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Mary Leanna Prater, Student

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Dr. Mary Shake, Director of Graduate Studies

Student Authored Digital Games as Authentic Learning:
Using the *Can You Create a Game Challenge* in Elementary Classrooms

Dissertation

A dissertation submitted in partial fulfillment of the requirements for the degree of
Doctor of Education
in the
College of Education
at the University of Kentucky

By

Mary Leanna Prater

Lexington, Kentucky

Chair: Dr. Joan Mazur, Professor, Department of Curriculum & Instruction

Lexington, Kentucky

2016

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Abstract of Dissertation

STUDENT AUTHORED DIGITAL GAMES AS AUTHENTIC LEARNING: USING THE CAN YOU CREATE A GAME CHALLENGE IN ELEMENTARY CLASSROOMS

This embedded single-case study examined an elementary classroom implementation of a digital game authoring challenge aligned with state mandated content standards. Teachers used the game challenge over four 50 minute class periods during a three month period of time. A total of twenty five (n=25) 4th grade students, nine (n=9) 5th grade students and three (n=3) STEM teachers participated in the study.

The central research question for this study is: How do elementary teachers use a game challenge specifically aligned with Common Core/Next Generation Science (NGSS) state standards for instruction? Qualitative data, drawn from participating teacher interviews, classroom observations, student project reflections and document analysis of the student-authored digital games, were analyzed using Hatch's (2002) typological analysis. Findings suggest that, while using a standards-based gaming task within instruction is effective in promoting dimensions of an authentic learning environment for students, more research is needed in the areas of 1) professional development for teachers in game design and computational thinking; 2) the use of a digital game task as an assessment for students with disabilities or who struggle in other content areas; 3) the use of a digital game task for assessment in other content areas; and 4) how the computational thinking skills and the dispositions of teachers affect the flow of knowledge in classrooms using a digital game task.

KEYWORDS: Digital game based learning; Authentic learning; Elementary education
Computational thinking; Assessment

Mary Leanna Prater

May 25, 2016

Student Authored Games as Authentic Learning:
Using the *Can You Create a Game Challenge* in Elementary Classrooms

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Date

Dedication

To my parents, Marsha Plybon and the late Rev. Frank Plybon, for instilling in me a love of learning, the value of an education and living a life of service to others; and to my sister, Rachel for her support.

To my amazing husband, Craig, for his continued encouragement and support of my educational journey; his selfless dedication to me, our family and home made it possible for me to pursue this degree.

To my daughters, Reagan and Emily, I love you both dearly.

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Chapter One

Introduction

“The issue of foremost importance is to develop thinking skills in our students so that they will be able to utilize the power of technological tools to solve problems and do useful work” (McCain, 2005, p. 84).

The influence of computers and technology in the home, work place and school creates a need for today’s learners to use technology as part of an authentic learning process. Since the 1980s, when the first computers began making their way into schools, teachers have struggled with how to use these new tools in the classroom (Jen-Hwa, Clark, & Ma, 2003; Laffey, 2004; Li, 2007). While computers evolved from early editions of Apple and DOS machines to laptops and handheld devices such as iPhones or Kindles, the problem seems to be the same. Instead of embracing these new engaging technologies in the classroom, 21st century teachers still mainly rely on 20th century tools (Cuban, 2001). The struggle to embrace new technologies in the classroom has historical roots. In the 1990s, researchers noted teachers did not integrate technology into the classrooms due to barriers. Ertmer (1999) identified two types of barriers that exist for the lag in teacher technology use, referring to them as the first and second-order barriers. The first order barrier includes issues such as the lack of access to digital tools and time while the second order barrier relates to the teacher’s belief about teaching and learning. In addition, initial attempts to introduce teachers to the use of technology in schools were

not effective because they were based on the wrong model of teaching with technology (Means & Olson, 1994). While educators continue to negotiate the best ways to use technology and navigate it in the classroom, today's learners are using technology to access content and tutorials on topics of interest. Students of all ages consume large amounts of media, partially due to the high use of mobile devices (Foundation, 2010; Tausend, 2013). Moreover, students are creating and sharing content on the Internet in free programs like Scratch (<http://www.scratch.mit.edu>), a creative computing software from the Massachusetts Institute of Technology (MIT). Of the more than 100,000 active monthly users on Scratch, the majority of the users range from 9 to 15 years of age and contribute thousands of projects to the online space ("Scratch community statistics," 2014).

In addition to the hesitant use of technology by classroom teachers and the extensive use of technology by today's learners outside of school, the need for a computer literate workforce continues to grow. Jobs in manufacturing and other areas requiring low skills are moving toward automation while the demand for workers with informational processing skills, high level cognitive skills and interpersonal skills is on the rise. The Organization for Economic Co-operation and Development (2013) stated "In addition to mastering occupation-specific skills, workers in the 21st century must also have a stock of information-processing skills, including literacy, numeracy and problem solving, and 'generic' skills, such as interpersonal communication, self-management, and the ability to learn, to help them weather the uncertainties of a rapidly changing labor market" (p.46). This finding is mirrored in job postings by corporations, businesses and government with jobs specifically in the area of computer science--the most difficult to

fill with skilled workers. For example, in 2011, Microsoft reported over 2500 computer science related jobs posted with the business spending an average of 65 days to fill one with a qualified worker (McDougall, 2011).

As the skill sets for jobs continue to change, so must the manner in which we prepare K-12 students for higher education and work in this century. Many students graduate from high school lacking the skills needed for college, such as the ability to work in groups, analyze information, seek help, and know how to ask questions to be self-reliant learners (Royster, Gross, & Hochbein, 2015). Ironically, while the rigorous state content standards developed during the 1990s and early 2000s outlined the breadth and depth of knowledge and content skills students should know and be able to do upon graduating high school, K-12 students often completed prescribed tasks which required little cognitive engagement and struggled to take ownership of their learning (Conley, 2007).

Consequently, schools developed a testing culture that promoted the use of summative assessments, designed in a format to test knowledge but primarily used to differentiate and rank both students and schools by achievement (Gulikers, Bastiaens, & Kirschner, 2004). To better prepare students for the challenges associated with work and life after high school graduation, many states have adopted newly distributed Common Core Standards designed to outline knowledge and skills needed for the 21st century. Unfortunately, even though the standards allow for a wide variety of student products to demonstrate understanding, many assessments of the new standards continue to be summative in nature and designed with typical multiple choice, short answer and essay questions (Miller, 2013).

The trend for using technology for assessment of content reflects traditional 20th century methods, with technology providing a teacher a simpler way to gather and disaggregate data. In an article posted on the National Council of Teachers of Mathematics website, the authors demonstrate a way for teachers to ask students tiered multiple choice questions and then use graphing calculators, cell phones or electronic response systems to quickly analyze student responses (Sanchez & Ice, 2004). While these tools make work easy for teachers and, when used properly, provide important information to the teacher to guide instruction, these feedback systems are typically used for trivial tasks such as to take attendance, or to ensure some cursory level of student participation or level of attention during a lecture (Deal, 2007). Teachers today have a wealth of freely available technologies and software at their disposal to integrate into instruction which, if implemented properly, promotes creativity and critical thinking while allowing students to use real world tools to solve problems. These technologies include apps for video and music editing, photo manipulation, video link software such as Skype and many other tools for productivity, communication and information as well as game authoring software.

