factors influencing behavior and personality development. For example, teachers using autonomy supportive methods are likely to elicit greater engagement from students (Jang, Reeve, Halusic, 2016). Further, Reeve and Halusic (2009) described specific strategies to support autonomy, such as respecting students' perspectives by empathizing what students share, exhibiting patience with students while they work through difficulties, providing rationales for rules or consequences that impact students, using noncontrolling language like could instead of should, and respecting students' ideas and feelings. Applying these strategies creates the potential for investigating intrinsic motivation, especially student persistence toward learning. Two subtheories within self-determination theory, cognitive evaluation theory and organismic integration theory, explain the relationship between motivationally supportive environments created by a teacher and outcomes such as persistence. Both cognitive evaluation theory, which attempts to clarify intrinsic motivation, and organismic integration theory, which describes a range of extrinsic motivation influence from internal to external, provide guidance toward the development of the context for this study.

Cognitive Evaluation Theory.

Cognitive evaluation theory explains intrinsic motivation, specifically how social elements, such as the school culture, teacher, and classmates, within a learning environment, impact the desire to develop competence (Ryan & Deci, 2017). Consider the way teachers interact and empathize with students. Suggesting ways to derive an answer rather than requiring all students think the same creates a culture within the classroom that fosters communication between the teacher, learner, and classmates. Additionally, intrinsic motivation accounts for a part of the reason participants express a range of characteristics towards activity, from indifferent to persistent or bored to engaged (Deci & Ryan, 2000). For example, a teacher who uses phrases like “you should,” gives the impression that the child must use the teacher’s way of thinking and reduces the need for the child to think. On the other hand, when a teacher uses phrases like “you could,” it communicates that more than one way to solve the problem exists and encourages continued thinking. A teacher’s support of students’ needs contributes to the development, wellbeing, and motivational outlook students experience toward learning (Kaplan, 2018). Therefore, teachers who reinforce students’ self-determination by letting them think for themselves also increase student engagement and the desire to persist. When teachers support intrinsic motivation, students drive their learning process by acting curious and interested from an internal desire (Schneider, Nebel, Beege, & Rey, 2018).

Organismic Integration Theory.

Where cognitive evaluation theory looks at intrinsic motivation, organismic integration theory examines different types of extrinsic motivation particularly a person's perceived motivational orientation (Ryan & Deci, 2017). Briefly stated, organismic integration describes the tendency of people toward adopting external expectancies and how the social context can influence positive or undermining perceptions of autonomy. Internalization and integration of external factors on motivation form the central concept of this subtheory. Organismic integration theory explores how autonomy support impacts a person's perceptions of extrinsic motivation due to the degree a person identifies with the activity (Deci & Ryan, 2000). In other words, I cannot assume that all behavioral persistence comes from intrinsic motivation, since other external factors like engaging in activities with friends, can influence participation. However, organismic integration theory informs the current study by encouraging the removal of external motivators that might shift students' perceptions away from affiliating a connection with the STEAM activity, like offering prizes to those who attend Chess Club. Deci, Koestner, and Ryan (2001) noted that external motivators in education often shift students' attention from the learning activity to the reward or punishment, making the external event more important than the learning target. In the previous example, the prize for attending Chess Club then becomes more important than playing chess. This subtheory also provides an understanding of the impact of natural occurring external motivators, such as attending Chess Club to be with friends. Hidi and Renninger (2006) further noted positive results in a person's developing interest in the activity through natural rewards, like being with friends. Lastly, organismic integration theory suggests that people internalize some external motivators in a way that causes them to perceive autonomy and experience psychological health (Ryan & Deci, 2000).

Consequently, applying self-determination theory, especially the subtheories of cognitive evaluation and organismic integration, provide the foundation for this case. Through the intentional support of psychological health, as described above, this study sought to explore who would persist when given the opportunity, and what activities would they choose. The following section describes the procedures implemented in this case study.

Method

To produce a well-designed case, the research design included multiple data sources, organized data into spreadsheets, and constructed a chain of events, as suggested by Yin (2014). Data sources included records of student attendance at optional activities, observational notes on student behavior, video recordings of students in action, and student demographic information, including gender, SES, standardized math achievement scores from the Smarter Balanced Assessment Consortium (2018), and grade level. The chain of events was constructed from descriptions of procedures that took place during activities to support specific observations. For example, the teacher/researcher observed student behavior during recess after introducing new materials during STEAM class and video recorded students interacting with the materials and each other. These multiple sources of information contributed to a broad view of this case and provided a way to address validity through triangulation.

The case data were obtained during the second semester of the 2017-2018 school year. Parental consent and student assent were received from 72% of the student population prior to the start of the semester. Data from the remaining 28% who did not have parental consent were excluded from analysis.

The macro-persistence, in this case, consisted of students voluntarily returning to the STEAM room to attend and participate in STEAM-related activities outside their regularly scheduled class time. Records of macro-persistence include student attendance at club and recess activities and they type of STEAM activity chosen. This study sought to answer two questions:

1. Based on student demographics of SES, gender, achievement, and grade level, which students demonstrate macro-persistence when given access to STEAM materials?
2. When students demonstrate macro-persistence using STEAM materials, what activities do students choose?

To answer the first question, the teacher/researcher recorded student attendance at each extracurricular STEAM event and gathered student participant demographics to generate descriptive statistics. The second question compared data between participant demographics and what the students chose to do at the various clubs. This alternate way of looking at the behavior of macro-persistence took place because some club activities overlapped, such as Minecraft Club and students who chose to play Minecraft during Wednesday Workshop, and other types of activities, such as crafts, took place in a club that allowed student autonomy toward activity choice.

Participants

Students from a rural elementary school participated in this study. Table 2.1 summarizes relevant demographic statistics regarding the participating students (N=129), also depicting information relevant to my results. Approximately 48% of the students were classified as low-income, based on qualification for free/reduced lunch. The case encompassed a total of 132 school days, not including the last two weeks of the semester, which were reserved for special end of the school year activities such as field trips, track meets, and other celebratory events. Students met once a week to participate in club activities throughout the semester for a total of 14 Chess Clubs, 15 Minecraft Clubs, 15 Coding Clubs, 15 Wednesday Workshops, and 15 Biology Clubs. More meeting times were available during recess, for a total of 55 recess opportunities. Students could choose to attend more than one club; this means club participation is an independent event and the proportion of students participating in each event is compared to the total number of students participating in the study (n=129). Club and recess opportunities are discussed in greater detail later in this methodology.

Table 2.1
Statistics regarding study participants

Participation	Total	Chess	Minecraft	Coding	WW	Biology	Recess	None
Participating students	129	23	57	21	67	14	84	4
Enrollment								
Third-graders	41	5	19	6	17	3	23	2
Fourth-graders	47	14	24	12	31	10	32	0
Fifth-graders	41	4	14	3	19	1	29	2
Gender								
Male	61	13	38	9	26	7	38	2
Female	68	10	19	12	41	7	46	2
SES								
Low SES	62	12	25	8	35	5	40	1
Not-low SES	67	11	32	13	32	9	44	3
Academic percentiles math								
≤ 25	17	2	7	0	7	0	14	0
26-50	24	3	8	5	9	0	18	0
51-75	36	3	14	3	19	5	17	3
76-100	52	15	28	13	32	9	34	1
Average attendance	10	11	20	14	44	5	12	0

Note: WW in the table heading refers to Wednesday Workshops

STEAM class projects

In-school STEAM units included, computer coding, designing a 3D model using Tinkercad, and constructing a chain-reaction machine. To understand student macro-persistence toward these projects, I added recess time to the list of opportunities for students. With this accommodation, students could continue working on projects during some recesses and at appropriate clubs.

Computer coding.

The computer coding unit took place during the first six weeks of the semester, leading up to Spring Break. The learning objectives for this unit came from the state content standards in computer science (Idaho State Department of Education, 2018), specifically “3-5.AP.02 - Construct and test problem solutions using a block-based visual programming language, both independently and collaboratively” (p. 16). Within the six-week unit, each class met for 45-minutes and interacted with the computer science materials 10 times during their regularly scheduled STEAM class. At the beginning of the unit, six of the nine classes encountered the tabletop materials first while the three classes encountered the digital materials first. This mixed introduction of the materials took place because of an empirical study the teacher/researcher conducted to understand the motivation students perceived toward the tabletop and digital lessons. Each class received a 10-minute introduction to new materials during the first five meeting times. During this introduction time, the teacher/researcher demonstrated one of the materials students could use to construct and test computer programs using a block-based code. The options included a tabletop decoding puzzle, the Hour of Code materials through code.org, the code.org course curriculum, Hopscotch, and Scratch. After introducing the first two lessons in a mixed order, the teacher/researcher introduced the rest of the options in the order listed. Students were instructed to use only the materials introduced in the first two lessons. After introducing the code.org course curriculum during the third lesson, students were able to choose from the list of all the introduced materials. The teacher/researcher did not give assignments to students during the unit but did limit activity in the classroom to computer science. This meant that students could work on computer science learning at their discretion, choosing to work alone or in groups. Each of the digital programs offered embedded tutorials and activities for coding/programming using drag-and-drop blocks, meeting the criterion for the unit objective and providing a means for students to work at their own pace. After the first five lessons, students entered the classroom, self-selected their materials, and worked on their own volition for the duration of the class period.

Students accessed code.org through tablets or laptops in the classroom and solved maze-like puzzles by navigating a virtual character to the goal. Students self-selected a difficulty level when launching the website. Instruction from code.org included videos consisting of professional computer scientists who introduced useful vocabulary. Students also received in-game help through a series of hints within the software. If students needed more assistance, they asked their peers or the teacher/researcher.

Hopscotch is a programming tool that works only on tablets. During app launch, students chose either a blank programming space or a game, such as Geometry Dash, to program. Students who selected to program a game received an in-app video tutorial with an overview of the game and step-by-step instructions on how to program the game. The tutorials described the process, programming approaches where to find characters and codes, and explained the purpose of each code block used. The tutorials also encouraged exploration by asking learners to stop and test the game at certain intervals. For example, the Geometry Dash tutorial showed the programmer which blocks, what order, and specific values to use to write a code in the programming space that made a character jump. After finishing that segment of the program, students tested the code by tapping on the play icon. At this point, students saw the results of the code and could change values such as speed, color, number of jumps, or height of jumps to see the effect of each change has on how the program works during gameplay. As students worked through tutorials, they learned to pause the video after short segments, complete what they remembered from the instructions, and either rewind or continue the video depending on their progress. Students who followed the tutorials to the end had a working framework of a game and enough knowledge to play with the code to embellish their game.

Scratch was accessed via a browser on classroom computers. Upon entering the website students saw an array of icons representing programs other people had made. The site also offered other options through navigation tabs, such as create and explore, at the top of the page. Students could select a pre-made game and remix it or start a new project, receiving help through written tutorials, their friends, or the teacher/researcher. A student could launch the create tab and open a new programming space. Within the new programming space, the Tips tab offered three types of tutorials, step-by-step instructions for an overall program like animating a word, how to program a specific item for a project like interacting with the microphone, and block descriptions. These tutorials explained the process through written instructions and short animations. For example, the tutorial on how to animate a name provided a brief written description of the program outcome, gave a link to a video example of a program outcome, and displayed written directions describing the process of writing the code. Students saw the instructions on the right-hand side of the screen as they followed along.

Designing a 3D model.

Immediately following Spring Break, the second in-school activity took place during two class periods, which means the activity lasted a little over a week to cover all three sets of third through fifth-grade classes. Students participated in this mini-unit to prepare for an event celebrating STEAM that took place at the end of the semester. Students used Tinkercad.com to add personalized details to a “quilt square” template. These “quilt squares” were fabricated on a 3D printer, connected together, and displayed in the school. The teacher/researcher allocated two 45-minute class periods for this project. During the first day, the teacher/researcher introduced the software, provided website login information, showed an example “quilt square,” provided the template, and provided time for students to explore the program. During the second class, students logged in to the website and finished designing their square.

Constructing a chain-reaction machine.

During the last eight weeks of the semester, students participated in a project-based unit developed around a Next Generation Science Standard for third through fifth-grade students in physical science. Each class obtained a 2x10-meter section of land on the school playground to build a chain-reaction machine using PVC pipe with the goal of demonstrating gravity, the predictability of motion, or the transfer of energy from one object to another. Students chose responsibilities from a list of job-assignments created by the teacher/researcher. Jobs included team leadership, project planning, machine building, or reporting through notes, videos, and photography roles. Class teams demonstrated their machines during a school-wide event involving the community.

Outside school opportunities.

Other activities took place at the school and were scheduled before school, during recess, and after school to minimize transportation concerns. Due to the high percentage of low-income students attending the school, the teacher/researcher focused on equity for all students. This meant that families were not charged to participate in any activity. Club activities, including Minecraft, chess, coding, and biology, took place 30 minutes before school started. Wednesday Workshop, which took place for one hour right after school, provided a unique opportunity for the students to develop familiarity with the STEAM equipment and was designed particularly with the low-income students in mind.

Chess Club.

Chess Club took place on Monday mornings for 30-minutes. The club was recreational in nature and did not compete formally. Beginning chess players learned from other club members who were willing to teach. Students played on inexpensive chess boards purchased by the teacher/researcher. Partners formed as students entered the room, and games took place at tables and on the floor. A parent volunteer facilitated set-up, clean-up, and rotating partners. The teacher/researcher recorded participation at the start of the club and then prepared for the school day, occasionally playing when challenged by a student.

Minecraft Club.

Minecraft Club took place on Tuesday mornings for 30-minutes. Students typically used Minecraft Pocket Edition, a version of the game developed for tablets. Students used the computer version when tablets were all taken, and sat on the floor, on tables, under tables, and on chairs, rearranging the learning space to fit their needs. Most students played in groups by joining a friend who hosted a server allowing collaboration for up to five players on tablets or 30 players on computers. Some students asked the teacher/researcher to provide a daily challenge, such as writing your name in dynamite, while others developed their own challenges. The teacher/researcher recorded participation at the start of the club, referred students to peers when questions about gameplay arose, helped troubleshoot technology difficulties, and prepared for the school day.

Computer Coding Club.

Computer Coding Club took place on Wednesday mornings for 30-minutes. Students entered the room and chose a coding activity; Hopscotch, code.org, or Scratch. Most students chose to use tablets, accessing Hopscotch or code.org. Typical interactions between teacher/researcher and students centered around the teacher playing the game a student programmed or watching a successful solution to a code.org puzzle. Students occasionally asked for help, usually during a software malfunction. Aside from these few interactions, the teacher/researcher recorded participation at the start of the club and spent time getting ready for the school day.

Biology Club.

Biology Club took place on Thursday mornings for 30-minutes. A retired biologist volunteered time to work with students interested in plants and animals. The biologist introduced experiences with materials such as mealworms, an anole, ripe flowering plants, and fruit flies. The teacher/researcher supported the activity by providing other supplies such as cameras, hand lenses, and tanks for the mealworms and the anole. Once the club activities began, the teacher/researcher recorded participation at the start of the club and worked on preparing for the school day.

Wednesday Workshop.

Wednesday Workshop took place immediately after school on Wednesday afternoons for an hour. The teacher/researcher designated this time for students who wanted to use any materials available in the STEAM classroom. Materials included iPads, laptops, robotics, LEGOs, 3D printers, art supplies, cameras, and more. Students were free to engage in projects of their own choosing during this time. The teacher/researcher recorded participation at the start of the workshop and then spent time with students, training them on network configuration to create a Minecraft server, managing memory cards for the cameras, retrieving paints, directing students to the paper supply, monitoring hand tool use, and supervising student safety.

Recess.

The teacher opened the classroom during four recess periods a week for students to continue working on STEAM-class specific projects; computer coding, designing a 3D model, and constructing a chain-reaction machine. Recess times were limited to macro-persistent endeavors, meaning that the teacher did not allow students free access to the materials but supported students' motivation to continue working on their in-class projects. While students worked on their projects, the teacher/researcher recorded participation at the start of the time, ate her lunch, and worked on school-related business. If students had questions or needs, the teacher/researcher provided individual support.

Data collection and analysis.

The earlier descriptions of extracurricular STEAM opportunities available for students to attend included details about the particular unit taking place in the STEAM classroom that corresponded mostly with student recess opportunities. I determined the behavior of attending these extra opportunities to be macro-persistence as this behavior demonstrated persistence in learning by autonomously extending determination and exertion through the barriers of time, context, and difficulty. Overcoming the barrier of time proves particularly insightful as the learner purposefully chooses to spend discretionary time outside of class engaging in STEAM activities. While collecting attendance at the extracurricular events, I also recorded information regarding the activities students chose, such as Joseph attended a recess opportunity on March 10 and used an iPad to computer code in Hopscotch. The club opportunities and the activities students chose were two different ways the teacher/researcher examined macro-persistence. Data collection, therefore, consisted of recording attendance and observational notes at each club opportunity regarding student activity.

Student activity categories were developed through the analysis of student behavior data in a spreadsheet. After examining student activity, I grouped similar behaviors and formed categories. Final activity categories consisted of 10 activities; coding, chess, biology, acting, craft, Minecraft, Roblox, machine construction, Tinkercad, and a category labeled "present," meaning students who came to visit with the teacher but not work on a specific activity. Since the action of being "present" does have some merit I included these students in these totals. I provide additional information below regarding the categories students demonstrated macro-persistence toward and the activities each category included in the context of the STEAM classroom.