In addition to Scratch, other free and low cost software for game creation such as Microsoft's KODU (<http://www.kodugamelab.com>) and Gamestar Mechanic (<http://www.gamestarmechanic.com>) provide children an opportunity to create playable games to share with others using simple programming language. Students who create their own digital games develop higher order thinking skills, experience deep learning and intrinsic motivation as well as improved retention of content and performance on standardized testing (Shapiro, 2013). While the use of digital games in the classroom has

increased over the years, teachers continue to struggle to make a connection between standards based content, assessment of student knowledge and skills and digital games (Korbey, 2014). In addition, previous research findings show that the use of game authoring software promotes transfer of knowledge, design thinking and development of computational thinking skills. However, existing models to integrate game authoring software in the classroom are not easily replicable or sustainable (Brennan, 2013; Harel, 1988; Kafai & Resnick, 1996).

Need for Research

Those in educational technology find these immersive, interactive technologies an influential social, technological and cultural force difficult to ignore, yet we know little about the consequences of game play on the cognition of those who play them (Squire, Giovanetto, Devane, & Durga, 2005). Current research on the use of digital gaming in education focuses on the use of commercial or other premade games for the purpose of exploration of specific knowledge, drill and skill or development of problem solving skills (Ke, 2008). Few studies exist on the use of student authored digital games for understanding specific subject content taught in a classroom (Baytak, 2009; Kafai, Ching, & Marshall, 1997; Wilson, Hainey, & Connolly, 2012). With the exception of Brennan's (2012) framework for assessing computational thinking skills in elementary students, no study had developed a replicable framework for use by elementary classroom teachers nor did they attempt to make a direct connection to the state mandated curriculum standards classroom teachers are required to teach and assess.

A specifically designed digital game task, the *Can You Create a Game Challenge*, was developed to provide this very connection to state mandated curriculum standards

adopted from the Common Core framework (Mazur & Prater, 2012; Prater & Mazur, 2014a, 2014b). Using the *Can You Create a Game Challenge* procedures, the intent is for teachers to provide students with a real world problem in which they will create a product for an authentic audience. As new digital tools continue to emerge, teachers need to know how to best connect them to current classroom instructional standards in a manner that is purposeful yet engaging and meaningful to students. It is this negotiation of digital tools, such as game authoring software within instruction that eventually will lead to a change in teacher's beliefs about teaching and learning with technology and ultimately better prepare students for work in this century.

Purpose

The purpose of this study was to determine if the use of a teacher created digital game challenge aligned with state mandated standards leads to authentic student learning. Results from this study offer suggestions for both the design of professional development for teachers to use digital gaming as part of authentic learning as well as rethinking assessment tasks and experiences for students to demonstrate their understanding of content. This single-case study examined how teachers used the *Can You Create a Game Challenge* within actual classroom learning environments to support instruction and assessment.

Research Questions

The central research question for this study is:

1. How do elementary teachers use a game challenge specifically aligned with Common Core/Next Generation Science (NGSS) state standards for instruction?

Supporting questions for this investigation were:

2. How does the teacher's use of a digital game based challenge work as an assessment of elementary students' understanding of Common Core/Next Generation Science state standards?
3. How does the specifically designed game challenge affect other dimensions of classroom instruction, assessment and students' engagement?

Table 1.

Terminology

Term	Description
Common Core State Standards	A set of national standards adopted by individual states which outline what K-12 students should know and be able to do in English language arts and mathematics at each grade level. This set of standards does not include science or social studies standards.
Next Generation Science Standards	A set of national standards adopted by individual states which outline what K-12 students should know and be able to do in the area of science and engineering. Though not a part of Common Core, the NGSS content cross connects to math and English language arts standards in the Common Core.

Table 1 (*continued*)

Term	Description
Computational thinking	The thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent (Cuny, Snyder, & Wing, 2010). It includes the dimensions of computational concepts, computational practices and computational perspectives (Brennan & Resnick, 2012).
Computational concepts	Concepts common in many programming languages, useful in Scratch projects and transferrable to other programming languages. Concepts include sequence, loops, parallelism, events, conditionals, operators and data ("Computational thinking with Scratch: Developing fluency with computational concepts, practices and perspectives," 2012).

Table 1 (*continued*)

Term	Description
Computational practices	Design practices students use when creating projects in Scratch, including experimenting and iterating; testing and debugging; reusing and remixing; abstracting and modularizing ("Computational thinking with Scratch: Developing fluency with computational concepts, practices and perspectives," 2012).
Computational perspectives	Shifts in perspectives observed in students using Scratch, including expressing; connecting; and questioning ("Computational thinking with Scratch: Developing fluency with computational concepts, practices and perspectives," 2012).

Significance of the Study

Research supports the benefits of students using creative computing software to create games for learning, yet teachers still struggle to connect standards based content, assessment of student knowledge and skills with digital games within instruction. Time

and increased teacher accountability as measured by student standardized test scores compound the struggle for teachers. This study investigated how teachers used a *Can You Create a Game Challenge* task to support instruction and provide insight as to how teachers use the task for assessment purposes, leading towards authentic student learning. Educators, or those who work with educators, will find this study useful because it provides information that enables them to better understand the benefits of using standards aligned digital game tasks like *Can You Create a Game Challenge* within the classroom.

After this initial Chapter, I present the relevant literature and describe the conceptual framework for the dissertation in Chapter Two. Chapter Three lays out the methodology for the study. In Chapter Four, I present the findings from the study and Chapter Five concludes the dissertation with a discussion of findings and implications as well as suggestions for further research.

Chapter Two

Conceptual Framework for the Study

“The role of the teacher is to create the conditions for invention rather than provide ready-made knowledge” (Papert, 1993a).

Seymour Papert (1980) argued the benefits of providing instruction based on the learner’s occupation. For children, these occupations include thinking, learning and playing. Papert’s occupations of children are the foundation for the theoretical framework for this study. For children, the ability to explore environments, both physical and digital, promotes a need to know from questions arising through experiences in an attempt to make sense of the world around them. These questions lead to conversations and a search for information from more knowledgeable others eventually leading to learning (Vygotsky, 1978). The following theories connect the ideas of playing, thinking and learning for children in regards to learning and their relationship to the use of game authoring software and digital game challenges within the classroom.

Constructivist Theory

Constructivism is a theory of learning based on the assumption that people construct knowledge through interactions with others, their environment as well as their experiences and is not something that can be easily delivered by a teacher and memorized by a student (Ackerman, 2010). Piaget argued that children learn through adaptation or their ability to adjust to their environment through assimilation or accommodation (Piaget, 1952). Through the use of old schema or modifications of schema, children

make sense out of new objects to make meaning (Ackerman, 2001; Piaget, 1952). In addition, Piaget believed children have their own view of the world, different from adults, and his theory of development supports his views on how children make sense of the world around them, moving from the very concrete to the ability to manipulate mental models (Ackerman, 2010). Dewey (1897) also believed that children learn best when they are active participants in the learning process, connecting prior experiences to classroom learning. “Constructivism, in a nutshell, states that children are the builders of their own cognitive tools, as well as of their external realities” (Ackerman, 2004, p.2).

Edith Ackerman, a former colleague of Piaget, summarized his views on constructivism as it relates to education:

- Teaching can never be direct; children interpret what they hear in light of their knowledge and experience.
- Knowledge is not information but lessons learned from experiences.
- A theory of learning that ignores resistance misses the point; teachers need to guide students helping them explore, express, exchange and expand their views from within. (Ackerman, 2010, p. 3)

Constructivists view learning as an active process; people learn to learn as they learn; that meaning is constructed in the mind; uses language, is social and contextual; takes time and motivation and requires some knowledge to build new knowledge upon (Hein, 1991).

Constructionism

Another theory, deeply rooted in constructivist theory, is one referred to as constructionism (emphasis added). Like constructivism, constructionism is a theory of

learning based on the idea that people make meaning for themselves. Constructionism views learning as a reconstruction of knowledge, but extends the idea that learning is most effective when learner activities and experiences include constructing a meaningful product using manipulative materials (Sabelli, 2008). Papert coined the term when he referred to constructionism to emphasize people building knowledge structures, both mental and physical (Papert, 1993a). These knowledge structures are artifacts of the learning process, reflecting information and skills acquired by the creators, helping to better understand the world around them. By creating artifacts whether it is a multicolored house of LEGO bricks or a new mathematical theory, a learner appropriates content in a personal way, eliminating barriers between imagination and content (Papert & Harel, 1991). Papert's ideas on constructionism developed from his work with LOGO, an early child-friendly programming language, as well as his own personal experience with gears. In an essay, *The Gears of My Childhood*, Papert refers to this initial experience of tinkering with gears at an early age as the foundational knowledge upon which his new knowledge was built (Papert, 1993b). In his own words, Papert believed that Piaget's greatest life's work was his impression of idea development in children's knowledge systems, which are parallel to the ways ideas develop historically. Papert stated this process of progressively constructing knowledge is invisible and inferred through sampling of what children can do with developing ideas. He argued that the use of a computer could make "the process more visible both to the informed observer and to the children themselves" (Papert, 2000, p.5).

Sometimes referred to as a learning theory to support learning through making, Papert argues constructionism is more complex than the phrase suggests.

Constructionism includes both the structured models of creating with a plan in place, similar to an engineer, as well as the less structured negotiation of the creator and the work in progress, similar to a painter (Papert & Harel, 1991). In regards to education, constructionism encompasses eight big ideas: (a) students are learning by doing; (b) students are using technology as building material; (c) students are engaged and enjoy what they are doing; (d) students are learning to learn; (e) students have adequate time to explore and work; (f) students have the freedom to fail and do it again; (g) students observe adults struggle with learning; and (h) students access and use digital tools (Stager, 2006).

In her article, *Piaget's Constructivism, Papert's Constructionism, What's the Difference*, Edith Ackerman clearly identified the difference between the two theories:

Piaget's constructivism offers a window into what children are interested in, and able to achieve, at different stages of their development. The theory describes how children's ways of doing and thinking evolve over time, and under which circumstance children are more likely to let go of—or hold onto—their currently held views. Piaget suggests that children have very good reasons not to abandon their worldviews just because someone else, be it an expert, tells them they're wrong. Papert's constructionism, in contrast, focuses more on the art of learning, or 'learning to learn', and on the significance of making things in learning. Papert is interested in how learners engage in a conversation with their own or other people's artifacts, and how these conversations boost self-directed learning, and ultimately facilitate the construction of new

knowledge. He stresses the importance of tools, media, and context in human development. Integrating both perspectives illuminates the processes by which individuals come to make sense of their experience, gradually optimizing their interactions with the world (Ackerman, 2001, p. 1).

In both constructivism and constructionism, students are constructing meaning for themselves. However, Papert's constructionism focuses on meta-learning and the importance of dialogue around created artifacts as compared to the developmental learning roots of Piagetian constructivism.

Vygotsky's Social Constructivism

Lev Vygotsky, a Russian psychologist whose work was virtually unknown in the United States until the mid-20th century, was also interested in how people learn. Vygotsky believed socialization was central in the development of thought and language — the foundations for the theory of social constructivism. His views varied from Piaget's theories in the belief that learning could not be separated from its social context and knowledge is not just constructed but co-constructed through social interactions (University of California, 2014). He argued that language and culture were crucial elements in both how people view the world and develop intellectually (Vygotsky, 1978). From observations of children, he noticed language was a tool to problem solve; their speech and action acted as one unit. As the tasks became more difficult, the use of language became more important. He concluded that “children solve practical tasks with the help of their speech, as their eyes and hands” (Vygotsky, 1978, p. 26).

Vygotsky also identified two development levels for children, their actual development level and their potential development level. The actual development level of children refers to what children already know or are able to do and the potential development level refers to what children can do with the guidance of a more knowledgeable other. The distance between these two development levels are referred to as the “Zone of Proximal Development” (Vygotsky, 1978, p. 86). The zone defines those functions that have not yet developed but are in the process of developing and permits us “to delineate the child’s immediate future and his dynamic developmental state” (Vygotsky, 1978, p. 87).

Though Vygotsky never used the expression “scaffolding” as a metaphor to elaborate on his idea of the Zone of Proximal Development (ZPD), discussions link the word to the theories of Vygotsky (Stone, 1998). In an article by Verenikina (2003), the author shared the history of the term, scaffolding, as well as identifiable features, citing Wood, Bruner, and Ross (1976) and Wells (1999). Wood *et al.*, (1976) introduced scaffolding to explain a process in which a teacher controls elements of a task that are initially beyond the learner’s capacity, allowing the learner to accomplish the task. In operationalizing Vygotsky’s idea of ZPD, Gordon Wells identified three features within educational scaffolding: “1) the essentially dialogic nature of the discourse in which knowledge is co-constructed; 2) the significance of the kind of activity in which knowing is embedded and 3) the role of artefacts that mediate knowing” (Well, 1999, p. 12). While the metaphor for scaffolding, if interpreted literally, could imply that a learner is a passive recipient of a direct instruction approach from the teacher, it is important to think

of this term in regards to the learning philosophies of Vygotsky and Piaget, where the child is an active learner (Verenikina, 2003).

Conversations around the artifact become important for constructing knowledge. The teacher selects the artifact in social constructivism whereas the learner creates the artifact in constructionism. Vygotsky's theory of social constructionism supports Papert's constructionist approach. Artifacts in social constructionism are teaching tools to mediate knowledge. In constructionism, the learners create knowledge through a negotiation between themselves and their work in progress. Papert's theory includes the important components of conversation around artifacts created by the learner during the learning process as it relates to construction of knowledge. Vygotsky's theory focuses on important conversations around artifacts selected as a teaching tool for co-constructing knowledge.