- Coding - This activity consisted of students using command blocks to direct intelligent behavior on a digital device and took place during coding club, recess, and Wednesday Workshop. Coding was divided into the subcategories of code.org, Hopscotch, and Scratch.
- Chess and Biology - Both of these activities only took place during the designated club previously described. This means the macro-persistent data for the club and the activity are the same.
- Acting - The acting category consisted of participants who used video recording devices to film themselves acting out make-believe scenarios, acting out a story, or talking about things of interest like how to braid hair. Acting took place mostly during Wednesday Workshop, except for one group of five students who made special arrangements to use the equipment at other times.
- Crafts - Activities such as painting pictures, using an iPad app to draw pictures, using the 3D pen or hot glue gun to create artwork, making decorative key-chains, and other similar activities made up the crafts category. The act of making things helps develop

important skills related to STEAM learning, such as knowing how to tie knots when assembling a pulley system for a chain reaction machine and demonstrate macro-persistence in STEAM.

- Minecraft and Roblox - Students engaged in these activities using iPads or laptops to access the digital game and engineered buildings, crafted tools, coded cheats, used in-game chat, and programmed modifications to the game. Students played Minecraft at both Minecraft Club and Wednesday Workshop but could only play Roblox at Wednesday Workshop.
- Construction - Student behaviors included cutting PVC pipe and building things, such as chairs, ramps, and levers with the pipe and connectors. This activity, which demonstrated macro-persistence toward a STEAM class unit, took place during recess and Wednesday Workshop.
- Tinkercad - Students used the 3D design program, Tinkercad.com, during recess and Wednesday Workshop to complete a STEAM classroom assignment and demonstrated macro-persistence toward a classroom STEAM unit.

After determining the categories for the types of activities students chose, I used a Mann-Whitney U test in SPSS (version 25) to determine significant differences between the dependent variable, macro-persistence, and iterations of dichotomous demographics including low/not low SES, low/not low math achievement, male/female, and third/fourth, third/fifth, and fourth/fifth grade level comparisons. The basic requirements to use a Mann-Whitney U test to interpret these results included meeting the following four assumptions. First, this data had one dependent variable, macro-persistence, measured at a continuous level. Second, I had multiple iterations of one independent variable that consisted of dichotomous groups or I made dichotomous groups as in the case of grade-level. Third, I had independence of observation in that students were only in one group at a time for each iteration. Finally, I visually inspected each distribution shape and observed a mixture of similar and dissimilar distributions. To remain consistent in my communication, I used mean ranks to discuss the differences between the independent variables.

Results

Club activities.

Table 2.1, from above, showed the ratio of macro-persistence per total students participating in this study, allowing us to calculate the percent of students who demonstrated macro-persistence at least once during the timeframe of this study. Table 2.2 below includes these percentages and summarizes how many times each club and recess opportunity was attended across the entire semester. Where Table 2.1 provides information about how many of the 129 students participating in this research project attended each extra opportunity, this table provides an overview of student preferences toward the available opportunities. The highest club attendance occurred in Wednesday Workshop, followed by recess, and then Minecraft Club. I present the total number of times each club was attended to reveal discrepancies in the number of opportunities while also conveying the volume of interest in the type of opportunity.

Table 2.2.
Percent participation, total number of clubs, total times attended, and average attendance

Club	Percent participation out of 129 students	Number of clubs	Number of times attended	Average attendance
Chess	18	14	154	11
Minecraft	44	15	433	29
Coding	16	15	209	14
Biology	11	15	77	5
Wednesday Workshop	47	15	664	44
Recess	65	55	643	12
None	3	--	---	--

Table 2.3 summarizes the number of students participating in each club and recess activity per week. One area of additional interest in macro-persistence is the relationship between the in-class units and the extracurricular participation during recess. The coding activity took place during weeks one through six. The 3D design project took place during week eight and Monday during week nine. The construction unit took up weeks nine through 17 and state testing took place during weeks 14 through 16. In attempting to understand persistence in STEAM activities, I examined the raw attendance data between opportunities. The average number of instances of macro-persistence during recess (n=12) were lower than during Wednesday Workshop (n=44) and Minecraft Club (n=29) because there were more recess opportunities compared to club opportunities. The average recess attendance, however, was comparable to Chess Club (n=11) and Coding Club (n=14). The decrease in Chess Club attendance during week four is due to a Monday school holiday. Biology Club had the lowest average attendance (n=5).

Table 2.3.
Weekly club participation as measured by attendance at each opportunity

Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
WW	48	49	46	40	49	45		38	46	38	40	44	46	44	47	44	-
Biology	7	7	2	1	8	1		7	12	5	8	4	4	5	2	4	-
Chess	-	8	6	-	12	11		13	10	13	12	10	11	11	10	14	13
Minecraft	-	19	19	30	40	30		27	32	17	30	34	33	32	31	30	29
Coding	-	15	19	17	16	17		11	13	15	15	14	13	8	11	12	12
Recess	28	53	55	26	13	6		20	35	46	90	68	65	27	20	42	34

Note: WW in the left column refers to Wednesday Workshop. Week 7 is blank as this corresponds to Spring Break, when no clubs or workshops were held.

Student choice activities.

Table 2.4 depicts the type of activity students showed macro-persistence toward while they attended club and recess opportunities. Minecraft stayed consistently higher than most of the other activities, except for the coding peaks in weeks 2 and 3 and the peak in week 11 during the construction unit.

Table 2.4.
Weekly club participation

Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
"Present"	--	1	7	--	--	--		--	2	3	2	1	--	2	--	--	--
Tinkercad	--	--	--	--	--	--		11	13	12	--	--	1	--	--	1	--
Acting	13	16	11	7	7	--		16	27	23	34	27	31	25	28	34	25
Crafting	6	4	4	3	6	4		5	3	5	2	5	5	5	4	7	1
Roblox	--	--	--	--	--	--		--	--	--	2	--	3	3	2	3	--
Minecraft	31	49	54	60	80	73		48	61	43	53	68	58	56	60	48	29
Chess	--	8	6	--	12	11		13	10	13	12	10	11	11	10	14	13
Coding	27	67	64	43	26	21		18	22	31	15	14	20	14	14	15	14
Hopscotch	18	59	55	31	23	18		17	18	22	14	12	19	13	14	15	14
Scratch	1	--	2	5	3	2		--	1	1	--	--	--	--	--	--	--
code.org	8	8	7	7	--	1		1	3	8	1	2	1	1	--	--	--
Biology	6	6	1	1	7	1		5	10	4	5	3	3	4	2	2	--
Construction	--	--	--	--	--	--		--	--	15	70	46	40	7	1	22	21

Student characteristics.

SES and achievement.

There were no significant differences in macro-persistence in the clubs or recess between students of low and not-low levels of SES. Neither were there any significant differences in macro-persistence considering types of activities between low and not-low levels of SES. Similar results were found in the differences of macro-persistence between low and not low math achievement. Achievement scores also revealed no significant differences in macro-persistence in club or recess opportunities, nor the type of activities students chose.

Gender.

Two differences between macro-persistence in male and female students appeared under the offered events. In Minecraft Club, macro-persistence scores for males (mean rank = 74.04) were statistically significantly higher than for females (mean rank = 56.89), U = 1522.5, z = -2.863, p = .004. In contrast, in Wednesday Workshop, macro-persistence scores for females (mean rank = 71.57) were statistically significantly higher than for males (mean rank = 57.67), U = 2521, z = 2.241, p = .025. When comparing the activity of Minecraft between the two clubs, Minecraft Club and Wednesday Workshop, no statistically significant difference between male (mean rank = 68.19) and female (mean rank = 61.24) macro-persistence occurred, U = 1818.5, z = 1.234, p = .217.

Acting, a Wednesday Workshop and a limited recess activity, registered gender differences. Females (mean rank = 70.59) chose acting over males (mean rank = 58.77) as a macro-persistent STEAM activity, U = 2454, z = 2.268, p = .023.

No significant gender differences (male mean rank = 63.51, female mean rank = 66.34, U = 2165, z = .489, p = .625) were found toward coding activities in general. However, gender differences occurred within the specific type of coding activity. Males macro-persisted in Hopscotch (mean rank = 70.98) and Scratch (mean rank =68.90) over females (Hopscotch mean rank = 59.63, U = 1709, z = 2.222, p = .026; Scratch mean rank = 61.50, U = 1.836, z = -2.86, p = .004). But females (mean rank = 69.48), demonstrated macro-persistence in code.org style of coding activities over males (mean rank = 60.01), U = 2378.5, z = 2.023, p = .043.

The grade level category required a three-way comparison of macro-persistence between third to fourth, third to fifth, and fourth to fifth grade. Table 5 summarizes the results of the Mann-Whitney U test regarding total activity, meaning total instances of macro-persistence throughout the 17-week period of this case. A statistically significant difference in macro-persistence occurred between fourth-grade participants (mean rank=50.17 and 53.94) when compared to the third-grade (mean rank=38.00) and fifth-grade (mean rank=33.68) respectively. A closer look at the macro-persistence shown in fourth-grade students' club participation compared to third and then to fifth-grade students revealed similarities across both other levels.

Out of the six possible activities, fourth-grade participants demonstrated macro-persistence in three clubs (chess, Wednesday Workshop, and biology) over third-grade participants and five events (chess, Minecraft, coding, Wednesday Workshop, and biology) over fifth-grade participants. Recess was the only activity that showed no statistically significant difference in macro-persistence between the grade levels.

Table 2.5.
Comparisons of total macro-persistence

Total Activity	(p)	Distribution	Mann-Whitney U	(z)	Mean Rank Third	Mean Rank Fourth	Mean Rank Fifth
Third to Fourth	.026	not similar	1230	2.231	38.00	50.17	----
Third to Fifth	.143	similar	638	-1.463	45.34	----	37.66
Fourth to Fifth	.000	not similar	520	-3.714	----	53.94	33.68

Fourth-grade students demonstrated a higher macro-persistence in Chess Club over the other grade levels. Differences in macro-persistence between fourth-grade students (mean rank = 48.2) and third-grade students (mean rank = 40.26) were significantly higher, U =

1230, z = 2.231, and p=.043. Again, comparing macro-persistence between fourth-grade students (mean rank = 48.94) and fifth-grade students (mean rank = 39.41) showed a statistically significant difference, U = 744, z = -2.475, p = .013.

Similarly, fourth-graders demonstrated a higher macro-persistence in Biology Club. A statistically significant difference in macro-persistence occurred between fourth-grade students (mean rank = 47.72) and third grade students (mean rank = 40.80), U = 1115, z = 1.991, p = .047. Once more, a statistically significant difference in macro-persistence was also found between fourth-grade students (mean rank = 47.77) and fifth-grade students (mean rank = 40.76), U = 810, z = -2.017, p = .044.

Wednesday Workshop offered students a unique opportunity to choose from a variety of activities. Fourth-grade attendance at this event was higher than the other two grade levels. Compared to the third-grade (mean rank = 37.63), the fourth-grade participants (mean rank = 50.49) demonstrated a statistically significant difference in macro-persistence, U = 1245, z = 2.482, p = .013. Further, compared to the fifth-grade (mean rank = 38.57), the fourth-grade participants (mean rank = 49.67) demonstrated a statistically significant difference in macro-persistence, U = 720.5, z = -2.25, p = .024.

Considering the students' chosen activities, chess and biology took place exclusively in their respective club and yielded no new information. The other seven categories, Minecraft, Roblox, acting, crafts, coding, biology, and present demonstrated results similar to the clubs, meaning the fourth-grade group demonstrated more macro-persistence in some of the activities at a statistically significantly higher level than the other two groups. A few statistically significant differences appeared between the third and fifth-grade groups.

Macro-persistence in acting, registered statistically significantly different between fourth (mean rank = 50.63) and third (mean rank = 37.48) -grade students, U = 1251.5, z =

2.988, p = .003 and fourth (mean rank = 49.67) and fifth (mean rank = 38.57) -grade students.

The activity of coding did not show any statistically significant differences in macro-persistence between the grade levels, third-grade (mean rank = 41.5) to fourth-grade (mean rank = 47.12), U = 1086.5, z = 2.357, p = .463, third-grade (mean rank = 42.27) to fifth-grade (mean rank = 40.73), U = 809, z = -.342, p = .732, and fourth-grade (mean rank = 47.01) to fifth-grade (mean rank = 41.62), U = 845.5, z = -1.109, p = .089. However, statistically significant differences in macro-persistence were measured between grade levels and the type of coding activity which included the subcategories of Hopscotch, Scratch, and code.org. Fourth-grade students (mean rank = 48.20) demonstrated macro-persistence toward code.org coding activities over third-grade students (mean rank = 40.26), U = 1137.5, z = 2.114, p = .034), and third-grade students (mean rank = 45.16) showed macro-persistence toward Hopscotch coding activities over fifth-grade students (mean rank = 37.84), U = 690.5, z = -1.882, p = .060.

Fourth-grade students demonstrated a significant difference in macro-persistence when compared to those in fifth-grade when it came to Minecraft Club (fourth grade mean difference = 49.67, fifth grade mean difference = 38.57) U = 630.5, z = -2.912, p = .004, and Minecraft activity (fourth-grade mean difference = 51.46, fifth-grade mean difference = 36.52) U = 636.5, z = -2.812, p = .005.

In summary, I found the extra-curricular opportunities provided a chance for 97% of the participating students to demonstrate macro-persistence to at least one activity. I also found that macro-persistence between student demographic groups, such as gender, SES, and math achievement, was similar. When comparing students' macro-persistence activity between grade-levels, I found that fourth-grade students demonstrated more macro-persistence than either of the other two grades levels.

Discussion and Conclusions

This case study explored student macro-persistence in STEAM activities at a rural elementary school in northern Idaho. The results present a picture of what activities students choose when given the opportunity and student characteristics as related to demonstrating macro-persistence. Self-determination theory informed the design and implementation of classroom units and extra-curricular activities. In particular, the teacher/researcher attended to student autonomy, competence, and relatedness. Because this project involved factors specific to one environment, the teacher/researcher makes no claims regarding generalizability. However, the findings in this project may be transferable to other STEAM contexts.

In the context of this case, I noticed students macro-persisting in STEAM activities related to the classroom units. This became evident when looking at student participation during recess, compared to participation in other clubs and the peaks in macro-persistence activities, such as coding during weeks two and three and construction during weeks 10-13, that happened during the scheduled times for the unit. Because Garcia (2015) reported that low-income students express less persistence than not-low income students, I expected to see a significant difference in macro-persistence between SES levels. I found no differences in macro-persistence at the recess opportunities in any of the demographic categories. This means that both levels of SES and math achievement, both genders, and all grade levels demonstrated a similar amount of macro-persistence toward STEAM learning during recess. I also noticed that 65% of the students participating in the study demonstrated macro-persistence at least once during the study. After examining this finding closer, I compared the participation levels of the STEAM room units (coding, 3D design, and construction) with other clubs and activities, particularly Minecraft and Wednesday Workshop. Data indicated macro-persistence at recess superseded the most popular clubs and activities for a short amount of time. As there were typically more recess opportunities per-week than the other opportunities, it follows that this activity might be more frequently related to the STEAM class units, reflecting student interest in the unit due to the macro-persistent behavior measured. The peak in macro-persistence in computer coding lasted for two weeks, after which time participation during recess fell drastically. Macro-persistence of any activity during recess did not increase again until the introduction of the construction unit in class. Two external factors might have influenced participation during recess. First, the coding activities took place inside when the weather changed from cold to warm and construction activities took place outside during warm weather, making weather one factor. Second, the novelty of the activity may have affected behavior. Novel activities are an attractive alternative to typical recess activity, and the STEAM room was made more accessible during this study.

Next, I found a high level of interest toward Minecraft. A similar interest in Minecraft was found across math academic levels, SES, gender, and grade level, except between fourth and fifth-grade. This could be because the fifth-grade students were less interested in attending Minecraft Club and Wednesday Workshop over other options available to them. These other options could come in the form of growing older and having more liberty to stay at home for short periods of time without supervision or being with a group of friends who all like to play football on the playground before school.

Coding was also another activity that showed similarities in participation among the different student demographic groups. As a whole, there were no significant differences in student participation with the activity of coding based on SES, gender, math achievement, and grade level. Significant differences arose when I compared what types of coding activity the students chose. The boys chose using Hopscotch or Scratch over the girls who preferred code.org. Hopscotch and Scratch both use code blocks to allow students to write code and make something, like a game. Code.org at this level does not support students programming a self-selected game but instead presents small puzzles that need solving by using the code blocks. It is unclear as to why this gender difference occurred. However, it might be that boys expressed goal-oriented behavior and girls demonstrated value-oriented behavior. In other words, boys wanted to play games like those that required coding to move an object from the bottom of the screen to the top without getting it by left-right moving obstacles in the path. On the other hand, girls chose to program games for the enjoyment of solving puzzles and may not have cared about the end result of the game. Regardless of the reasons behind why a difference arose between the genders, this phenomenon demonstrates an important reason for teachers to provide students with multiple pathways toward growth in competency, especially when supporting intrinsic motivation and encouraging persistence.

An unexpected and unclear difference occurred between total macro-persistence at the fourth-grade level compared to demonstrations of macro-persistence at the third-grade and also at the fifth-grade level. These differences took place in club participation which caused differences in the corresponding activities. Both the third and fifth-grade demonstrations of macro-persistence in Chess Club, Wednesday Workshop, and Biology Club were lower than fourth-grade. Fifth-grade also demonstrated lower macro-persistence in Minecraft Club and Coding Club. The teacher/researcher discussed this phenomenon with other teachers at the school to generate possible explanations. The internal culture of each group emerged as a strong suggestion from multiple fourth-grade teachers. These teachers felt that the parents of the fifth-grade students kept to themselves and did not interact with the school compared to the parents of the fourth-grade class. Additionally, the fifth-grade group had more social undercurrents that negatively influenced group dynamics compared to the fourth-grade group. For example, one fifth-grade group had multiple students who sabotaged group sharing times by blurting out irrelevant things, like "My pencil broke," when a peer was sharing about how he solved something such as a computer coding problem, thus distracting the attention of the group. Another possibility that helps explain differences in macro-persistence might be that other activities the STEAM opportunities compete with other activities available at the school. However, the school in the study provides identical opportunities for every grade level and generally avoids schedule conflicts. Thus, further investigation is warranted to determine the reasons for the differences displayed in macro-persistence between fourth-grade and the other grade levels. Longitudinal data regarding STEAM persistence might provide a better understanding of these differences.

The results of this study suggest using the activity of Minecraft to support student growth in STEAM education. The intrinsic motivation students demonstrated through their macro-persistence toward Minecraft offers an advantage to using Minecraft as a medium for students to use to demonstrate STEAM understanding. An advantage to utilizing Minecraft in STEAM education may be the opportunity to connect the interest many elementary students have toward Minecraft and STEAM learning, using situational interest to enhance learning as suggested by Flowerday and Shell (2015). Additionally, students using Minecraft have the opportunity to explore and experiment with STEAM ideas in a playful manner, further developing interest and intrinsic motivation. Combining the use of Minecraft and STEAM education might affect student learning and behavior outside the school environment, as demonstrated by student macro-persistence toward the activity of Minecraft in this study.

The study results also suggest that offering multiple ways to engage in computer science learning could provide a better learning experience for all students because some students demonstrate a preference for building computer games with block code while others preferred solving puzzles using similar block code. An advantage to offering different methods for students to choose from during a computer coding unit may provide the opportunity for students to develop a positive self-perception toward computer coding, affecting their identity formation as discussed by Kaplan and Flum (2010). Also, the context of engaging in a particular learning situation with autonomy support and the opportunity for the student to return to the learning activity at their own discretion supports the development of a disposition in the student toward the learning activity.

Finally, the club that encountered the highest average attendance, Wednesday Workshop, offered students the most freedom determine a STEAM activity. During this club, students demonstrated a wide range of interests, not all stemming from school-related activities. Students took the opportunity to explore equipment unavailable for larger groups because of the lack of quantity, such as the video camera or a 3D drawing pen. Students also chose to play Minecraft with friends in this group situation. Essentially, during this constructivist learning club, students demonstrated self-determination toward personal interests and learning goals.

In STEAM education, student learning often encounters barriers of access to materials that support exploration and play. With accessible STEAM opportunities offered at the school during students' discretionary time, students could enhance their intrinsic motivation toward a learning activity and develop non-cognitive skills, such as macro-persistence. The idea of providing time for students to explore STEAM materials in a low-risk environment originated from the imbalance of access to STEAM materials the teacher/researcher saw among students attending the school. Despite this effort, there is still a need to make more time available for students to explore STEAM materials.

Limitations

This study was conducted at one elementary school with events surrounding the offerings of one STEAM teacher, making results transferable to similar situations but not generalizable to all populations. The teacher/researcher used a constructivist approach to teaching and supports students' self-determination and intrinsic motivation through interactions with the students, meaning findings discussed might not be repeatable if the STEAM teacher demonstrates different teaching pedagogy and style.

In this study, a pre-test baseline was not used. Instead, the state standardized achievement test, taken by the students during the same semester as this case, provided the data used to interpret participation differences between low and not-low mathematics achievement. Results from this achievement test may be skewed to show more low students than actually exist due to technical difficulties with the internet and the state mathematics website during testing.

It should be noted that some opportunities restricted access to the available materials offered by the teacher/researcher. This limitation required students to choose a predetermined activity, such as chess, over a different activity, such as recess. To further clarify, the teacher/researcher only allowed students to persist in activities related to the classroom units and had to turn away many students asking if they could play Minecraft at recess. Additional data collection is necessary to determine if the motivation behind the macro-persistence when options are controlled or limited supports the development of intrinsic motivation toward the chosen activity.

Further Research

The current case aimed to explore factors surrounding macro-persistence. Data analysis focused on student choice and student characteristics. Although grade level does not indicate marginalization, it is unclear about the factors influencing the significant difference in macro-persistence demonstrated by the fourth-grade students. A longitudinal study of macro-persistent activity at the third through fifth-grade levels would provide more information about grade-level persistence and the peak witnessed in this study. Aside from the difference between grade level macro-persistence, a number of outliers impacted data analysis. Some students (n=8) demonstrated an unusual amount of macro-persistence compared to their peers. For example, one third grade boy attended every recess opportunity and every coding club in order to macro-persist in coding. Although these individuals are only mentioned here, a more in-depth look at who they are, what activities they chose, and why these particular students chose to persist might provide a better understanding of macro-persistence in STEAM activities.

Offering opportunities for students to indicate, through *macro*-persistence, the activities that interest them provides meaningful information toward the future development of STEAM units during class. The findings from this work support results found in other studies, such as Fortus and Vedder-Weiss (2014), who suggested that motivation toward science learning may be manifest through engagement in extracurricular science-related activity. The underlying principles of supporting student autonomy provides a means for understanding students intrinsic motivation and *macro*-persistence toward STEAM activities.

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Chapter 3: The hour of code: Impact of materials on persistence in computational thinking

Abstract

The type of materials used during computational thinking activities can impact student behaviors and perceptions. The present study investigated student persistence and intrinsic motivation toward learning computational skills during their free time using tabletop and digitals materials to determine which materials best support students' desire to continue. A teacher/researcher presented two similar game-based learning situations during the first week of a computational thinking unit in which 154 students participated during a regularly scheduled elective class. During this time, students also had the option to participate in before and after school clubs along with recess opportunities. These clubs provided access to classroom materials during some of the students' free time. Students demonstrated more intrinsic motivation and a certain type of persistence toward using digital materials to learn computational thinking skills.

Introduction

Picture a school without digital technology, teaching students how to program and code. In such a situation, students might use squares on graph paper to represent pixels. The act of coding might consist of directional arrows, indicating instructions that will reveal a picture. Students could engage and enjoy the activity, but what happens when errors ruin the activity? Instead of experiencing the enjoyment of discovering the solution, which is a picture of a Minecraft Creeper, some third through fifth-grade students are in tears because the mouth does not line-up with the eyes or worse. The students try to fix their mistake, but the eraser rips a hole in the paper and stains remain on the page. Rather than working from the mistake in the decoding process, the student starts over from the beginning. In contrast, students who learn computer coding using digital technology might use drag-and-drop learning software. This software presents problems in the form of puzzles. Students who make mistakes can easily revise their answer. Others, who struggle to keep track between their place between the puzzle and the code can check their progress by running the program after each step. With a limited amount of time allotted to computer science learning, teachers need to select materials that engage students, particularly those that access students' intrinsic motivation to learn. When students express intrinsic motivation toward a learning objective, they are more likely to continue learning during their free time beyond the classroom situation (Hagger & Chatzisarantis, 2016). Therefore, it is important to understand the effect the materials have on persistence while learning computer science.

Learning materials

Different learning materials offer unique contributions to student learning, interest, and motivation. However, designing an experiment to determine the effect instructional materials have on persistence and motivation presents difficulties. Clark and Feldon (2014) argued that teaching methods interfere with any research involving the comparison of different media. An example to support this supposition might be differences in using a paper book as opposed to an ebook for a reading activity. Both media support the objective of gathering information from reading. The differences lie in the ability of the medium to respond to the learner and support the teaching strategy. Paper text is static in that the information is fixed on the page. Digital text, on the other hand, can respond to the reader by providing supporting information. To further illustrate, think of reading text that contains an unfamiliar word. If the reader is using a paper book and wants to know the meaning of the word, he or she must generally find an external reference to provide the answer. Depending on the activity structure, this action can interrupt a flow or otherwise be disruptive. With some digital texts, however, the reader can highlight the word and the medium will list options that include providing the definition of the word. In this situation, the action has a minimal effect beyond the reader. While the instructional methods might appear similar, the medium has the potential to limit or free the learning situation. Extending the example, digital-based materials can support quick, personalized feedback in a low-risk setting, while paper-based materials rely heavily on external or teacher feedback. Shaffer, Nash, and Ruis (2015) similarly argued that technology allows teachers to provide learning situations more in tune to students' specific needs. Because of the unique contributions to learning that each medium brings to a learning situation, it is difficult to say if the tool itself sparks motivation to learn. Perhaps some tools minimize barriers to learning and motivation more than others. The unique attributes each tool offers, also contribute to student perceptions of the learning situation, which can connect the learning objectives to students' intrinsic motivation.

In this study, I analyzed student perceptions and behaviors toward two similar game-based activities that used different materials. Instructional materials cannot be evaluated separately from instructional methods because different materials afford different types of interactions between the teacher, student, and materials. However, when teaching computational thinking, do the materials and the interactions they provide, affect the perceptions students have toward continuing the activity? To answer this question, I used game-based pedagogy, supported student exploration, and the teacher used autonomy supportive methods to facilitate the interventions. These parameters helped reduce the amount of disruption I faced when trying to understand which materials supported students' intrinsic motivation and persistence. I elaborate on the parameters, along with the two materials used in this study, in Section 2 below.

Study Objectives

This study provides information on student perceptions and behavioral persistence that elementary students have toward tabletop and digital materials in order to determine the influence each material contributes to motivation and persistence toward learning the content.

I define persistence in learning as the non-cognitive trait of autonomously extending determination and exertion through the barriers of time, context, and difficulty. In this study, I am particularly interested in student persistence through the barrier of time. Researchers have measured persistence toward learning objectives through time in two ways. One method involves timing how long a participant continues working on an activity during a free-choice time immediately following the activity (Deci, 1970; Marinak & Gambrell, 2008). The other method tracks participants' plans to engage or engagement in an activity at a different time (Hagger & Chatzisarantis, 2016; Fortus & Vedder-Weiss, 2014). Since both types of persistence are of interest in the current study, a continuance of an activity at the moment is characterized as micro-persistence and re-engagement in an activity at a free-choice time after leaving the intervention area is characterized as macro-persistence. The following research questions guided this inquiry:

- What is the difference in persistence toward computer coding when students use tabletop or virtual materials during a computational thinking unit at the third through fifth-grade level?
- What is the difference in intrinsic motivation toward computer coding when students use tabletop or virtual materials during a computational thinking unit at the third through fifth-grade level?

Adapting a game-based learning model.

The input-process-outcome model developed by Garris, Ahlers, and Driskell (2002) is one method used to represent the objectives of a game-based learning situation. The teaching and learning model filled a gap in understanding the characteristics of instructional games, which include additional parameters compared to non-instructional games. The model provides a structure to plan the features surrounding the game which lead to intentional skill development and chosen learning outcomes. Adapting the input-process-outcome model to reflect the study context scenario involves adjusting the input, replacing the process with the game cycle, and selecting outcomes related to the research project. Using this adapted model, I could investigate the influence of the materials through the learning process (Figure 3.1).

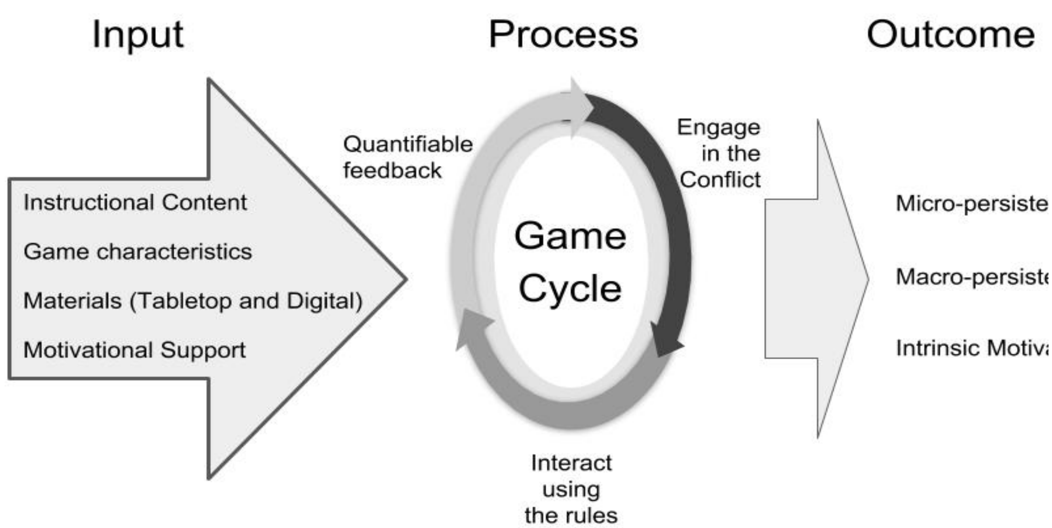

Figure 3.1. Adapted input-process-outcome game model

The Input into the Game Cycle.

The adapted input consists of four aspects, the instructional content (learning computer coding), game-based learning characteristics (through solving puzzles), instructional materials (one-time paper and the other digital), and motivational support (from the teacher) directed towards a student's intrinsic motivation.

Instructional content.

The content in the study addresses computational thinking through computer coding. Computational thinking, in this situation, refers to a method of problem-solving that recognizes patterns, reduces a problem into smaller parts, and represents a solution using an abstract language (Tedre & Denning, 2016). The instructional content determines the goal of the fundamental activity in the process phase of the model which contains the game. The game must encourage the development of competency among the participants toward the content of computational thinking. Understanding and development of computational thinking gets checked during the process during a phase called quantifiable feedback, which allows students to self-assess progress toward the goal. Note that measuring growth in computational thinking will not be a measured outcome for this study, instead, the goals focus on persistence and intrinsic motivation.

Game characteristics.

Another input in this present study includes the use of puzzles. Puzzles are games in which the goal is to find a solution (Restak & Kim, 2012), and they contain all of the defining elements, including artificial conflict, rules, and a quantifiable outcome (Tekinbas & Zimmerman, 2003). This study uses two similar puzzles, each with similar game elements, adapting the puzzle to fit with tabletop or virtual materials.

Materials.

As stated by Tekinbas and Zimmerman (2003), materials are an element of a game and the learning situation but do not form the entire system. In other words, the students are not learning how to use the materials, instead, they are using the materials for a different objective, to learn computational thinking. The two materials of interest for this study include tabletop materials, which consist of graph paper and pencils, and a choice of digital materials in the form of a laptop or iPad, to access the Hour of Code on code.org. Even though the learning situations in the game cycle have similarities, the materials, in this case, offer unique traits that may affect the outcome.

Motivational support.

Multiple theories related to learning motivation contribute to the growing field of game-based learning. Expectancy-value theory (Wigfield & Eccles, 2000) attends to the expectation a person has toward levels of success. For example, a child solving digital puzzles might believe she can write a code to make her virtual character get safely to the goal. Attribution theory (Weiner, 2000) explores the psychological process people use to justify their actions. In the previous example, if the child wrote code to turn her virtual character to the right but the character turned to the left, she might say to herself, "I did not face the same direction as my virtual character and that is why I wrote the wrong direction in my code." Social-cognitive theory (Zimmerman, 2000) links a person's observations of events to future ability. Returning to the example, the child, not knowing how to get to the right program on her iPad, might watch a classmate successfully complete this action and copy the behavior. Goal orientation theory (Dweck, 2008) explains a disposition individuals have toward validating personal ability in achievement settings, such as the example student successfully programming a virtual character from the start to finish and telling her friend she solved the puzzle. Finally, self-determination (Ryan & Deci, 2017) relates to a person's natural tendency for growth, as shown by a student who engages in solving puzzles by writing computer code on her own volition. While students may be motivated in various ways, I am particularly interested in intrinsic motivation which is revealed through the activities people chose at their discretion.

Self-determination theory provides the most structure from prior research, to measure persistence and intrinsic motivation. For example, Deci's (1970) early research studied the effect of rewards on people who worked on interesting puzzles and used a free-choice method immediately following the intervention to measure persistence at the moment. In his experiment, Deci examined intrinsic motivation through the amount of time the participants' spent continuing the activity immediately after the completion of the intervention. Researchers using self-determination theory continue to use the free-choice method to measure motivation because intrinsically motivated people tend to persist longer in a given task compared to those perceiving controlled motivation (Vansteenkiste, Lens, & Deci, 2006). Thus, self-determination theory concentrates on the type of motivation participants express by examining the forces that cause people to act, specifically autonomous and controlled motivation (Deci & Ryan, 2008; Ryan & Deci, 2000a).