Activity Theory

Activity theory is based on Vygotsky's idea of object-oriented action mediated by cultural tools as a unit of analysis (Vygotsky, 1978). Historically, it is used to discover artifacts and people within a dynamic activity system (Engestrom, 2004-2005). In activity theory, the unit of analysis is the activity, defined as an action performed within a situated context. The action is directed towards an object which is considered the goal of the desired outcome (Engestrom, 2001). The nature of the activity is determined by its object and noted the reversal of object and instrument in regards to traditional school learning (Engestrom, 1987). In reference to school activity, historically the tool of text is used with the motive of restating the text on written tests for the purpose of higher grades (Engestrom, Miettinen, & Punamaki, 1999). Miettinen's (1999) review of studies over a

30 year period supported this use of text through the practice of lecture driven, question and answer format in many classrooms. For Engestrom (1987), the object of genuine learning in school cannot be reduced to text but in societal productive practice. Examining the activity reveals activity theory's relationship to constructivist theories, including constructionism and social constructivism. In making this connection, Miettinen (1999) references the work by Dewey (1906) and Dewey and Childs (1933) in defining the organization of school work in two ways: First, an activity which is intellectually and practically united and, second, reproduces or runs parallel to work activities in which the contents are taught in reference to their social context of use.

For this study, activity theory provided a framework to contextualize the use of the *Can You Create a Game Challenge* as an instructional tool used for authentic instruction and to then connect authentic instruction and assessment to authentic learning. The desired outcome is authentic student learning from the use of a digital game challenge within authentic instruction. In the activity system, the teachers in the study used the *Can You Create a Game Challenge* as an assessment tool within instruction in order to arrive at the intended outcome of authentic learning. The mediating artifact facilitating interaction between the members of the community is the *Can You Create a Game Challenge* task. The theories of constructivism, constructionism and social constructivism support the pedagogical methods of authentic instruction used to present the *Can You Create a Game Challenge* and provide a scaffold for the interactions between the students and teacher.

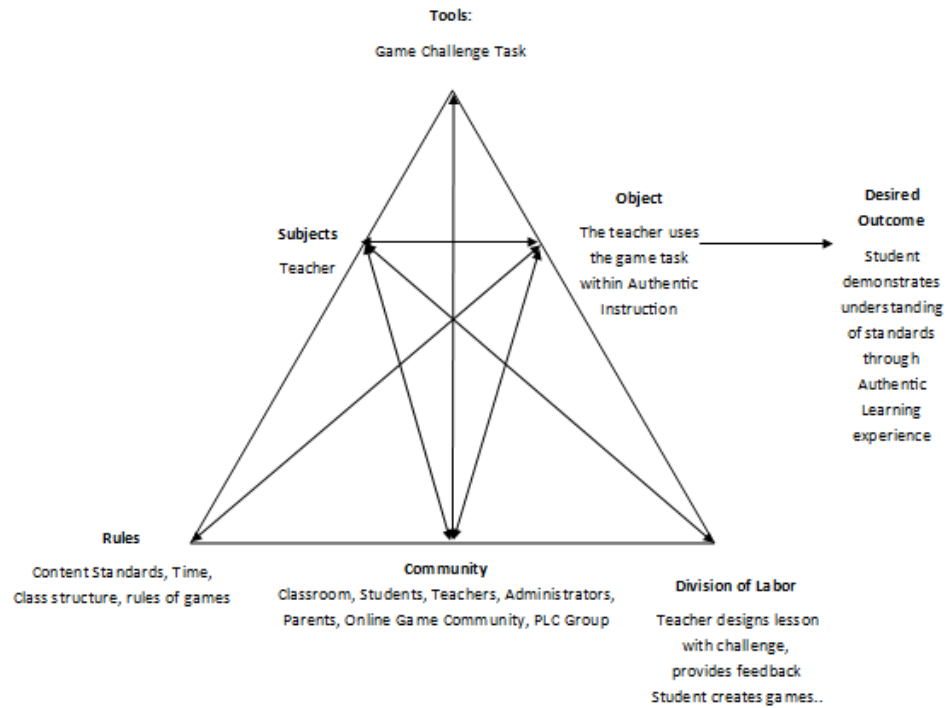


Figure 1. Activity theory framework for the use of the *Can You Create a Game* tool for instruction.

A metaphor of a three-legged stool connects the theories and shows how they relate to authentic learning. Imagine constructionism, Vygotsky's theory of learning (social constructivism) and activity theory as three supporting legs of the stool, all carved from a branch of constructivism. Papert's occupation of children as playing, thinking and learning offer the internal supports connecting the legs of the stool, reflecting the importance of creative exploration and artifact building which reflects real world work within an environment where community is promoted through sharing and discussion. Situated on top is authentic learning. While each theory provides support to authentic learning, the removal of one will cause the stool to wobble and become unstable.

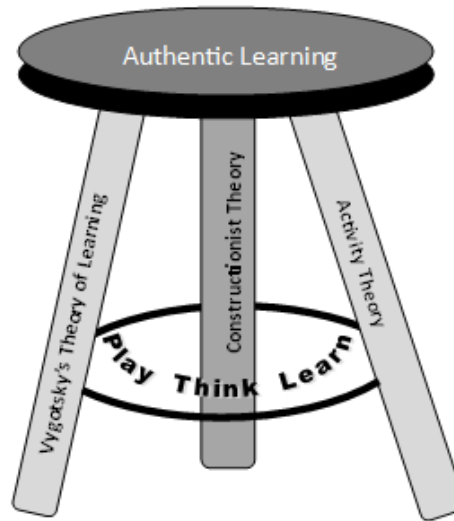


Figure 2. Three-legged stool metaphor for connecting theories.

Literature Review

Inquiry in Instruction

Children are naturally inquisitive. They ask questions and use trial and error techniques to learn about the world around them. Then, they change ideas based on what they have learned (Loucks-Horsley & Olson, 2000). While inquiry can refer to the way scientists study the natural world and propose evidence based explanations of their work, it also refers to classroom activities used to develop student knowledge and understanding of scientific ideas (Colburn, 2006). Learning through inquiry can empower students and provide them with skills and knowledge to be lifelong learners (Llewellyn, 2013). After Sputnik spurred the start of science education reform in the 1950s, educators used the term “inquiry” to form curriculum goals, design instruction and

assess learning (Chiappetta & Adams, 2004). Some teachers view inquiry as an instructional strategy to motivate students through hands-on activities, yet students need inquiry-based instruction to question phenomenon, to think logically and critically while becoming aware of the scientific way of knowing (Minstrell, Van Zee, & Science, 2000).

With constructivist roots, inquiry-based instructional approaches value student prior knowledge and experiences which provide an anchor for student construction of new knowledge and experiences. (Bransford, Brown, & Cocking, 2000; Llewellyn, 2013). John Dewey, an influential philosopher in modern education, recognized the importance of student knowledge and curiosity in learning (Crippen & Archambault, 2012). Because he felt the science instruction at the time did not provide meaningful connections for students between the content taught and the world around them, Dewey encouraged science teachers to use inquiry as a teaching strategy to actively involve the student while the teacher facilitated instruction (Barrow, 2006). In addition to Dewey, Joseph Schwab (1960) stated the importance of inquiry in science curriculum design including the need for educators to consider the science lab “lead instead of lag” the classroom phase of science teaching (p. 187). The work of Dewey and Schwab contributed to reform efforts in science education with their ideas of students doing science versus listening to lecture and the importance of students understanding the processes of science instead of just science subject matter (Loucks-Horsley & Olson, 2000).

Inquiry in Science, Technology, Engineering and Mathematics (STEM)

STEM, often defined as an acronym for science, technology, engineering and mathematics, also refers to “a standards-based, meta-discipline residing at the school

level where all teachers, especially STEM teachers, teach an integrated approach to teaching and learning; where discipline-specific content is not divided, but addressed and treated as one dynamic, fluid study” (Merrill, 2009, p.49). Over the last two decades, the National Science Education Standards have praised inquiry-based practices as key to science and mathematical learning (Borrego & Bernhard, 2011). Additionally, inquiry-based instruction provides teachers with a way to address today’s issues through a multidisciplinary STEM approach (Crippen & Archambault, 2012). In STEM education, students work to solve problems and apply knowledge through the creation of artifacts, that uses a cycle of inquiry to stress a continuation of process reflection and product refinement (Markham, 2011).

Next Generation Science Standards

A national push for a new science standards occurred in 2007 in order to address skills students needed upon graduation from high school to be college and career ready for the changing global workforce ("The need for new science standards," 2014). Designed to equip students with needed 21st century skills, the framework for the new science standards emphasizes an integrated approach to science and engineering instruction, including crosscutting concepts, disciplinary core ideas, as well as the practices needed for science inquiry and engineering design ("Appendix E: Progressions within the Next Generation Science Standards," 2014). By including both science inquiry and engineering design, the Next Generation Science Standards help clarify the relevancy of science, technology, engineering and math to everyday life for students ("Three Dimensions," 2014). Additionally, the types of inquiry activities classroom teachers used for science instruction lacked authenticity indicating a need for new

complex and cognitively demanding authentic inquiry activities for classroom instruction (Chinn & Malhotra, 2002).

The Next Generation Science Standards attempts to address this need to move instructional practices from simple inquiry to authentic learning experiences for students. It recommends asking students to actively participate in learning through tasks such as asking questions and defining problems; participating in sustained investigations over extended time; using math and computational thinking to analyze and interpret data in order to construct explanation or design solutions to real problems; and communicating information learned to a wider audience ("The need for new science standards," 2014).

Inquiry as Authentic Instruction

Inquiry-based instructional design, such as the 5E Biological Sciences Curriculum Study (BSCS) model supports authentic learning environments (R. Bybee, 2009; R. Bybee *et al.*, 2006). This model engages students with a real world, relevant question/task; allows for student exploration of content, including exploration as an individual and as a group; an explanation from a more knowledgeable other such as the need to answer student questions, clarify misconceptions and guide student learning; provides an opportunity for students to extend or apply the learning in a new context and formatively assesses students in each phase of instruction. While the 5E BSCS model does not dictate the form by which students demonstrate knowledge, a product or presentation is often used (R. Bybee, 2009). Since students are building a product, they are demonstrating knowledge structures as outline by constructionist theory, a branch of constructivism.

Authentic Learning

Within instructional design, there exists an interworking relationship among instruction, learning and assessment, referred to as constructive alignment. Biggs's theory of constructive alignment emphasizes the compatibility among instruction, learning and assessment for education (Biggs, 1996). Because of this relationship, authentic instruction, authentic learning and authentic assessment are aligned (Gulikens *et al.*, 2004).

In order to learn effectively and develop both confidence and competence, students need to have authentic learning experiences (Russell-Bowie, 2012). There are various definitions of authentic learning. Rule (2006) noted authentic learning included contexts that promote real life applications of knowledge. Similarly, Rockman (1995) views authentic learning as an approach to teaching and learning where students learn in the context of a real world problem rather than a lecture and a pedagogical approach that allows students to explore, discuss, and meaningfully construct concepts and relationships in contexts that involve real world problems. Donovan, Bransford & Pellegrino (1999) define authentic learning as projects that are relevant to the learner and Carlson (2002) describe it as pedagogy that values learner-centeredness, active learning and authentic tasks in which the learning experience takes place around real world situations. Newmann, Marks, and Gamoran (1996) defined authentic academic achievement through construction of knowledge, disciplined inquiry and value beyond school. Many researchers identify authentic learning through set criteria or specific components. As shown in Table 2, researcher criteria differ slightly, but most agree on

the components included in authentic learning: Tasks, processes, environment, roles of the teacher, products and assessments.

Table 2

Summary of researchers' articulations of criteria for the components of authentic learning

Authentic Learning Criteria	Source
Student Task Authentic and challenging; student centered; interdisciplinary; real world relevance; ill-defined problem; connectedness to the world; higher order thinking is central	(Callison & Lamb, 2004; Herrington, Oliver, & Reeves, 2003; Lombardi, 2007; Maina, 2004; Newmann & Wehlage, 1993; Renzulli, Gentry, & Reis, 2004)
Process Sustained investigation; allows for collection of data; multiple sources and perspectives; students practice advanced skills; multiple interpretations and outcomes; students as scientific apprentices; depth of knowledge	(Callison & Lamb, 2004; Herrington <i>et al.</i> , 2003; Lombardi, 2007; Means & Olson, 1994; Newmann & Wehlage, 1993)
Environment Learning takes place in meaningful situations; work takes place in heterogeneous, collaborative groups; learning occurs over extended time, flexible use of time; substantive conversations; social support for student achievement	(Herrington <i>et al.</i> , 2003; Lombardi, 2007; Maina, 2004; Means & Olson, 1994; Newmann & Wehlage, 1993)

Table 2 (*continued*)

Authentic Learning Criteria	Source
Role of the Teacher	(Means & Olson, 1994)
Teacher is the coach	
Products	(Archbald & Newmann, 1988;
Designed for a real audience; polished; solutions to change people's attitudes, beliefs or actions; include production of discourse, things, performances	Herrington <i>et al.</i> , 2003; Lombardi, 2007; Renzulli <i>et al.</i> , 2004)
Assessment	(Callison & Lamb, 2004; Herrington <i>et al.</i> , 2003; Lombardi, 2007)
Integrated; authentic; includes student reflection; leads to lifelong learning	

In addition, Rule (2006) identifies four themes from a qualitative analysis of 45 journal articles which align with the findings above:

1. The activity involves real world problems that mimic the work of professionals in the discipline with presentation of findings to audiences beyond the classroom.
2. Open-ended inquiry, thinking skills and metacognition are addressed.
3. Students engage in discourse and social learning in a community of learners.
4. Students are empowered through choice to direct their own learning. (p. 2)

While the majority of the research on criteria for authentic learning focuses on environment, task, product and assessment, the findings lack the explicit inclusion of the tools students need to scaffold experience for 21st century learning. The inclusion of technology within authentic learning allows the extension and enhancement of student products, makes complex assignments seem feasible and provides an entry point to

content areas and inquires that might otherwise be inaccessible until much later in school or work (Means & Olson, 1994).