The insights, learned through research on intrinsic motivation, encourage the use of autonomy supportive methods described in self-determination theory, as a specific input in game-based learning design. For example, Hagger and Chatzisarantis (2016) posit a positive impact that non-controlling words, such as using could instead of should, have on intrinsic motivation. Self-determination theory integrates well with game-based learning methods and the interactions in this classroom between the teacher and the students. The use of game-based learning methods may influence student motivation to the learning situation, particularly through assisting self-determination (Ryan, Rigby, & Przybylski, 2006). Intrinsically motivated learners demonstrate self-determined behavior (Ryan & Deci, 2017), characterized by functioning with perceived autonomy, competence, and relatedness. Moreover, self-determination theory can be used to investigate participant preference between gaming materials through a free-choice method (Ryan, Kostner, & Deci, 1991).

Self-determination theory provides information key to accessing intrinsic motivation through teacher support for autonomy, competence, and relatedness (Hagger & Chatzisarantis, 2016). Autonomy refers to a person's perceptions of originating force (Deci & Ryan, 2004). When a person believes that actions originate from themselves, they are identified by the person as autonomous actions. If the person perceives the action as originating from other forces, the action is identified as external and falls in a range according to the degree the person has endorsed the behavior (Deci & Ryan, 2000). In the game-based learning scenario, students exercise autonomy in how they solve the puzzles. The teacher also plays a part in assuring students the freedom to solve the puzzles using autonomy by using supportive wording, such as using the word "could" instead of "should" (Hagger, Chatzisarantis, Culverhouse, & Biddle, 2003). The second factor in self-determination theory, competence, means feeling effective at a chosen task (Ryan & Deci, 2000b). The need for competence shows when a person seeks a challenge that meets their current capacity and persists in that activity to grow (Deci & Ryan, 2008). A teacher shows respect for developing learner competence when classroom activities allow for differing levels of engagement (Nguyen & Deci, 2016). In the scenario, puzzles might range in difficulty, students pick which puzzle they want to solve, and students are encouraged to work together. The third factor, relatedness, means feeling accepted and connected to others (Deci & Ryan, 2000). Relatedness works reciprocally between others in the social context, meaning an extension and reception of companionship between other members in the context (Ryan & Deci, 2017). In a classroom setting, the teacher plays a crucial role in nurturing relatedness, particularly by supporting autonomous motivation (Ryan & Niemiec, 2009). The scenario teacher nurtures relatedness by encouraging students to work together, empathizing with students' frustrations, and proactively adjusting the assignment or offering additional help when needed. When autonomy, competence, and relatedness are supported, students tend to experience intrinsic motivation toward a learning activity (Vansteenkiste et al., 2006). For the above reasons, supporting student motivation using self-determination theory informs the study goals.

The Process of the Game Cycle.

In the original model, Garris et al. (2002) represented the process of the game cycle with three categories: user judgments, user behavior, and system feedback. The three attributes of the game cycle Garris et al. (2002) chose to focus on participants' interactions with the game and do not attend to game features. Thus, I used three aspects of a game as defined by Tekinbas and Zimmerman (2003), engaging in the conflict, interacting with the rules, and the presence of a quantifiable outcome, to represent common game characteristic between the two forms, tabletop and virtual. Puzzles represent a special type of game in which there is one correct answer and fit the definition of a game because players use predetermined rules to engage in an artificial conflict that results in a quantifiable outcome. During the output phase of this model, full attention is given to the participant. Thus, the process of the game cycle for the current study emerged as an attempt to align game characteristics between the two materials.

Differences in the materials, however, governed the game-play thus making the games dissimilar between the two materials. The paper puzzle introduced an artificial conflict between the player and the promised picture, by way of offering a code that revealed a pixelated picture after the player successfully followed the instructions. The teacher or another student creates a code that directs the player to move from square to square on a sheet of graph paper depending on the arrow's direction, and a special code indicates when the player needs to fill in the graph square (Figure 2). The table top puzzle's quantifiable outcome derives from revealing the pixelated picture related to the puzzle's code.

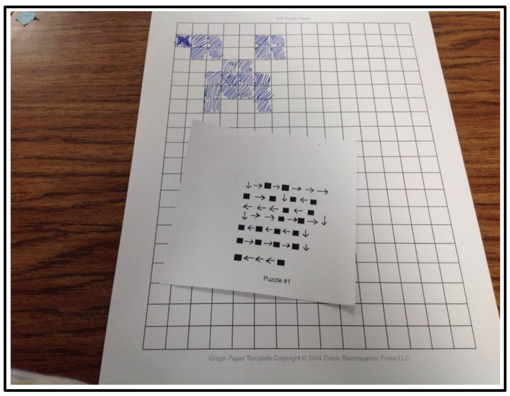

Figure 3.2. Sample tabletop game

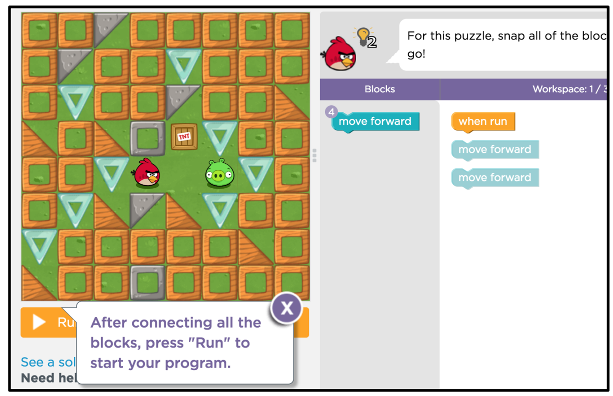

Figure 3.3. Sample digital game

By contrast, the digital puzzles took the form of a maze, where artificial conflict happened between the player and the puzzle. When engaging in the game, the player must move the virtual character from the starting point to the appropriate destination using command blocks (Figure 3.3). Directing the character through the maze while avoiding traps to the correct destination, determines success. Both game cycles provide motivation through autonomy support between the puzzle and each participant's method to solve it (Ryan et al., 1991). The games also provide an intrinsically motivating situation for most students in which to measure persistence (Ryan et al., 2006).

Engaging in the conflict.

The scenario puzzles present an artificial conflict between the player and the goal of the puzzle. One puzzle's system requires the player to decipher a code that reveals a pixelated picture while the other's system presents a maze that the player needs to use coding to direct a virtual character through. The artificial conflict, using the game rules to find a solution, in each puzzle allows the user to develop simple or complex strategies of computational thinking when reaching a solution. This flexibility relates to the phase in the original model labeled user judgments (Garris et al., 2002), meaning the game allows the player to engage in the conflict at varying levels of competence in the content and supports multiple ways to develop a solution. For example, the tabletop game allows players to decode the puzzle command by command, or by grouping similar commands (Figure 3.2). The tabletop game supports players who choose to move one square at a time. It also supports players who count how many times they need to move in one direction before changing directions. Using the example in Figure 3.4, the player might read the code as, move four to the right, move their position on the graph, and then return to the code for further instructions, thus grouping the code in patterns. Conversely, they might read the code as move one square to the right, do the move, and return to the code for more instructions. Either way of reading the code engages in the conflict and solves the puzzle.

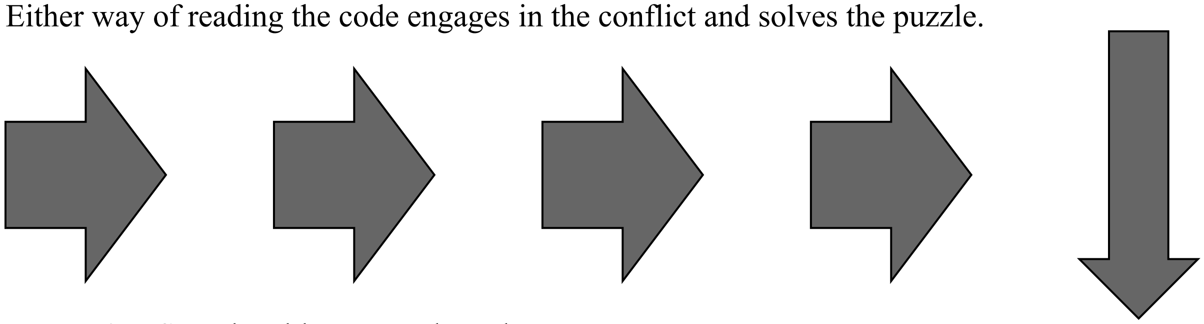

Figure 3.4. Sample tabletop puzzle code

Similarly, the digital game supports the ability for students to write a simple code, step-by-step, or a more complex code which groups command in patterns (Figure 3.5.) to solve the puzzle. In other words, both games contain aspects which allow user judgments to devise a solution, meeting the need to provide similar game characteristics between the two types of puzzles correlating with the materials.

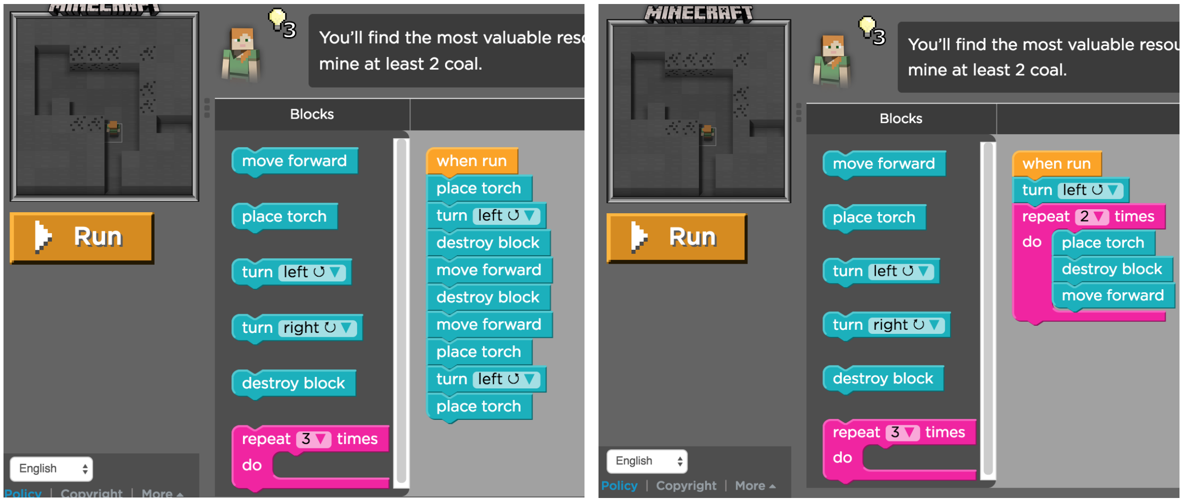

Figure 3.5. Sample solutions to the same digital puzzle

Interacting with the rules.

The rules for the games incorporate a similar learning objective, to develop computational thinking. The tabletop puzzle instructs learners to use a system of arrows and a filled in box to practice computational skills. The rules challenge students to read the code from left to right and only move when and where the code directs. Similarly, the digital puzzle uses a system of drag and drop blocks that the player places in particular order to direct a virtual character through a maze. The virtual character, in turn, can only move when and where the code directs. The rules differ in perspective between the games, meaning the tabletop game provides commands for the player and the digital game requires the player to command a virtual character in the game.

Quantifiable outcomes.

The games' quantifiable outcomes take the form of personalized feedback. In the case of the tabletop puzzle, students check their answer with a picture corresponding to their puzzle number. Learners may or may not receive formative feedback while working on the tabletop puzzle, because the learning environment may contain anywhere from 18-25 students at one time, making it difficult for one teacher to meet with each student. During the outcome stage of the tabletop game, each student compares his or her solution to a picture corresponding to their puzzle number. Unlike the finite aspects surrounding the quantifiable outcome of the tabletop game, the digital game provides additional feedback. The digital game provides formative feedback through tutorials and hints and indicates summative feedback after the student submits a final solution by displaying a colored dot. A dark green dot indicates that the puzzle was solved in the most efficient manner, a light green dot means that the puzzle was solved but a more efficient code exists, and a yellow dot means that student tried the puzzle but did not solve it. The teacher might encourage students to work toward getting all dark green dots by phrasing a question like, “I see you’ve found a solution to the puzzle. Are you going to try to find a more efficient code for this puzzle?” By phrasing encouragement in this manner, the teacher aligns their feedback during the process stage to support self-determination, similar to the methods discussed by Hagger and Chatzisarantis (2017), who used the autonomy supportive ideas of self-determination theory to understand the impact of teacher suggestions instead of directives on students’ free-time intentions.

The Outcomes from the Game Cycle.

Outcomes in the model align to questions about student persistence toward and perceptions of the games. Garris et al. (2002) developed the input-process-output model to guide practitioners and researchers. Their description of this phase of the model acknowledges different types of results including affective learning outcomes. Affective reactions include two different forms of persistence, micro-persistence, and macro-persistence, and perceptions of motivational orientation (McAuley, Duncan, & Tammen, 1989), which relate to the outcomes of the current study. The chosen outcomes of persistence and intrinsic motivation help us understand how the materials impact students’ perceptions and behaviors.

Persistence.

A free-choice method of measuring persistence, as discussed by Deci, Koestner, and Ryan (2001), consists of an intervention activity, enacts a free-choice period immediately following the activity, and measures how long the participant continues to engage in the intervention activity after its completion. The amount of time a participant persists in completing the intervention is theorized to indicate the level of intrinsic motivation that person has toward the activity (Chen & Risen, 2010). Since this activity takes place in an authentic learning situation, measuring each participants' micro-persistence using time is unrealistic, instead, the researcher could tabulate persistence using a dichotomous scale, indicating students who continue to engage in the activity after the teacher announces a free-choice period immediately following the activity.

Similarly, a different type of free-choice model could be used to measure macro-persistence. Hagger et al. (2003) developed the trans-contextual model to measure the impact of autonomy support perceived by students on their future intentions to participate in an activity during their leisure time. The model has been used to support persistence in physical education (Hagger et al., 2003), math homework (Hagger et al., 2016), and increase interest, engagement, and enjoyment in math (Whaley, 2012). The trans-contextual model relies on the theory of planned behavior (Hagger & Chatzisarantis, 2016); however, intentions can be blocked by other factors (Ajzen, 2011) such as transportation and parental permission. These other factors can provide a roadblock to the fruition of intended persistence, especially in elementary school children who are not in full control of their free-time schedule. To address this limitation, a better measurement than intentions might be to count student engagement with materials during the extra opportunities that take place at school, where the equipment is made equally available to all students during students' free-time before school, at recess, and after school the week during and after the intervention.

Intrinsic motivation.

The Intrinsic Motivation Inventory (IMI), validated by McAuley et al. (1987), consists of four subscales, interest/enjoyment (α = .78), perceived competence (α = .80), effort/importance (α = .84), and felt pressure and tension (α = .68). The overall inventory (α = .85) contained a total of 18 items that demonstrated stability and coherence through factor analysis. The IMI also supports slight modifications to the items so they reflect the specific activity being investigated. An item worded, "I enjoyed doing this activity very much," might be changed to say, "I enjoy learning to program using virtual games very much," thus stating the specific activity rather than leaving the statement in general terms. Whaley (2012) used a similar combination of subscales in his study on the influence of intrinsic motivation and academic achievement in mathematics. He found that autonomy support was not correlated to math achievement scores, but it was strongly correlated to students' enjoyment of the subject matter and interest to continue learning math. These findings support using such inventories to investigate student perceptions of materials used during a programming/coding activity focused on computational thinking.

Experimental Design

The context for the current study was a tabletop versus digital game-based learning scenario. The teacher/researcher wanted to promote student persistence by accessing students' intrinsic motivation to continue learning the material during free time. Since some of the computer coding curriculum that supports the development of computational thinking uses both types of materials, the teacher/researcher created an activity with which to understand which materials best support persistence and intrinsic motivation.

Methods.

A quasi-experimental design informed the investigation of differences in persistence and intrinsic motivation when using tabletop and digital materials during a computational thinking computer science activity. The teacher/researcher conducted the experiment to make an informed decision about which materials, tabletop, digital, or both, to use when presenting a computational thinking unit to third through fifth-grade students.

Participants and design.

The study took place at a rural elementary school in the Inland Northwest. The computational thinking unit occurred at the beginning of the third instructional quarter and lasted for six weeks. Data collection occurred at the start of the unit for two weeks. A convenience sample of 154 out of 184 students were selected. Students and parents were informed that their participation was voluntary and that students would not receive differential treatment based on their decision, meaning that everyone in the class would participate in the same activities. Parental consent forms and student assent forms were collected to determine which data to include in the analysis. The study used a no-control group, within-subjects, repeated measures design. Students with incomplete data were dropped from the study, reducing the number of participants to 144. Only complete data was used, dropping the number of participants to 144. The gender ratio of final participants was 43% male to 57% female. Of the participants, 55% come from low-income families, as determined by qualifying for free/reduced lunch. The racial demographics indicate the following percentage of students in each group, 80% white, 7% Asian, 7% Hispanic, 4%

Black, 1% Native American, and 1% identifying with more than one race. Nine percent of the students qualify for the English Language Learners program at the school.

Materials.

Options for the digital puzzles included Hopscotch, Scratch, and code.org. The code.org curriculum was chosen because it already included both tabletop and digital curriculum lesson plans that contained the desired elements. Students could play the digital game using their choice of tablets or computers. The tabletop lesson from code.org was modified in an attempt to create a more game-like activity. Instead of decoding a message that revealed a meaningless image (Figure 3.6), the activity was modified to be more game-like by making the message a meaningful picture (Figure 3.7) using the same system of symbols given in the code.org lesson.