The Gulikers *et al.*, (2004) general framework for authentic assessment identifies three foundational pieces to authentic learning: (1) authentic instruction, including authentic learning task, authentic learning context, social learning context and epistemology/didactic form; (2) perception of authenticity by the student and (3) authentic assessment.

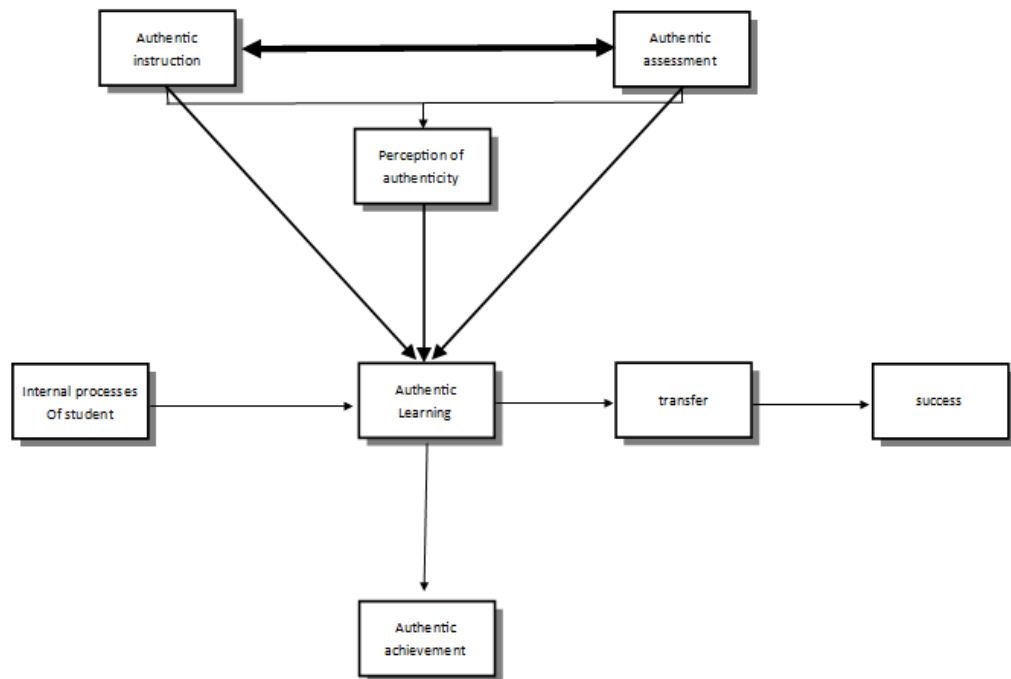


Figure 3. Guliker, Bastiaen & Kirschner's Framework for Authentic Assessment (2004, p. 70)

Constructivist theory supports the criteria with authentic learning environments. The teacher assumes the role of a guide, who leads students to learning while students construct meaning through real world, challenging problems.

Authentic Learning Environment

The environment is an important element within authentic instruction. Teachers use collaborative learning as an education approach to learning by creating assignments for groups of students to work together to solve a problem, complete a task or create a product (Hmelo-Silver, 2004). Typical assessments in school focus primarily on what a student can accomplish independently, while outside of school achievements depend on questions, feedback and help from peers and authorities (Archbald & Newmann, 1988). Collaboration is social and occurs naturally in learning situations, with learners talking among themselves to share information and ideas, perspectives and wonderings. In both scenarios, it is through talk that learning occurs (Emary, 2012). Gulikers *et al.*, (2004) stated the social context of the learning environment is important to support the authenticity of instruction, noting that the use of collaboration should be implemented in assessment if it reflects how one would complete the task in the real world. The task and learning environment should reflect an age appropriate equivalent of real social processes, including both group and individual components as expected in the real world outside of the classroom. Teamwork is a skillset identified for a game designer because of the necessary collaboration with computer programmers, artists, animators, audio engineers and producers on a given task (CreativePool, 2012). The ability to communicate and work with others to achieve a common goal or solution is a computational thinking disposition that reflects the collaborative work of computer

programmers (ISTE, 2011). In the current study, students completing the *Can You Create Game Challenge* using Scratch software explored the roles of a game designer and a computer programmer within a collaborative learning environment.

The physical space for the classroom can enhance learning as well by supporting the ease of collaboration, movement of students and access to resources needed.

Ritchhart (2015) notes three areas to consider when designing space for optimal learning environments:

1. Flexibility: Classroom furniture is easy to move, accommodating and allows the teachers and students to reconfigure the space as needed quickly, without the assistance of outside help (p. 251). If flexibility of space is not an option for teachers, then rooms might be set up to facilitate project work, dialogue or lectures (p. 252).
2. Zones: Zones are clearly defined areas of a classroom designated for different activities. A teacher may have a rug for a reading area, tables arranged for group work and small, quiet areas for independent study (p. 252).
3. Movement: Students need to be able to move within a space in order to avoid fatigue and muscle strain. Furniture in classrooms should be adjustable to accommodate various heights of students. Chairs with tilting backs can provide small movement for students without risk of injury (p. 253)

Assessment

Assessment is defined as “the ongoing process of gathering and analyzing evidence of what a student can do” (Burke, 2009, p.3). Assessment and feedback are crucial components of learning, providing teachers and students with information needed

to effectively inform instruction while measuring progress toward learning goals (Bransford *et al.*, 2000). Types of assessments vary depending on what a teacher is trying to measure and how the teacher intends to use the results, including diagnostic, formative, summative, criterion referenced, norm reference and interim for benchmarking purposes. Students may have to demonstrate understanding through answering multiple choice questions, writing papers or performances. The methods of assessment in schools are typically based on beliefs about teaching and learning (Burke, 2009). Traditional views of assessment include objective tests or essay writing following instruction where the teacher is the sole assessor, criteria is not transparent and results are used in a summative manner (Strijbos, Kirschner, & Martens, 2004). Newer views of assessment see them as instructional, a way to help students learn how to learn, to allow for ‘do overs’ and to be differentiated for students so that assessments are formative in nature and help teachers improve their teaching (Burke, 2009; Wiggins, 1989a). Authentic assessments in the form of projects, performances and tests are valuable, not only for evaluation purposes but also, as a guide to focus and inspire teaching and learning (Archbald & Newmann, 1988).

Authentic Assessment

Grant Wiggins (1989b) originally defined authentic tests, in reference to mathematics, within an article for Kappan, as tests which are (a) representative of challenges within a given discipline; (b) designed to emphasize realistic but fair complexity; (c) stress depth more than breadth; (d) and must necessarily involve somewhat ambiguous, ill-structured tasks or problems. Later definitions focused on the similarity of thinking required in the assessment and the real life situation. Darling-

Hammond and Snyder (2000) asserted assessments should require students to integrate skills and knowledge used in the practice being assessed, including multiple sources of evidence collected over time. Savery and Duffy (2001) noted the importance of student self-reflection as part of authentic assessment, including an evaluation of resources used and student application of what they have learned in re-examining the problem.

Additional techniques used for authentic assessment, including portfolios or dramatic performances, are not viewed in isolation from instruction but instead are intertwined with the curriculum and happen when teachers engage children in intellectual challenges (Noori, 1993). The alignment of learning, assessment and collaboration reflects the social-constructivist view of assessment (Strijbos *et al.*, 2004).

To define authentic assessment, Guliker, Bastiaens & Kirschner (2004) identified five dimensions which vary in their level of authenticity (a) the assessment task, (b) the physical context, (c) the social context, (d) the assessment result or form and (e) the assessment criteria. The Guliker, Bastiaens & Kirschner framework, as well as criteria established by other researchers regarding authentic assessment, support these dimensions (see Table 3).

Table 3

Supporting Research for Authentic Assessment Criteria

Five Dimensions for Authentic Assessment (Gulikers <i>et al.</i> , 2004)	Supporting Research	Social Constructivist View (Strijbos <i>et al.</i> , 2004)
<i>Assessment Task</i> Realistic/real world; cognitively demanding;	(Ashford-Rowe, Herrington, & Brown, 2014; Frey, Schmitt, & Allen, 2012; Wiggins, 1989a)	Challenging and collaborative task; elicits thinking and understanding

Table 3 (continued)

Five Dimensions for Authentic Assessment (Gulikers <i>et al.</i> , 2004)	Supporting Research	Social Constructivist View (Strijbos <i>et al.</i> , 2004)
<i>Physical Context</i> Promotes discussion and feedback, collaboration; realistic	(Ashford-Rowe <i>et al.</i> , 2014)	Both individual and collaborative learning; is dynamic and ongoing process embedded in instruction
<i>Social Context</i> Students collaborate with each other and/or the teacher; student present work and publicly defend it	(Ashford-Rowe <i>et al.</i> , 2014; Frey <i>et al.</i> , 2012; Wiggins, 1989a)	Collaborative learning
<i>Assessment Result/Form</i> Product or performance based, mastery of content	(Ashford-Rowe <i>et al.</i> , 2014; Frey <i>et al.</i> , 2012)	Both learning processes and products
<i>Assessment Criteria</i> Formative; Students are informed of the assessment criteria or help design it and teachers give attention to the teaching/learning of the criteria; includes student self-assessment; multiple indicators or portfolio	(Frey <i>et al.</i> , 2012; Wiggins, 1989a)	Expectations made clear to students with explicit criteria and rubrics to scaffold student learning and collaboration. Students play active roles in assessing their own work and peers' work.

Activity theory fits within Gulikers *et al.*, (2004) general framework for authentic assessment. As teachers mediate the *Can You Create a Game Challenge* task as a tool within authentic instruction, the expected outcome is student authentic learning. If the *Can You Create a Game Challenge* is an authentic assessment task and the community views it as authentic, then the Guliker framework supports the theory that it leads to authentic learning. The internal processes of the learner, mentioned in the Guliker framework are developed and nurtured through the use of instructional design based on

Vygotsky's theory of learning, constructivism and constructionism. I placed the Guliker framework as an overlay to activity theoretical framework (see Figure 4).

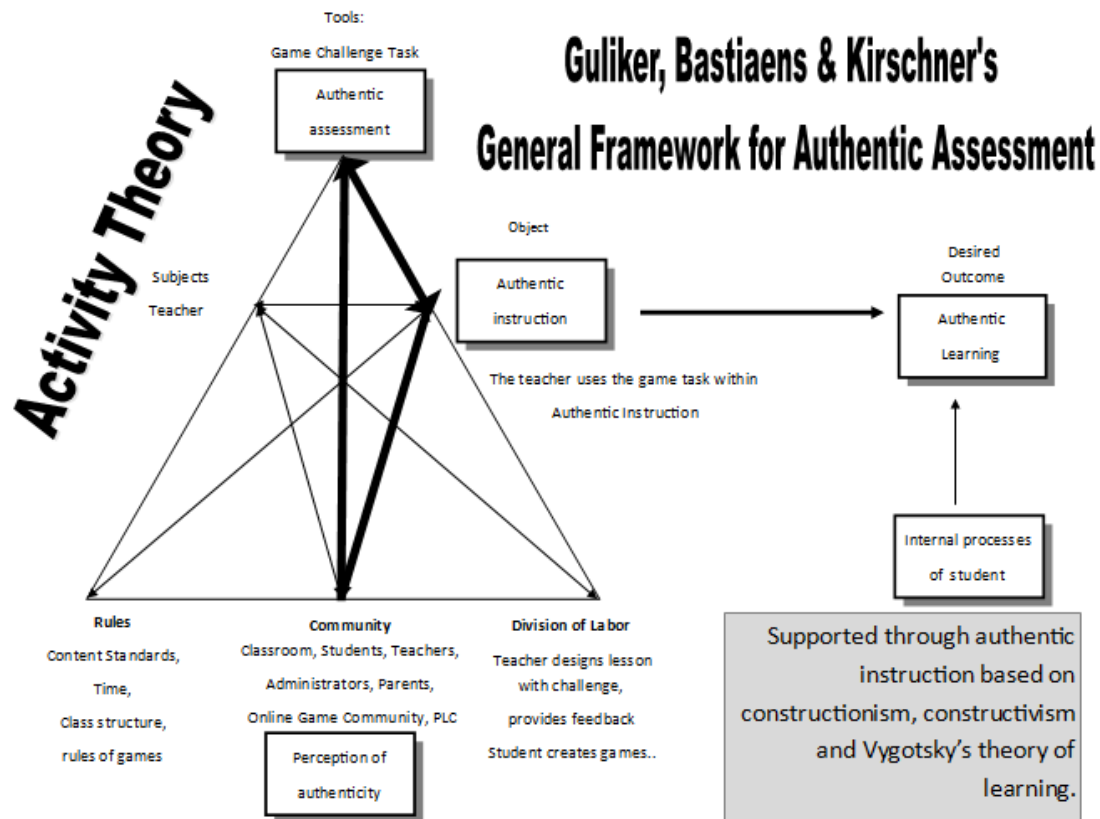


Figure 4. Activity theory framework in conjunction with Gulikers *et al.*, (2004) general framework for authentic assessment

Game Design

Mark Prensky (2007) identified eleven design elements that can be found in computer and video games which keep people engaged:

- a clear overall vision
- a constant focus on the player experience

- a strong structure
- highly adaptive
- easy to learn, hard to master
- stays within the flow state
- provides frequent rewards, not penalties
- includes exploration and discovery
- provides mutual assistance, one thing helps to solve another
- has a very useful interface
- includes the ability to save progress (p. 135)

In addition, Prensky suggests the unique combination of these elements sparks our creativity, adrenaline, ego gratification, emotion and learning while maintaining structure, flow and enjoyment (p. 106). A good game captures a player's attention and keeps them playing until the end. This engagement relates to the design features of a great digital game.