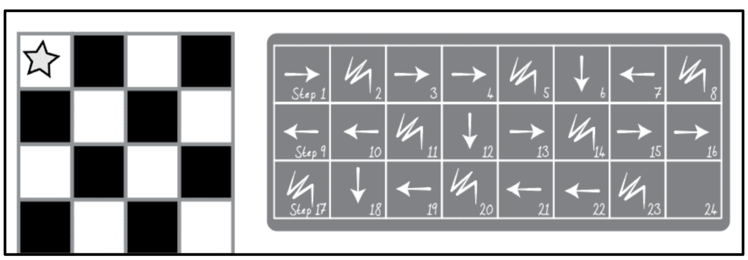

Figure 3.6. Tabletop puzzle and code from code.org lesson plans

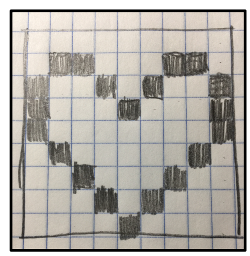

Figure 3.7. Example of a modified puzzle

The objective of the modified puzzle was to decode the program, written with arrows and shaded squares, to reveal a picture on a square section of graph paper. Puzzle solutions included a Minecraft® creeper face, a figure 8, or a Pac-Man® ghost. Students also had the option to create their own puzzle for someone else to solve. Digitally, students chose one of the Hour of Code options on code.org, including Minecraft®, Ice Age®, Star Wars®, Frozen®, and Classic Maze with Angry Birds® and other popular other characters. (See Figure 2 and Figure 3 for an illustration of both materials.)

Procedure.

A total of 144 students participated in the interventions within their regularly scheduled STEAM class. Table 3.1 summarizes the two-week schedule used to present the lessons using the tabletop and digital materials and collect survey information. Three classes, labeled as A, B, and C respectively, at each grade level (3rd-5th), for a total of nine classes, took part in the study. The A and C classes at each grade level received the tabletop materials first, as suggested by the code.org curriculum, followed by the digital materials. The B classes, on the other hand, received the interventions in reverse order. This was done to reduce an external validity threat caused by the order of events.

Table 3.1
Two-week intervention schedule and survey collection

	Class Times	Monday	Tuesday	Wednesday	Thursday	Friday
Week 1		Tabletop	Digital	Tabletop	Digital	Tabletop
	8:30-9:15	4th-grade A	4th-grade B	4th-grade C	4th-grade A	4th-grade B
	9:15-10:00	5th-grade A	5th-grade B	5th-grade C	5th-grade A	5th-grade B
	10:00-10:45	3rd-grade A	3rd-grade B	3rd-grade C	3rd-grade A	3rd-grade B
Week 2		Digital	Survey	Survey	Survey	
	8:30-9:15	4th-grade C	4th-grade A	4th-grade B	4th-grade C	
	9:15-10:00	5th-grade C	5th-grade A	5th-grade B	5th-grade C	
	10:00-10:45	3rd-grade C	3rd-grade A	3rd-grade B	3rd-grade C	

In two consecutive 45-minute class periods, students were introduced to the materials and puzzle (10 minutes), given a chance to work alone or in groups to solve the puzzles (25 minutes), and offered a period of free-choice time (10 minutes). After the introduction and during the 25-minute work time, students sat in self-selected groups on yoga-balls or office chairs around tables spread around the room. Students had the freedom to move around the room to get more supplies or regroup with someone needing or offering support. The tabletop materials required students to use pencils, erasers, and graph paper, while students primarily use an iPad to interact with the digital materials. Records were kept indicating what activities students chose during their free-choice time immediately following the intervention. Students who continued to work on the computer science activities demonstrated micro-persistence toward that activity. Macro-persistent records were also kept regarding students who returned to the classroom to continue working on the computer science activities, before or after school or on their recess time for two weeks after the start of the intervention. After participating in the tabletop and digital activities, students took two, back-to-back, Intrinsic Motivation Inventories. Researchers using the IMI typically choose to measure only the factors relevant to understanding the issues in question. In the current study, I measured student perceptions as they relate to interest/enjoyment, effort/importance, and perceived competence and included 18 items. These combined factors included 18 items and provide a valid ($\alpha = .85$) and reliable measurement of intrinsic motivation (McAuley et al., 1987). Students had the option to take the inventory online through Google Forms or on paper (See Table 2 for sample items). In order to assist students during the survey data collection process, the teacher read each prompt to the students.

Table 3.2.
Sample IMI Items

Tabletop Items	Digital Items
I enjoy learning to program using real-life games very much.	I enjoy learning to program using virtual games very much.
After learning to program using real-life games for a while, I feel pretty competent.	After learning to program using virtual games for a while, I feel pretty competent.
It is important to me to do well at learning to program using real-life games.	It is important to me to do well at learning to program using virtual games.

Results

The Intrinsic Motivation Inventory.

The inventory in this study demonstrated a high level of internal consistency, as determined by a Cronbach's alpha of 0.895 for the tabletop version and $\alpha = 0.891$ for the digital version, using SPSS (version 25). An analysis of the factors revealed the consistency of the sub-scales, tabletop perceived competence ($\alpha = 0.814$), tabletop interest/enjoyment ($\alpha = 0.893$), tabletop effort/importance ($\alpha = 0.683$), digital perceived competence ($\alpha = 0.767$), digital interest/enjoyment ($\alpha = 0.810$), and digital effort/importance ($\alpha = 0.680$).

Which mode did students prefer?

A paired-samples t-test determined whether there was a statistically significant mean difference between tabletop and digital materials when the participants shared perceptions on the Intrinsic Motivation Inventory. Two outliers, more than 1.5 standard deviations below the mean, were detected. Inspection of these values by conducting an additional paired-samples t-test without the outliers did not reveal the data to be extreme, and the results were kept in the analysis. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test ($p = .067$), which calculated a significance above 0.05 and indicated a normal distribution. Participants perceived more intrinsic motivation toward the digital materials ($M = 5.843$, $SD = .985$) as opposed to the tabletop materials ($M = 5.579$, $SD = 1.044$), a statistically significant mean difference of 0.264, 95% CI [0.109, 0.048], $t(143) = 2.413$, $p < .017$. The effect size, $d = 0.201$, reveals a small measure of practical significance.

The Intrinsic Motivation Inventory used in this research project consisted of three subscales, interest/enjoyment, perceived competence, and effort/importance. A deeper look into the factors reveals statistically significant mean differences between tabletop and digital materials in the interest/enjoyment subscale ($M = 6.018$, $SD = 1.095$) compared to (M =

5.563, SD = 1.424) and in the perceived competence subscale (M = 5.654, SD = 1.138) compared to (M = 5.300, SD = 1.330), but not in the effort subscale (M = 5.858, SD = 1.157) compared to (M = 5.875, SD = 1.104).

Persistence in time.

One hundred forty-four participants were recruited to take part in an intervention designed to understand students' persistence toward a tabletop and a digital computer science game. A related samples McNemar test was used to compare student behaviors toward the tabletop game and the digital game materials.

Which mode promoted more macro-persistence?

At the start of the study, no students demonstrated macro-persistence toward either game. Following the intervention, the number of students demonstrating macro-persistence toward the digital game had increased to 32 students (22%) while no students demonstrated macro-persistence toward the tabletop game. An exact McNemar's test determined that the difference in the proportion of students who demonstrated macro-persistence toward the digital game over the tabletop game was statistically significant, $\chi2(1) = 30.031$, $p = .000$.

Which mode promoted more micro-persistence?

Of the 144 students participating in the study regarding students' persistence toward a tabletop and a digital computer science game, few demonstrated micro-persistence toward either activity during the unit. The final number of students demonstrating micro-persistence toward the digital game was 10 students (7%) while four students (3%) demonstrated micro-persistence toward the tabletop game. An exact McNemar's test determined that the difference in the proportion of students who demonstrated macro-persistence toward the digital game over the tabletop game was not statistically significant, $\chi2(1) = 2.083$, $p = .149$.

Discussion

The results from this project suggest that students perceive more intrinsic motivation toward digital materials when learning computational thinking. First, the Intrinsic Motivation Inventory surveys revealed a significant difference in students' perceptions of intrinsic motivation toward the digital materials, although the effect size was small. Interestingly, the students perceived exuding similar effort between the lessons with differing materials but expressed more interest/enjoyment and perceived competence toward the digital materials. This means that students viewed the tasks as similarly worthy of effort, even though they felt more successful and interested in the digital materials. These results align with student behavior during the coding intervention. The teacher/researcher observed students crying while using the tabletop materials for reasons such as their paper ripping or making one mistake that ruined their picture. This behavior occurred because students wanted to succeed in revealing the image but found the materials frustrating. The effect of crying was not witnessed during the digital materials; students instead laughed, talked with their friends, and tried again when their virtual character went to the wrong location in the puzzle.

Students showed little micro-persistence between either material. Students chose to play a game called Minecraft during their free choice time rather than continuing their coding activity. However, other forms of persistence were observed but not measured during this project, such as extending determination and exertion through the barrier of difficulty. For example, students using the tabletop materials erased mistakes or used new sheets of paper and tried again, some students asked the teacher for help and worked as a group to solve the problem, and the teacher did not notice any students who stopped working altogether. Students also displayed determination and exertion through a self-imposed barrier of difficulty when using the digital materials. The digital puzzles contain extra reward points if a player took a more difficult route to the end by collecting a gem in the maze along the way to the solution. Some students discovered these gems and, without prompting from the teacher, decided to collect the gems. Additionally, students further demonstrated persistence during the activity when they chose to repeat a puzzle to create a more efficient code than the one initially written.

When comparing student macro-persistent behavior between the tabletop and digital materials, students returned to the classroom to continue working with the digital materials but not the tabletop materials. This phenomenon could have been due the short amount of time students have during recess, making it impractical to use the tabletop materials which are messier than the digital materials. Although the majority of students in the study demonstrated a preference for other activities at recess than computer coding, the availability of the materials supported student interest in those who did choose to use them.

Limitations and future directions.

The results of this study provide a research base for the implementation of a computational thinking program that supports students' intrinsic motivation to continue learning computer coding outside class time. However, the sample size of this study, consisting of 144 students from one elementary school, limits the generalizability of this research. Since data comes from one school, particular aspects of the school culture may influence the direction of the results. Future iterations of this study are needed in order to develop a deeper understanding of the impact of the materials on persistence in computational thinking.

This study also lacks pre/post-test data which limits the interpretation of the results to student perceptions of interest and persistence. It was determined that a pre/posttest would not adequately reflect the difference between the two materials. This decision was made because the researcher had no way of creating a digital assessment similar to the digital activities. Future directions of this study might consider developing a set of assessments able to adequately capture the growth in computer science learning between the different materials.

Another factor, the game rules, could also have influenced the results. Each game, tabletop and digital, presented the puzzle from different perspectives. When students played the tabletop game, the puzzle gave the movement directions to the student; however, during the digital game, the student commanded the movements of a virtual character. These differences in game rules may have influenced persistence, reflecting a limitation of my study as no data was collected to examine this variable.

Conclusion

Results of this research suggest that using digital materials during computational thinking activities evokes more intrinsic motivation and macro-persistence than using tabletop materials. Thus, when teachers have curricular time-constraints and access to computers, laptops, netbooks, or tablets, skipping the tabletop activities might increase the amount of time students spend persisting in the primary content.

Acknowledgments

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Chapter 4: Minecraft in education: Impact of external directives on an intrinsically motivating activity

Abstract

Accessing student's intrinsic motivation is an important consideration when designing lessons to present to elementary students. This research project investigated student perceptions and behavioral persistence when a teacher embedded learning tasks in a pre-existing motivational activity, Minecraft. Cognitive evaluation theory provided the theoretical basis to study how students perceived the teacher directed influence of standards-based and problem-based interventions. Findings of this study suggest that learners' perceive similar intrinsic motivation between the two styles of teacher interference but demonstrate a significant increase in persistence toward the problem-based methods.

Introduction

Much of the research on effective pedagogy related to intrinsic motivation analyzes the social context, especially support for autonomy given by a teacher (Black & Deci, 2000; Burgers, Eden, van Engelenburg, Buningh, 2015; Cheon, Reeve, Lee, & Lee, 2018; Hagger & Chatzisarantis, 2016). By contrast, studying intrinsic motivation can also focus on how external requirements alter the perception of a pre-existing intrinsically motivating activities that students choose to do in their free time. This type of research on motivation draws upon self-determination theory (Deci & Ryan, 2000; Ryan & Deci, 2000a), which explains human motivation across many domains. Under this guiding framework, I investigated a previously existing motivational activity and provided an autonomy-supportive environment as described by Hagger, Chatzisarantis, Culverhouse, and Biddle (2003), to understand the impact of external requirements, such as teacher-imposed directions, on student's intrinsic motivation toward the activity. To assist with this investigation, cognitive evaluation theory, a mini-theory in self-determination theory, specifically focuses on intrinsic motivation (Ryan & Deci, 2013) and examines strategies that access intrinsic motivation and contribute to characteristics such as persistence. Applying cognitive evaluation theory, particularly autonomy support, provides a social context which supports intrinsic motivation (Cheon et al., 2018; Cheon, Reeve, Yu, & Jang, 2014). However, if the intrinsic motivation for a particular activity already exists, what kind of external requirements can a teacher place on the activity before the students lose interest?

The current study sought to use a pre-existing motivational activity, Minecraft, to investigate the differences between standards-based directives and problem-based directives from the teacher on students' perceptions of intrinsic motivation and behavioral persistence. In contrast, Deci (1970) used puzzles in his research to represent an intrinsically motivating activity, not taking into account if his participants showed prior interest in puzzles. By providing an intrinsically motivating activity self-selected by the participant and a supportive social context, the research focused on student perceptions and behavioral persistence toward targeted competency development through two styles of teacher directives. To set the stage for this study, I review the motivational theory and activity, followed by the two types of directives given, and finally the measurement of student's perceptions of motivational orientation and behavioral persistence.

Self-Determination Theory.

Deci and Ryan (2008) posited that self-determination theory focuses on types of motivation that range from autonomous to controlled. Autonomous motivation encompasses both intrinsic and extrinsic motivation, in which people behave according to their likes and dislikes, whether internally motivated or driven by an outside factor. For example, Michou, Matsagouras, and Lens (2014) worked with high school and college students investigating their perceptions of motivational orientation towards school. Students who felt an internal need to achieve (intrinsic motivation) had healthy attitudes toward homework, while those who felt compelled to achieve (extrinsic motivation) experienced anxiety and a fear of failure. Studies like this indicate that intrinsic and extrinsic factors can affect students. These studies on motivational orientation also provide insight into the balance that must be struck between teacher directives such as homework and supporting student's intrinsic motivation to choose an activity. Ryan and Deci (2000a) further explain the difference between the two types of motivation. Intrinsic motivation refers to participation in an activity because it brings pleasure and satisfaction, and the mental focus remains on the activity. Extrinsic motivation, in contrast, refers to participation in an activity because of some other reason than the activity itself, such as rewards or punishments, and the mental focus stays on the external force, meaning that the reward or punishment has a higher value to the person than the activity itself.

Since the introduction of educational standards, a goal in applying self-determination theory is to design a learning environment that taps into a student's internal motivation while following policy-prescribed, grade-level standards. Educators can use self-determination theory research highlighting the role the learning environment plays in supporting autonomy and yielding positive connections leading to associated interest. Consequently, developing learning environments that support intrinsic motivation may help students increase interest, achievement, and persistence in school (Black & Deci, 2000). Understanding the importance of the social context in supporting intrinsic motivation, Deci and Ryan (1985) further developed their theory, proposing cognitive evaluation theory and exploring specific factors influencing intrinsic motivation.

Cognitive Evaluation Theory.

Cognitive evaluation theory, developed from self-determination theory, helps explain motivation based on satisfaction of specific behaviors, such as exploration and play (Ryan & Deci, 2013). Play usually produces personal satisfaction with an activity and triggers the association of intrinsic motivation toward the activity, as opposed to participation in an activity because of an external reward (Deci, Koestner, Ryan, 2001). Individuals who participate in an activity through bribes, such as money and points, are extrinsically motivated (Kohn, 1999). Therefore, designing a learning situation that encourages a playful and exploratory nature should target intrinsic motivation toward an activity.

After reviewing studies on tangible rewards and intrinsic motivation, Ryan and Deci (2017) articulated formal propositions of cognitive evaluation theory. Two of these propositions relate directly to this study. The first proposition addresses the influence of external events on intrinsic motivation, particularly a person's perceptions of feeling either controlled or autonomous, toward their behavior. This premise posits how people who feel externally controlled to engage in an activity typically experience a decline in intrinsic motivation toward the activity, while those who feel as if they engage in autonomous typically develop a stronger intrinsic motivation toward the activity. The second proposition focuses on the interaction between the event and the person's perceived competence. This proposition posits that events promoting positive feelings toward competence typically result in intrinsic motivation, while those eliciting negative or diminishing feelings of competence lead to a weakening of intrinsic motivation. Both propositions provide a basis for further investigation regarding a person's interpretation of external directives on a self-selected and intrinsically motivating activity.

As mentioned in both propositions, the method used by the person giving the external directive frames each instruction can influence a person's perception of where the motivation to participate originates. Positive feedback increases intrinsic motivation (Haggar, Koch, and Chatzisarantis, 2015); however, if students perceive the feedback as a method of controlling behavior, the motivational attempt undermines the positive effect (Ames, 1992). For example, a visible external reward or constraint can change the motivational orientation perception, from internal to external (Guay et al., 2010). In other words, a person's perception of the motivational strategy influences the direction of the orientation of motivational force from extrinsic to intrinsic.

Much is still unknown about the effect of non-contingent rewards on an activity, such as using an intrinsically motivating reward like Minecraft, as a medium to teach science. Hidi and Harackiewicz (2000) suggested that further investigation is needed to understand this relationship between external directives and intrinsic motivation during an interesting task. Ryan and Deci (2017) also note that little empirical information exists which supports assumptions made regarding naturally occurring rewards. This call for further research includes examining the effects that an existing intrinsically motivating activity might have on students' perceptions of motivation when an external force directs the activity. Similarly, Burgers et al. (2015) called for a better understanding of the use of educational games on intrinsic motivation toward a learning goal because researchers and educators lack empirical insight, particularly regarding the motivation to continue playing in the moment or at a later time. Research regarding the interplay of intrinsic motivation and educational games will provide evidence to make better teaching strategy decisions. Therefore, this study sought to explore student perceptions and behavioral persistence when a teacher uses an intrinsically motivating activity and imposes external tasks.

A motivating activity.

Since its creation in 2009, Minecraft has grown in popularity, selling over 100 million copies (Hill, 2016). Minecraft is a sandbox video game, mimicking play found in playground sandboxes, that runs on most computers. The game consists of virtual blocks that players build and destroy using tools wielded by block-shaped avatar characters in the game. Gameplay occurs through two primary modes, creative or survival. In creative mode, the game provides all resources for play. In contrast, survival mode requires characters to gather resources, sometimes in a competitive way with other players or with in-game characters. The objective of the game develops from the player's imagination. Minecraft allows players to alter the game's program through a process called modding. This ability means players can create their own code that changes the way the game functions, which in turn contributes to the formation of communities that connect players through their interest in the game (Dodgson, 2017). In these communities, Minecraft players work together to build items and share their expertise through in-game chat, video tutorials posted on YouTube, and/or live stream game-play via the Twitch app. These modes of interaction and popularity of the game demonstrate a strong intrinsic motivation to play Minecraft. A cursory analysis of Minecraft's mechanics reveals support for autonomy, by allowing the player to determine the game's objective, competence, as players access online tutorials to learn more, and relatedness, as shown by the growing Minecraft communities. Further, these three constructs are identified in self-determination theory (Ryan & Deci, 2017) as fulfilling the basic needs for psychological health and the foundation for intrinsic motivation. Since the game develops from a player's imagination it lends itself well to the purposes of this investigation by allowing the imposition of external tasks. With this motivational activity in mind, I describe the imposed task.

Imposing an external task.

Building on the concept of Minecraft as an intrinsically motivating activity, the next step involves determining how to impose tasks in a way that supports self-determination theory. In the context of the current study, students attended a science, technology, engineering, art, and math (STEAM) camp with activities designed to meet state science content standards. The external task will be presented in two ways, one originating from and focused on a standard, which I will call a standards-based lesson plan, the other will emerge from a problem, which I will call a problem-based lesson plan. Even though I used two methods of presenting the external task, students provided evidence of their understanding through a model they built in Minecraft. The next two sections provide further insight into the design of the camp.

Standards-based directives.

A standards-based directive in this research study means the teacher selects one specific learning standard and asks students to demonstrate their understanding of that standard. The teacher targets the instruction and activities to the standard. Student demonstration of understanding can take the form of a test generated by the teacher or a model built and explained by the student. Lesson plan designs based on the Next Generation Science Standards (NGSS, 2013), by nature should focus on making sense of a phenomenon. Lessons should help students explore the selected phenomenon through three aspects; grade level appropriate science and engineering practices, disciplinary core ideas, and crosscutting concepts. Grade level practices help make underlying scientific knowledge and skills accessible to the learner. Disciplinary core ideas address broad connections, providing a foundation for further investigation, and crosscutting concepts link different science domains. Ideally, lesson strategies reveal student understanding through evidence-based observations.

Guidelines proposed by NGSS (2013) further suggest using student-generated questions and prior experience to motivate learning toward the targeted standard. In other words, as a teacher facilitates discussion about a standard, students share what they know and ask questions about what they would like to discover, and then students demonstrate their understanding through a test or project.

Standard 5-PS2-1, fifth-grade performance expectations for space systems taken from the NGSS (2013) handbook (see Appendix A for more information about the NGSS standard), expects students to support an argument using evidence, data, or a model regarding the downward direction of the force of gravity on the Earth. Scientists typically use models to understand and provide evidence about natural phenomenon. For example, the popular anecdote attributed to Isaac Newton's inspiration regarding gravity, an apple falling from a tree, provides a model of gravity. Similar to Newton, students experience the force of gravity in their everyday life, and teacher directed assignments require students to connect the phenomenon of gravity to a practical example or model. As you can see, a standards-based lesson does not adopt a particular pedagogy, instead, the instruction, activity, and assessment originate and focus on a predetermined learning standard.

Problem-based directives.

Instead of directing students to demonstrate their understanding of a learning standard, problem-based directives provide the student with a problem. The problem presented to students can be real or imagined and initiated by the teacher or by the students. Students use their prior understanding to address the problem and grow in understanding as they work toward a solution. While engaged in the activity of solving the problem students encounter the principles outlined in the standards. During these encounters, the teacher, aware and versed in the standards outlined for the grade level, uses appropriate terms and asks probing questions to challenge student growth and understanding.

Problem-based lesson designs show promise for long-term retention over lecture-based methods. Strobel and van Barneveld (2009), compared the achievement scores of students receiving either lecture-based or problem-based instruction. While no significant difference was identified during the immediate time of the intervention, students who learned through problem-based methods tended to demonstrate better long-term retention than their lecture-based counterparts. Even though the immediate gain between the two instructional systems seems similar, the long-term effects of problem-based learning methods supports student's lifelong learning more effectively.

In addition, the process of learning through problem-based methods helps students develop an approach to learning that extends beyond the immediate learning situation. For example, Loyens, Jones, Mikkers, and van Gog (2015) noted during their problem-based learning system that students used prior knowledge, acquired new knowledge, critically analyzed arguments, and developed a deep understanding of the topic. This suggests that problem-based lessons might support more skill development than a lesson focused on a specific learning target. Take for instance the problem of building an underwater base in Minecraft. Students had to face the problem of the water falling into their structure as they built the base. Broughton, Sinatra, and Nussbaum (2013) noted that the discussions, produced by the nature of the problem, expose individual student understanding and facilitate conceptual change as students compare other viewpoints with their own. While the above evidence shows support for using a problem-based pedagogy, it is also important for us to cover content standards and understand how instructional design impacts student motivation.

Measuring Intrinsic Motivation.

Fulmer and Frijters (2009) suggest using a multidimensional approach to measuring motivation because of the complexity of the construct. Intrinsic motivation has been measured using self-report methods (Deci & Ryan, 1985), engagement measures (Reeve & Lee, 2014), as well as behavioral observation (Deci et al, 2001). Self-report questionnaires, such as the Patterns of Adaptive Learning Scales (Ross, Blackburn, Forbes, 2005), Social Support Scale for Children (Harter, 2012), and the Intrinsic Motivation Inventory (McAuley, Duncan, & Tammen, 1989), have been used to measure perceptions of motivation. Constructs researchers have measured to understand behavioral motivation include, free-choice, persistence, engagement, and participation (Deci, 1970; Pierson, 1999, Reeve & Lee, 2014). Ryan and Deci (2017), in their book on self-determination theory, suggested combining self-report, such as the Intrinsic Motivation Inventory (McAuley, Duncan, & Tammen, 1989), and behavioral, such as the free-choice paradigm, measures to assess subjective interest and resulting actions. Following the suggestion provided through self-determination theory, this study seeks to measure different aspects of motivation through self-perceptions of motivation and behavioral persistence. Below I explain the measurement instruments and observation protocols which best fit this study.

Student perceptions.

The self-determination theory website contains a guide for constructing an intrinsic motivation inventory (IMI) specific to a particular research project (IMI, 2018). In its entirety the intrinsic motivation inventory consists of seven factors; interest/enjoyment, perceived competence, effort/importance, pressure/tension, perceived choice, value/usefulness, and relatedness. The factors contain a total of 45 items, but researchers may reduce the number of items by selecting specific factors related to a researcher's interests with minimal impact to validity and reliability.

For this research project I specifically wanted to measure four factors, interest/enjoyment (I/E), effort/importance (E/I), perceived competence (PC), and perceived choice (C). The I/E subscale measures student perceptions of intrinsic motivation (Black & Deci, 2000), the E/I subscale is relevant to this study on persistence and indicates the amount of investment the participant put into the activity (Deci et al., 1994), and the PC and C subscales predict motivational orientation (Ryan, Williams, Patrick, & Deci, 2009). This combination of factors will help us better understand the perceived impact of the two teacher-directed activities on the student's motivational orientation.

McAuley, Duncan, and Tammen (1989) used a similar set of factors when they validated their 18 items form of the intrinsic motivation inventory ($\alpha = .85$), measuring student's perceptions of the origin of motivation toward an activity. The four factors included, interest/enjoyment ($\alpha = .78$), perceived competence ($\alpha = .80$), effort/importance ($\alpha = .84$), and felt pressure and tension ($\alpha = .68$). In my study, I replaced the factor pressure and tension used in the McAuley et al. (1989) study with perceived choice because of my particular interest in student perceptions between the two methods the teacher used to present directives toward the student's Minecraft activities.

Behavioral persistence.

Persistence has been measured in various ways throughout research but has not been consistently defined. Some researchers (Deci, 1970) use a free-choice method to measure persistence to indicate intrinsic motivation (see also Deci et al., 2001). Other researchers use persistence to refer to a person autonomously returning to an activity repeatedly over time, such as the study that introduced the trans-contextual model (Hagger et al., 2003), which explained the influence of autonomy supportive language given by a teacher toward students' intentions to participate in an activity learned at school but during the student's free time. Along these lines, Burgers et al. (2015) used a record of a participant's immediate replay of a game to indicate persistence and concluded that future research might include investigating the participant's free-choice to return to the game outside the intervention time. In the current study, I define persistence in learning as the non-cognitive trait of autonomously extending determination and exertion through the barriers of time, context, and difficulty. I am interested in two types of persistence particularly related to the timing of the persistence, referring to the autonomous continuance of an immediate activity as *micro*-persistence and the autonomous participation in an activity repeatedly over time as *macro*-persistence. Thus, both types of persistence include a determination to continue an activity past a barrier of time, where one is immediately following the activity, *micro*-persistence, and the other happens after a period of time away from the activity, *macro*-persistence. I provide more information below to further explain these two constructs.

Micro-persistence.

Micro-persistence pertains to the time spent persisting in or returning to an activity immediately following previous engagement. The idea of measuring time spent persisting in a current activity was used by Deci (1970) as well as Deci et al., (2001) to quantify the construct of intrinsic motivation. In each case, participants who freely continued participating in the intervention activity demonstrated more intrinsic motivation toward the activity than those who chose a different activity after the time set aside for the intervention activity. Furthermore, *micro*-persistence emerges when a student has a difficult time stopping the activity but may or may not indicate a preference toward the activity. Chen and Risen (2010) caution that available offerings in a study's context might limit true preferences. In other words, it is important to offer typically appealing options for the participants to choose after the intervention, or else a false indication of intrinsic motivation might occur.

Macro-persistence.

Macro-persistence relates to autonomously returning to an activity after a period of time. Through the trans-contextual model (Hagger, et al., 2003; Hagger & Chatzisarantis, 2016), I find that students demonstrate intrinsic motivation when they intend to persist in school-related activities during their leisure time. For example, physical education teachers who use autonomy supportive language when presenting a tennis unit might hear of student's intentions to play tennis outside school hours. Fortus and Vedder-Weiss (2014) referred to persistence as continuing motivation. However, the context of the Fortus and Vedder-Weiss study delineates a few differences between continuing motivation and the concept of *macro*-persistence. First, the contextual conditions of continuing motivation require the activity to occur in a location other than school, while *macro*-persistence allows for the activity to take place in and/or outside the school during free time. Second, measurements of continuing motivation in the Fortus and Vedder-Weiss study included watching science YouTube videos, reading science magazines, and taking something apart to see how it works, depicting a broad scope of measurable science activities. M*acro*-persistence, on the other hand, looks at a narrower set of behaviors, targeting a specific learning activity, such as responding to an assignment to build an underwater base in one moment of time and voluntarily returning to the activity at another period of time.

Methods

Given the prior research on persistence and autonomous motivation, I understand that external rewards can reduce an activity's appeal, making the task less intrinsically motivating. However, little empirical information exists about the impact of external directives on a previously existing and intrinsically motivated activity. This study seeks to compare the difference between two type of external directives, standards-based and problem-based, given by the teacher while the student engages in a common and popular activity. In particular, I investigate the difference in student perceptions of intrinsic motivation and behavioral persistence toward teacher directives in Minecraft when the teacher implements either standards-based, (originated from a standard) or problem-based (originated from a problem) methods. I hypothesize that students perceive more intrinsic motivation toward the problem-based directives in both perceptions and behavior than the standards-based directives because of the open-ended nature of the problem-based prompts compared to the narrow focus of the standards-based prompts.

Participants and research design.

The population of this study consisted of third through fifth-grade participants (N=22) who self-selected to attend a week-long camp during their Spring Break. A total of 19 students, 11 female and eight male, completed two IMI surveys, one regarding the standards-based lessons and the other about the problem-based lessons. Three students did not complete both inventories, resulting in exclusion from the data analysis. All 22 participants contributed data to the analysis of free-choice behavior.

Materials.

Students used the pocket edition of Minecraft (Minecraft PE) available as an iPad app. Minecraft PE supports the creation of a server that hosts a community game for up to five players if they are on the same network. The student who creates the game world is designated as the owner and controls the availability of the world to others, meaning that he or she has to be in the world in order for others to continue playing. In order to minimize the limitation this might have on persistence, students who hosted a game with others were required to use the same world for all work in Minecraft throughout the research project. The IMI was used to measure student perceptions of the two different methods of directing the activity. As previously explained, the subscales consisted of interest/enjoyment (I/E), effort/importance (E/I), perceived competence (PC), and perceived choice (C). Students took the IMI on Google Forms. See Appendix B for the items used in both iterations of the IMI.

Procedures.

Students were allowed the freedom to work individually or in groups. The equipment determined the size of the largest group, n=5. The teacher wrote the lesson objective on the chalkboard for everyone to see and spent no more than five minutes reading the objective and leading the group in a preparatory discussion for the ensuing activity. This process included connecting students' prior knowledge with the lesson objective through small and large group sharing. The two lesson designs were alternated so that problem-based assignments were given on days one and three and standards-based assignments were given on days two and four. Appendix C shows an outline of the schedule for the week.

Teacher-directed prompts.

The teacher posted the following four prompts at the beginning of each directed activity time on the wall using large poster paper.

1. Standards-based assignments - These assignments originate directly from the Next Generation Science Standards (2103).
    a. Support an argument that gravitational force exerted by Earth on objects is directed downward.
    b. Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.

2. Problem-based assignments - These assignments originate from the teacher/researcher's imagination and were chosen because students will need to use their understanding of the rules governing the virtual world to produce a solution.
    a. Build an underwater base inhabitable by air-breathing organisms.
    b. Build an air base with aircraft that stays in the air without being connected to anything.

While the teacher/researcher has identified the orientation of the prompt, students could respond to the prompts in a self-selected manner within the world of Minecraft regardless of whether it came directly from the standards or indirectly addresses standards through the presentation of a problem.

Measuring micro-persistence.

Following the introduction, students had 20 minutes to work on an assignment. At the end of the allotted time, the teacher asked students to record an entry in their electronic learning journal. The instructions called for a screenshot of what they built in Minecraft and an explanation of how the model fulfilled the requirements of the assignment. The schedule allotted 10 minutes for journaling, but the researcher fabricated this time constraint to measure *micro*-persistence.

In the context of a school day, some teachers experience difficulty getting students to stop an activity and transition to the next activity or class. Regardless of the student's motivation for not stopping, they demonstrate *micro*-persistence toward the activity because the student keeps working even through the barrier of following the teacher's next instructions, meaning the student should stop and do something different but does not. After announcing the next scheduled activity, journaling, the teacher did not continue to press students to stop working in Minecraft, instead, two minutes after announcing the end of the activity, the teacher recorded which students were still working on their previous assignment. This demonstration of will to continue an activity in the face of opposition exemplifies *micro*-persistence. Students who persisted working on their response to the problem or standards-based prompt in Minecraft until the two-minute mark received a 1 for persisting with the activity and those who stopped working on their Minecraft response before the two-minute time period received no mark. When the teacher finished recording who continued to work on their project past the first call for a journal entry, the teacher asked students again to stop working on their assignment and make a journal entry, this time reinforcing the request by standing next to amiss students until they started their journal entry. Once everyone started entering information in their journal, the teacher allowed at least 10-minutes before starting the group sharing activity.

Measuring macro-persistence.

In the class schedule (Appendix C), lunch followed the journaling and group sharing activity, providing the break-in time from the intervention activity (Activity 1). Each day throughout the week, students were allowed time to choose from a variety of Minecraft activities, including those with goals outside the daily assignments they determined for themselves. Anytime during the week at this choice-time, students who autonomously returned to the standards- or problem-based assignment given by the teacher received a 1 for *macro*-persistence. Students who did not return to the assignment received no mark. Some students repeatedly returned to the same activity multiple times throughout the week; however, to maintain consistency between measuring *micro*- and *macro*-persistence a decision was made to adhere to a dichotomous scale.

Measuring intrinsic motivation.

Students completed the IMI survey twice; once on day three, referring to the problem-based lesson and again on day four, referring to the standards-based lesson. The IMI consisted of the interest/enjoyment (I/E), perceived competence (PC), and effort/importance (E), and perceived choice (C) subscales with a total of 24 items adapted for the two directives. Students responded to each item on a 7-point Likert-type scale (1=not at all true, 4=somewhat true, and 7=very true). Table 4.1 compares sample items between the two iterations of the IMI.

Table 4.1
Sample IMI wording between problem and standards-based forms

Factor	Problem-based sample items	Standards-based sample items
I/E	I enjoy building a space station in Minecraft very much.	I enjoy using Minecraft in science very much.
PC	I think I am pretty good at building a space station in Minecraft.	I think I am pretty good at using Minecraft to show science learning.
E	I put a lot of effort into building a space station in Minecraft.	I put a lot of effort into using Minecraft to show science learning.
C	I believe I had some choice about how to build a space station in Minecraft.	I believe I had some choice about how to use Minecraft to show science learning.

Results

Student perceptions.

Though 22 students participated in the study, only 19 participants completed both IMI surveys. All data analysis was completed using SPSS version 25. The IMI in this study demonstrated a high level of internal consistency, $\alpha = 0.952$ for the standards-based version and $\alpha = 0.922$ for the problem-based version. An analysis of the factors revealed the consistency of the sub-scales, standards-based factors I/E ($\alpha = 0.814$), PC ($\alpha = 0.904$), E ($\alpha = 0.846$), and C ($\alpha = 0.928$), and problem-based factors I/E ($\alpha = 0.911$), PC ($\alpha = 0.804$), E ($\alpha =$

0.666), and C (α = 0.910). Table 4.2 contains a list of averages and medians for each factor as well as for the total IMI.

Table 4.2
IMI averages and medians

	Intervention	I/E	PC	E	C	Total
Average	Standards	6.02	5.23	5.95	5.68	5.72
	Problem	6.3	5.6	6.32	5.2	5.85
Median	Standards	6.57	5.67	6.6	6	6.09
	Problem	6.57	5.67	6.8	5.67	6.11

Note. Standards refer to standards-based directives and Problem refers to problem-based directives

The difference between scores were symmetrically distributed, as assessed by a histogram (Figure 4.1). A Wilcoxon signed-rank test determined that there was no significant difference (Mdn=-.035) in perceived intrinsic motivation between the standards-based directive (Mdn=6.093) compared to the problem-based directive (Mdn=6.114), z=.201, p=.841.

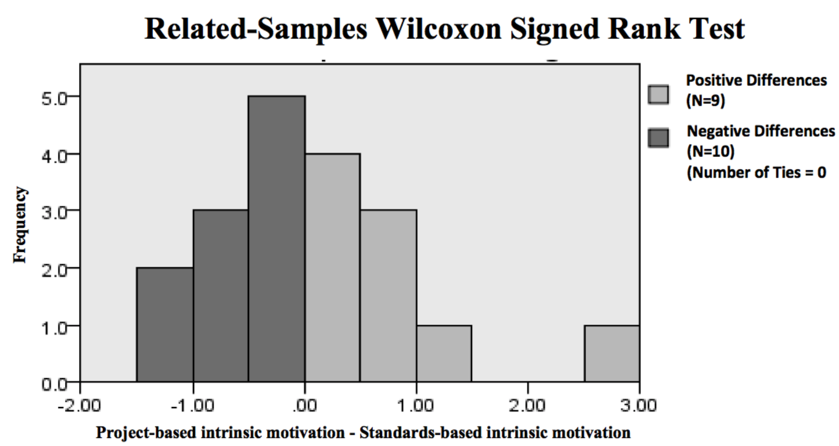

Figure 4.1. Histogram of mean differences

Persistence.

All 22 participating students engaged in four lessons, two based on science standards and two presented as a problem, for a total of 44 observations for each lesson type and a total of 88 observations altogether. A digital record of participants' *micro*-persistence and *macro*-

persistence was kept after each lesson and tabulated in Excel. Of the total population, participants demonstrated *micro*-persistence during the problem-based lesson 24 times compared to the 11 times shown during the standards-based lesson. An exact McNemar's test determined that the difference in the proportion of *micro*-persistent behavior between the problem-based lesson and the standards-based lesson was statistically significant, p = .002. An exact McNemar's test also determined that the difference in the proportion of *macro*-persistent behavior between the problem-based lesson and the standards-based lesson. Participants demonstrated *macro*-persistence during the problem-based lesson 29 times compared to the six times shown during the standards-based lesson, significance p = .000. Table 4.3 shows an overview of the results.

Table 4.3
Comparison of two types of behavioral persistence

Persistence	Population	Test Statistic	Standards	Problem	Significance
Micro-	44	8.471	11	24	p = .002
Macro-	44	19.36	6	29	p = .000

Discussion

The objective of this study was to investigate student perceptions of intrinsic motivation and persistent behaviors when placing teacher-imposed requirements on a pre-existing intrinsically motivating activity. A combination of the intrinsic motivation inventory, free-choice behavior immediately following an activity (*micro*-persistence), and student's choice to re-engage in the activity at a later time (*macro*-persistence) provided different indicators of intrinsic motivation. In this study, students did not identify a significant difference in intrinsic motivation between a standards-based and problem-based directive while playing Minecraft. However, student behavior revealed significant differences regarding both *micro*- and *macro*-persistence between the two lesson delivery methods.

I found that students did not distinguish a difference in intrinsic motivation between the two types of external directives while playing Minecraft. This lack of distinction could mean that the students did not perceive one directive as influencing their behavior differently than the other. Also, the activity of Minecraft still seems to remain intrinsically motivating, regardless of the external directives, with an average rating on the Intrinsic Motivation Inventory for the standards-based directive (Mdn=6.093) and the problem-based directive (Mdn=6.114), both at least 2.5 ratings above the median on a 7-point Likert-type scale. From this, I conclude that the students did not perceive either external directive as controlling and that the difficulty of the directive also did not diminish student perceptions of competence. While student perceptions of the external directives did not differ, I did notice a difference in student behavior.

Using a dichotomous free-choice measurement, the participants' behavioral preference statistically demonstrated more *micro*- and *macro*-persistence toward the problem-based directive than the standards-based directive. Although the teacher/researcher constructed the two styles of prompts to direct student activity toward similar physical science properties, the nature of the prompts, standards-based or problem-based, determined the limitations of student interpretation. In other words, the standards-based prompts asked students to demonstrate an understanding of one skill while the problem-based prompt allowed the students to determine when the final product met their ideals. A deeper look into the activities presents a better understanding of this result.

On the first day, participants were given 20-minutes to build an underwater base. After forming groups and discussing a plan, there was not enough time to complete the activity in the way the group envisioned. When the time came to make a journal entry, 12 out of the 22 participants did not want to stop. Similar results occurred on day three. This demonstration of *micro*-persistence means that students were engaged enough to continue working when they were asked to switch activities. In other words, the teacher needed to apply additional force, such as reminding students how much time they had left until the group meeting time, to encourage the students to stop working and make an entry in their journal. By demonstrating determination through the time constraint fabricated by the teacher/researcher, I interpret the behavior of these students to be intrinsically motivated toward the activity. However, other factors, besides not having enough time to satisfactorily answer the problem-based directive, may have swayed student behavior.

One factor, collaborating with peers, seemed to influence both *micro* and *macro*-persistence. Each of the 12 students who demonstrated *micro*-persistence were involved in a group that had other members who also continued with the activity after the teacher asked the group to produce a journal entry. The other half of the students, who did not demonstrate *micro*-persistence, were either in a group consisting of no members who showed *micro*-persistence or individually stopped working on the Minecraft assignment when the teacher announced journaling time even though their group mates did not stop. This finding is consistent with research conducted by Hidi and Harackiewicz (2000), who suggested that situational interest and social context influence motivation. They concluded that internal and external factors work together to develop interest. The insight given by Hidi and Harackiewicz (2000) relates to my situation because the external factor of collaborating with peers contributes to the demonstration of *micro*-persistence by some student. Similarly, Deci and Ryan (2000) found that relatedness plays a role in experiencing psychological health. In other words, the social context of the groups, making plans together and working as a team to carry out the group vision, affected some student’s desire to persist at the moment, regardless of their intrinsic motivation toward the activity at the time. This collaboration also impacted some student's desire to return to the activity at a later time to continue working on the group's solution to the problem. The standards-based directive revealed a different group dynamic than I saw during the problem-based directive.

On days two and four, when facing the standards-based assignment, the students interacted differently than they did with the problem-based assignment. Even though participants joined the same Minecraft server, not everyone worked together. For example, one group with four people produced four different responses to the prompt in the same area of the game. Possible reasons for this difference include the fact that the solutions tended to be simple, the question was less complex, and students did not need help to construct an answer. Examples of gravitational force models included a waterfall, lava flowing down a hill, or a character falling off a cliff. By contrast, one group worked to create a single, collaborative response modeled after a game that uses gravity as a factor, taking turns to drop colored pebbles corresponding to each player into a vertical grid to match four colors. Collaboratively building the game-style response required extensive planning and communication between the students. This group of students who engaged in group planning and building, demonstrated *micro*-persistence as they worked through the entire journaling time. Other displays of *micro*-persistence toward the standards-based energy conversion prompt occurred for different reasons than trying to complete a complex answer like the game-style response. First, some students seemed less familiar with the practical application around the scientific idea of the transfer of energy. Also, the students seemed inexperienced with red stone, an in-game material which creates a virtual electrical circuit. For this exercise, not finishing the model may have slightly increased the instances of *micro*-persistence.

Another factor that influenced students' desire to persist with the teacher directed assignments included the group sharing time after journaling. During this time, students projected their world on the large TV screen and talked about their project. Authentic feedback from peers in other groups seemed to increase the value of the project. One group demonstrating *micro*-persistence toward their underwater base installed sponges along the bottom of the walls. The sponges pumped the water out of their base once students sealed the top of their Minecraft structure. Although other groups devised different methods, some students expressed curiosity about the sponge method, providing acceptance and connectedness to the sponge group, and fulfilling a need for relatedness as described by Deci and Ryan (2000). After this sharing occurred on the first day, some of the other students returned to their underwater base during free time to add sponges or other features mentioned during the sharing time. This demonstration of *macro*-persistence seemed to illustrate the value students developed toward their project, which in turn seemed to increase intrinsic motivation. Although students received no additional directives regarding the problem-based assignment outside of the initial task, many continued to work on and share about their underwater base throughout the week, illustrating continued *macro*-persistence.

Additionally, an interesting phenomenon occurred between the problem-based and the standards-based assignments. Even though a significant number of students did not *macro*-persist with their standards-based assignments, mostly because students seemed to feel they satisfactorily answered the prompt, elements of these designs showed up in the problem-based assignments. For example, one group created a short railroad ride in response to the standards-based assignment of applying the idea of transfer of energy. This group used a switch and Redstone to start rolling the cart. After the group shared their project, others built a similar rail system in their underwater or air base. The appearance of some of the standards-based responses in the problem-based solutions demonstrates how students found value in the ideas others had in the standards-based assignments. Loyens et al. (2105) suggested that the design of a problem-based lesson allows for students to revise their ideas when new information becomes available, as demonstrated by the incorporation of ideas that originated from standards-based prompts into some problem-based solution.

Theoretical Implications

Findings of this study suggest that learners who like to play Minecraft may not perceive a significant intrinsic motivational difference between using the game for a problem-based and a standards-based lesson. These findings align with the supposition from self-determination theory (Deci & Ryan, 2008) that people perceive autonomy while experiencing intrinsic motivation and types of extrinsic motivation in which people value the activity. Expressions of autonomous motivation align with individual likes and dislikes (Black & Deci, 2000). In the current study, students expressed an internal desire to play Minecraft, possibly influencing their perceptions of motivation toward the teacher directed prompts. This finding implies that student engagement in pre-existing and intrinsically motivating activities may provide a medium for students and teachers to use while exploring and assessing new competencies.

Practical implications.

Using a pre-existing intrinsically motivating activity to embed teacher directed assignments may provide a framework for supporting self-determination during school. This project used Minecraft, a popular game amongst the students at the school, and embedded content standards in the student's gameplay. Once the teacher gave the assignment, students drove the learning process in that they generated individual plans and researched how to accomplish the goals they determined. This strategy accessed the intrinsic motivation of the students and produced a positive experience as shown by their perceptions and behaviors. Also, because of the interplay I found in *macro*-persistence between the standards-based and problem-based directives and the similar perceptions of intrinsic motivation between the two methods of directing students' activity, I determined that a combined approach to presenting teacher directives might prove beneficial to sustain student interest and encourage cognitive growth.

Empirical contributions.

The current study hypothesized that students would perceive more intrinsic motivation toward the problem-based assignment because the narrow constraints of a standards-based assignment seem more limiting and controlling than those of a problem-based assignment. The participants in this study, however, did not perceive any difference in intrinsic motivation between the two activities. Furthermore, within the factors of the intrinsic motivation inventory, participants did not perceive a significant difference in motivational control. Mean scores for each subscale, (see Table 4.1), however, did show a slight preference in intrinsic motivation toward problem-based assignments over standards-based assignments except under the perceived control factor. These results suggest the need for further investigation of students' perceptions of the orientation of motivation while embedding learning activities in a pre-existing motivational activity.

Limitations and future directions.

The participants in this study were familiar with one another, the teacher, and the environment, reflecting an authentic school situation. Only students who indicated pre-existing motivation toward Minecraft received approval to attend the week-long camp and participate in the study. This non-random sample and the grouping of like-minded students presents an inherent limitation to the study design as they may represent a very special group of students and results from this group may not generalize to other types of students. Future directions of this study might take place in a pre-existing classroom setting, with other approaches to group formation around a preexisting and intrinsically motivating activity.

Although the intrinsic motivation inventory has been used in the past to determine intrinsic motivation, it was originally validated in 1989 (McAuley et al., 1989). New research indicates that this inventory may need updating. For example, in the perceived competence factor one item, "I think I did pretty well at this activity, compared to other students," requires respondents to compare their performance with others as an indication of competence. This item seems contradictory to current implications of self-determination theory (Ryan & Deci, 2000), which imply that a healthy view of competence is based on mastery, not performance relative to others. Further, Dweck's (1986; 2008) research on mindset indicates benefits of mastery- rather than comparative performance-based evaluations.

Other limitations of this study include the sample size (N=22, n=19). The small sample size and the use of a convenience sample of participants means that the results are not generalizable to a larger population. In addition, this study used a singular game to represent a pre-existing intrinsically motivational activity. Also, the order of events, presenting the problem-based and then the standards-based, might have influenced the results. Since the teacher/researcher gave the problem-based directive first, students may have had more time to demonstrate *macro*-persistence toward that activity. Continued research is needed with more participants, other activities, and reversed order of events to provide more robust information regarding students' perceptions of intrinsic motivation and persistent behaviors when embedding teacher directives in a pre-existing intrinsically motivational activity.

In response to the limitations mentioned in this research project, future steps will refine or create an intrinsic motivation inventory that contains items indicative of previous research in self-determination and mindset. This new inventory could also reduce the number of items that need to be reversed score, making it more applicable to measure the perceptions of elementary students.

Conclusion

This study provides insight about the interplay of external directives on a previously existing and intrinsically motivated activity. During a Minecraft Camp, I measured students' perceptions and behavioral persistence when given standards-based and problem-based directives in Minecraft, a pre-existing and intrinsically motivating activity. I found little evidence to show a difference in perceptions of motivational orientation between the two instructional methods, meaning that students did not view one method more or less intrinsically motivating. However, statistically significant differences were found in *micro-* and *macro*-persistence between the two methods, with students favoring problem-based over standards-based instruction while playing Minecraft. This indicates that students experience more intrinsic motivation toward the problem-based assignment and chose to autonomously return to the problem-based assignment over the observed responses to the standards-based assignment. Research regarding *micro-* and *macro*-persistence will help teachers make informed decisions about which methods support students' behavior toward autonomous learning.

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Chapter 5: Conclusion

I started my dissertation journey attempting to discover why some students persist with STEAM activities more than others. Along this journey, I noticed the impact of students' intrinsic motivation on their desire to continue working on an activity. Perhaps this type of motivation is the key toward persistence. However, intrinsic motivation and desire can be blocked through lack of access to supporting materials, such as access to the internet or digital devices or subverted through external pressure. When students do not have access to explore the materials in a low-risk environment, it limits their understanding to what they can attain during their in-class experience. While using the materials in school, students often feel external pressures including the length of class time allotted and the specific learning objective decided by the teacher, which can thwart curiosity and the development of persistence. This research project highlights the importance of access to persistence in STEAM activities.

Theme of Persistence

The three articles encompassing this dissertation complement each other to create a view of persistence in STEAM learning at the elementary level. By defining persistence and the timing of two types of persistence, *micro* and *macro*, all three articles exemplify the importance of providing access and time for students to demonstrate persistence. In the case study, Chapter 2, I explore data regarding student demographics, participation, and activity choice. For the most part, comparing *macro-persistence* in student participation in STEAM opportunities between gender (male and female), SES (low and not low), and math achievement (low and not low) revealed similar involvement among the independent groups. The lack of differences in the results indicate that when schools offer programs to all groups, instead of catering to any one group, the programs solicit an impartial representation of students. In other words, general programs do reach marginalized groups in STEAM learning, such as females and students from low SES households (Chen & Soldner, 2013), and include other students who are similarly interested in STEAM activities. This result encourages educators, community leaders, and government officials to support programs offering equitable access to students for exploratory and playful use of STEAM materials. One difference in *macro-persistence* occurred when comparing the type of activity to gender. Aside from acting and hanging out with the teacher, which were activities girls preferred, the differences in coding and Minecraft were a matter of matching the type of curriculum or when the opportunity happened. In other words, it was important to offer more than one style of learning to computer code, since the boys demonstrated a preference for programming games and the girls demonstrated a preference for solving puzzles. In addition, it was also important to offer different opportunities to attend because boys demonstrated a preference to play Minecraft at the morning Minecraft Club while the girls demonstrated a preference to play Minecraft at the afterschool club, Wednesday Workshop. This case study examined general student behavior throughout the course of the second semester; whereas the other two studies examined specific phenomenon related to particular STEAM activities, coding, and Minecraft.

In Chapter 3, I investigated the potential of curriculum to impact student persistence, especially *macro-persistence.* By comparing recommended computer science lessons using tabletop and digital materials, this research highlights students' behavioral preferences toward learning computational thinking using digital materials and further analyzes the autonomy support provided by digital materials compared to tabletop materials. Student preference for digital materials can also be connected to the choice many students make to play Minecraft. Findings from this research offer curriculum developers, researchers, educational funding agencies, and educators an understanding of the importance of materials on student persistence.

In Chapter 4, I connected the theoretical knowledge represented in self-determination theory and the practical outcomes from the study to inform future development of STEAM curriculum. From the data gathered for Chapter 2, Minecraft stood out as an intrinsically motivating activity to many students and therefore made a good platform for students to engage in STEAM learning. Findings revealed high perceptions of intrinsic motivation while students demonstrated understanding of scientific principles, when coupled with problem-based methods students, showing increased persistence over responding to a standards-based learning objective. Since students did not perceive any differences between the two methods of delivering external directives, a practical application to these findings might be to use problem-based directives to introject standards-based concepts. This manuscript offers practitioners insights on how to support motivation to continue working on necessary skills and knowledge development during students' leisure time.

Personal Reflection

Overall, these three manuscripts address phenomena I witness in my classroom and the decisions I face as I construct STEAM curriculum presented to students at my school. My personal motivation for this research included watching how students react to these decisions. More specifically, I wanted to compare tabletop and digital materials because I consistently witness students crying when I present the tabletop lesson, which made me feel as if the tabletop materials were inhibiting the development of future interest and motivation toward computer science. The study in Chapter 3 revealed that students perceive similar intrinsic motivation toward both activities and feel like they put in similar effort between the two materials. Students did, however, express more *macro*-persistence toward the digital materials, demonstrating a behavioral preference for digital materials. Now that I have the data, including an increase of *macro-persistence* in computer coding activities during the computational thinking unit, to support such a decision, I will avoid the tabletop lessons recommended by national computer science curriculum in favor of a variety of digital materials.

I have also witnessed a growing student affinity towards Minecraft and often have students ask if they can play during class. While recognizing the naturally occurring learning that takes place as someone plays Minecraft, I am still responsible to address learning objectives during class time. Therefore, when planning the STEAM curriculum, I have been unsure about how to use leisure time activity as a tool to demonstrate learning. This concern comes from the possibility that adult interference with this intrinsically motivating activity may cause some students to lose interest in the game. This research project leads me to believe that students who enjoy Minecraft equally enjoy demonstrating their STEAM learning regardless of the directives they receive, but some students show more persistence responding to a problem-based prompt. In the future, I plan on incorporating a problem-based Minecraft unit that includes models of standards-based learning objectives.

Finally, the number of opportunities I offered students to provide ample occasions for students to demonstrate *macro*-persistence is not sustainable for a full-time teacher. While I will still continue to host four mornings and one afternoon club, I decided not to continue hosting recess opportunities. I use these breaks instead to refresh myself physically and emotionally. By setting this boundary, I feel able to continue volunteering my time to students before and after school at the moment. My hope for the future is to develop extra-curricular STEAM programs offered to students at the school and hosted by others, such as parents, preservice teachers, volunteers, and/or potentially paid professional staff. Delegating program components creates opportunities for the community to become more engaged, supporting other factors that contribute to school and student success.

Broader Impacts

Prior research about intrinsic motivation identifies persistence over time as a central component of motivation (Ryan & Deci, 2017). Yet, persistence remains a construct with broad implications. By defining persistence in learning as the non-cognitive trait of autonomously extending determination and exertion through the barriers of time, context, and difficulty, I have constructed a definition that allows researchers to focus on particular aspects of persistence. I focused on refining and measuring the barrier of time, one aspect of time being in the moment and the other being at a later time. Incorporating both immediate and return persistence in the studies necessitated a way to communicate what type of persistence was under investigation. Based on this need, I termed the autonomous continuance of an immediate activity, *micro-persistence* and the autonomous participation in an activity repeatedly over time, *macro-persistence*. Viewing persistence in two ways provides a better understanding of student's intrinsic motivation toward the interventions in this study, addressing the multidimensionality of persistence as it relates to motivation. For example, few students showed *micro*-persistence toward the tabletop and the digital game during the computational thinking study, however students did demonstrate a significant difference in *macro*-persistence toward the digital over the tabletop materials. I hope other researchers will continue to extend this construct of *macro*-persistence as presented herein.

Equally important to the distinction made in the timing of persistence are the styles of activities available for students to use as they gain competence. Because the overarching study introduced various methods of learning computer coding, we found no differences in *macro-persistence* between the genders. If, however, students were limited to Hopscotch or code.org, the results would have presented a different picture. In other words, male students demonstrated *macro-persistence* toward Hopscotch over the females and the females demonstrated *macro-persistence* toward code.org over the males. Further research is necessary to understand gender preferences when making curricular decisions in computer science curriculum. Insight into preferred methods and activities demonstrated by genders might help teachers choose curriculum to support an equal representation of both genders in STEAM fields.

Now that we know that in how students in the current studies demonstrated persistence in different ways over time, and that there is no statistically significant difference in *micro* and *macro-persistence* amongst the dichotomous groups of gender, SES, and achievement, future studies should investigate the same phenomenon in different contexts. Consequently, these studies provide a stepping stone to further explore intrinsic motivation and different types of persistence such as *micro* and *macro*-persistence towards STEAM activities. It is possible that similar results may be found across different contexts, such as different grade levels from kindergarten through 12^{th}-grade, urban settings and smaller rural communities, but replication studies are necessary to verify such a hypothesis. Further, these results were possibly witnessed due to the positive rapport built between the teacher and students as a function of the school's culture, support for autonomy felt by the students, and access to popular and innovative STEAM materials. The influence of these variables represents indicators for future comparison. Finally, if we, as a society, want to increase student interest and persistence in STEAM-related activities, it is critical to find ways to support a student's intrinsic motivation and offer accessible opportunities for students to persist.

References

Chen, X., & Soldner, M. (2013). *STEM attrition: College students' paths into and out of STEM fields* (Statistical Analysis Report No. NCES 2014001REV). Washington D.C.: U.S. Department of Education.

Ryan, R. M., & Deci, E. L. (2017). *Self-determination theory: Basic psychological needs in motivation, development, and wellness*. Guilford Publications.

Appendix A:
NGSS (2013) Fifth-Grade Performance Expectation

5.Space Systems: Stars and the Solar System

5.Space Systems: Stars and the Solar System

Students who demonstrate understanding can:

5-PS2-1. Support an argument that the gravitational force exerted by Earth on objects is directed down. [Clarification Statement: "Down" is a local description of the direction that points toward the center of the spherical Earth.] [Assessment Boundary: Assessment does not include mathematical representation of gravitational force.]

5-ESS1-1. Support an argument that differences in the apparent brightness of the sun compared to other stars is due to their relative distances from Earth. [Assessment Boundary: Assessment is limited to relative distances, not sizes, of stars. Assessment does not include other factors that affect apparent brightness (such as stellar masses, age, stage).]

5-ESS1-2. Represent data in graphical displays to reveal patterns of daily changes in length and direction of shadows, day and night, and the seasonal appearance of some stars in the night sky. [Clarification Statement: Examples of patterns could include the position and motion of Earth with respect to the sun and selected stars that are visible only in particular months.] [Assessment Boundary: Assessment does not include causes of seasons.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and Interpreting Data Analyzing data in 3–5 builds on K–2 experiences and progresses to introducing quantitative approaches to collecting data and conducting multiple trials of qualitative observations. When possible and feasible, digital tools should be used. ▪ Represent data in graphical displays (bar graphs, pictographs and/or pie charts) to reveal patterns that indicate relationships. (5-ESS1-2) **Engaging in Argument from Evidence** Engaging in argument from evidence in 3–5 builds on K–2 experiences and progresses to critiquing the scientific explanations or solutions proposed by peers by citing relevant evidence about the natural and designed world(s). ▪ Support an argument with evidence, data, or a model. (5-PS2-1),(5-ESS1-1)	**PS2.B: Types of Interactions** ▪ The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center. (5-PS2-1) **ESS1.A: The Universe and its Stars** ▪ The sun is a star that appears larger and brighter than other stars because it is closer. Stars range greatly in their distance from Earth. (5-ESS1-1) **ESS1.B: Earth and the Solar System** ▪ The orbits of Earth around the sun and of the moon around Earth, together with the rotation of Earth about an axis between its North and South poles, cause observable patterns. These include day and night; daily changes in the length and direction of shadows; and different positions of the sun, moon, and stars at different times of the day, month, and year. (5-ESS1-2)	**Patterns** ▪ Similarities and differences in patterns can be used to sort, classify, communicate and analyze simple rates of change for natural phenomena. (5-ESS1-2) **Cause and Effect** ▪ Cause and effect relationships are routinely identified and used to explain change. (5-PS2-1) **Scale, Proportion, and Quantity** ▪ Natural objects exist from the very small to the immensely large. (5-ESS1-1)

Connections to other DCIs in fifth grade: N/A

Articulation of DCIs across grade-levels: **1.ESS1.A** (5-ESS1-2); **1.ESS1.B** (5-ESS1-2); **3.PS2.A** (5-PS2-1),(5-ESS1-2); **3.PS2.B** (5-PS2-1); **MS.PS2.B** (5-PS2-1); **MS.ESS1.A** (5-ESS1-1),(5-ESS1-2); **MS.ESS1.B** (5-PS2-1),(5-ESS1-1),(5-ESS1-2); **MS.ESS2.C** (5-PS2-1)

Common Core State Standards Connections:

ELA/Literacy –

RI.5.1 Quote accurately from a text when explaining what the text says explicitly and when drawing inferences from the text. *(5-PS2-1),(5-ESS1-1)*

RI.5.7 Draw on information from multiple print or digital sources, demonstrating the ability to locate an answer to a question quickly or to solve a problem efficiently. *(5-ESS1-1)*

RI.5.8 Explain how an author uses reasons and evidence to support particular points in a text, identifying which reasons and evidence support which point(s). *(5-ESS1-1)*

RI.5.9 Integrate information from several texts on the same topic in order to write or speak about the subject knowledgeably. (5-PS2-1),(5-ESS1-1)

W.5.1 Write opinion pieces on topics or texts, supporting a point of view with reasons and information. (5-PS2-1),(5-ESS1-1)

SL.5.5 Include multimedia components (e.g., graphics, sound) and visual displays in presentations when appropriate to enhance the development of main ideas or themes. *(5-ESS1-2)*

Mathematics –

MP.2 Reason abstractly and quantitatively. *(5-ESS1-1)*,(5-ESS1-2)

MP.4 Model with mathematics. *(5-ESS1-1)*,(5-ESS1-2)

5.NBT.A.2 Explain patterns in the number of zeros of the product when multiplying a number by powers of 10, and explain patterns in the placement of the decimal point when a decimal is multiplied or divided by a power of 10. Use whole-number exponents to denote powers of 10. *(5-ESS1-1)*

5.G.A.2 Represent real world and mathematical problems by graphing points in the first quadrant of the coordinate plane, and interpret coordinate values of points in the context of the situation. (5-ESS1-2)

Appendix B:
IMI Items

Standards-based Items

1. I enjoy using Minecraft in science very much.
2. Using Minecraft to show science learning is fun to do.
3. I think using Minecraft to show science learning is a boring activity.
4. Using Minecraft to show science learning does not hold my attention at all.
5. I would describe using Minecraft to show science learning as very interesting.
6. I think using Minecraft to show science learning is quite enjoyable.
7. While I am using Minecraft to show science learning, I think about how much I enjoy it.
8. I think I am pretty good at using Minecraft to show science learning.
9. I think I do pretty well at using Minecraft to show science learning, compared to other students.
10. After using Minecraft to show science learning for a while, I feel pretty competent.
11. I am satisfied with my performance at using Minecraft to show science learning.
12. I am pretty skilled at using Minecraft to show science learning.
13. Using Minecraft to show science learning is an activity that I could not do very well.

Problem-based Items

1. I enjoy building a space station in Minecraft very much.
2. Building a space station in Minecraft is fun to do.
3. I think building a space station in Minecraft is a boring activity.
4. Building a space station in Minecraft does not hold my attention at all.
5. I would describe building a space station in Minecraft as very interesting.
6. I think building a space station in Minecraft is quite enjoyable.
7. While I am building a space station in Minecraft, I think about how much I enjoy it.
8. I think I am pretty good at building a space station in Minecraft.
9. I think I do pretty well at building a space station in Minecraft, compared to other students.
10. After building a space station in Minecraft for a while, I feel pretty competent.
11. I am satisfied with my performance at building a space station in Minecraft.
12. I am pretty skilled at building a space station in Minecraft.
13. Building a space station in Minecraft is an activity that I could not do very well.

<u>Standards-based Items</u>

14. I put a lot of effort into using Minecraft to show science learning.
15. I do not try hard to do well at using Minecraft to show science learning.
16. I try very hard at using Minecraft to show science learning.
17. It is important to me to do well at using Minecraft to show science learning.
18. I do not put much energy into using Minecraft to show science learning.
19. I believe I had some choice about how to use Minecraft to show science learning.
20. I felt like it was not my choice on how to use Minecraft to show science learning.
21. I didn't really have a choice about how to use Minecraft to show science learning.
22. I felt like I had to show science learning in Minecraft because I had no choice.
23. I built used Minecraft to demonstrate science learning because I wanted to.
24. I used Minecraft to show science learning because I had to.

<u>Problem-based Items</u>

14. I put a lot of effort into building a space station in Minecraft.
15. I do not try hard to do well at building a space station in Minecraft.
16. I try very hard at building a space station in Minecraft.
17. It is important to me to do well at building a space station in Minecraft.
18. I do not put much energy into building a space station in Minecraft.
19. I believe I had some choice about how to build a space station in Minecraft.
20. I felt like it was not my choice about how to build a space station in Minecraft.
21. I didn't really have a choice about how to build a space station in Minecraft.
22. I felt like I had to build a space station in Minecraft because I had no choice.
23. I built a space station in Minecraft because I wanted to.
24. I built a space station in Minecraft because I had to.

Appendix C:
Minecraft Camp Schedule

Time	Activity	
9:00	Welcome Set SMART goals	Specific, Measurable, Attainable, Relevant, Timely
9:30	Work on SMART goals	
10:00		
10:30		
11:00	Teacher directed activity time	Allot 20 minutes for activity and 10 minutes for journaling in Seesaw (Monday/Wednesday problem-based assignments; Tuesday/Thursday standards-based assignments)
11:30	Group discussion	Students project their iPad onto the large TV screen and share their solutions to the prompts, difficulties they encountered, and how they overcame. (IMI given on Wednesday and again on Thursday)
12:00	Lunch	
12:30	Choice activities	Continue working on SMART goals or Monday - make invitations for parents to Friday's Minecraft Gallery, Tuesday - use Perler beads to make Minecraft characters, Wednesday - Play Zombie tag (everyone required to attend), Thursday - Paint Minecraft characters on T-shirts, Friday - Minecraft Gallery
1:00		
1:30		
2:00	Daily Journal Entry	Share SMART goal progress plus other items of interest on Seesaw
2:30	Group discussion	Students project their iPad onto the large TV screen and share their activities.
3:00	Dismissal	