A game is a system in which players interact, and engage in artificial conflict defined by rules that result in a quantifiable outcome (K. Salen & Zimmerman, 2004). In addition to goals, rules and interactivity, games have players, objectives, resource/resources management, game state, information, sequencing, theme/narrative/backstory/setting (Schreiber, 2009). Games are typically designed based on a game style which include, but are not limited to, game shows, action, sports, role-play, adventure, multiplayer interaction, puzzles, strategy, timed, reflex and invention (Prensky, 2007). Game design also takes into consideration game mechanics such as achievements, reward schedules, guessing, tile laying, combinations and risk.

Digital game designers use learning principles and techniques. Prensky's (2007) list of interactive learning techniques include practice and feedback; learning by doing; learning from mistakes; goal-oriented learning; discovery and guided discovery learning; task based learning; question led learning; role playing; coaching; constructivist learning; multisensory learning; selecting from learning objects and intelligent tutoring (p. 157). Gee (2007) identified four learning principles that are built into good video games and relevant to learning in content areas

- distributed principle or how knowledge and meaning is distributed throughout a game;
- dispersed principle or how a learner shares knowledge and meaning with others outside the game;
- affinity group principle of how a group is bonded through shared goals and practices;
- the insider principle where the learner is the producer and able to customize the learning experience.

While all of Gee's principles relate to game design and learning from a player perspective, they can be principles for game design from a designer perspective as well.

Game Design and Constructivist Theory

Winn (2002) offered the idea of four ages for education technology (a) the age of instruction, (b) the age of message design, (c) the age of simulation and (d) the current age of learning environments. This move toward learning environments offers an alternative to the traditional factory model of education where students are doing the same assignments at the same time (Dickey, 2006a). Research shows educational games

may enhance existing curriculum and materials as well as provide strategies for the design of educational media and interactive learning environments (Dickey, 2005a).

Dondlinger (2007) analyzed constructivist and constructionism learning theories found in articles on educational video game research in a review of the literature. The findings included:

- Learning with well-designed video games followed constructivist principals. (Dede, Nelson, Ketelhut, Clarke, & Bowman, 2004; Dickey, 2005b, 2006b; Gee, 2007; Schrier, 2006)
- Constructionist theory supports children learning through game design and development. (Robertson & Good, 2005; Robertson *et al.*, 2004)

The research on children as game designers encompasses the principles of constructionism. El-Nasr and Smith (2006) noted two activities in using game design for learning which align with constructionist theory. These were the construction of knowledge through experience and the creation of personally relevant products. The design, process and product are meaningful to the creator and learning is both active and self-directed through the construction of the piece.

Student Authored Digital Games

Games are tools that teachers often use as part of instruction. From playing a quick round of spelling baseball to Scrabble, games are great for transforming a simple drill and skill task to an activity that is fun and competitive. Games promote many skills students need to develop such as collaboration, communication, strategic thinking and problem solving. Since the development the computer and video game systems, interest has grown in the use of these new types of games for training purposes and learning

across all age levels. Endeavors such as the game, FoldIt (<https://fold.it/portal/>), are using the skills of game players to solve problems in areas such as medicine that scientists have been working on for years (Moore, 2011). Games such as Darfur is Dying (<http://www.darfurisdying.com/>) and iCivics (<https://www.icivics.org/>) work to bring about social awareness and change through awareness made by playing games (iCivics.org, n.d.; mtvU, 2009). Many books and articles, published recently, address the importance of including digital games in the classroom, offer suggestions of ways to connect them and share research supporting positive results when used for the purpose of learning. In addition, schools, such as Quest to Learn in New York ("Quest to Learn," 2016) and Minds on a Mission in Chicago ("Minds on a mission: Chicago quest schools," 2016), along with Playmaker in California ("Playmaker school," 2012) have curriculum and structures based on games and game principles.

A new area of game-based learning is student created digital games. This category of game-based learning has emerged from the development of free or low cost digital game authoring software programs, programming language tutorials and apps designed for children. In addition, organizations such as the Learning Games Network and Games for Change are working with schools and youth organizations to promote game making in after school environments ("Games for change," 2014; "Learning games network," 2014). Students at Bryan Station High School and Lafayette High School in Lexington, KY designed games for a competition as part of an after school program called the Student Technology Leadership Program ("STLP Kentucky," 2016) and won the opportunity to work with members of the Learning Games Network at the Massachusetts Institute of Technology in Boston, Massachusetts (Schools, 2011, 2014).

Students in the sixth grade at the Playmaker school in California worked on teams to design and develop the spy adventure video game “Gold Medallion.” Students coded, conducted beta testing, created a website, a commercial and an Instagram feed, as well as incentives to get people to play (Brown, 2014). While students, organizations and schools are promoting student created digital games, there has been little research conducted on the educational benefits of this movement, especially regarding a direct connection to classroom content standards.

Seymour Papert and Wally Feurzeig developed LOGO programming language in the late 1960s for the purpose of creating a “mathland” where kids could play and explore with words and sentences. Papert (1993b) became interested in the potential educational impact of this new tool, especially the Turtle Graphics which allowed a user to program a small retractable pen to create graphics. He found that students who played in the LOGO programming environment acquired new ideas and personal relevance to traditional school problems. In order for students to be able to program the computer to draw a square, they needed to explore turning at each vertex leading to an applicable understanding of angles and their relationship to shapes. Because teachers and students were both learning how to solve problems in this environment that neither had experience with before, this situation allowed for a true collaborative effort. A student could see how an adult thinks through a problem with an unknown solution. It was the experiences of watching children build knowledge through programming in LOGO that led to Papert’s (1991) theory of Constructionism.

Students of Papert researched computer game design as a context for learning. Idit Harel (1988) investigated how elementary students could use LOGO to develop an

understanding of fractions. Her work, called the Instructional Software Design Project, involved fourth grade students attending a MIT project school in Boston. These students learned fractions and LOGO programming software over a four month period. Two classes of students in the study participated in Integrated LOGO programming, a project based approach integrating LOGO into curriculum, with one class working on isolated LOGO consisting of learning to program with no project in mind, just short tutorials. Harel gave students in the Software-Design-LOGO treatment group the task of designing a fractions game for a younger student. Her findings from the study included: (a) students who used LOGO to create a fraction game performed significantly higher on a post fraction test than peers receiving traditional instruction on fractions, (b) students in the treatment became better programmers than students in the other two groups, and (c) the importance of the designer's notebook as tool for students in the development of their digital games. The designer's notebook provided enhancement to planning, reflection and other metacognitive and cognitive control skills (Harel, 1988, 1991). One suggestion from the study included the integration of other subjects into this instructional software design as well as the need for future research. A significant point mentioned in the results regarded the importance of the classroom teacher's experience with both the philosophies of teaching and learning as a project school and the close collaboration with the researcher on the project. Harel doubted the study could be replicated at a different site. Unfortunately, she did not create curriculum materials making it nearly impossible for other educators to use this model in their classroom (Harel, 1988).

Yasmine Kafai (1995), a student of Harel, continued to investigate the Instructional Software Design project, but through the lens of design and the acquisition

of programming skills taking it a step further. Kafai called the program the Game Design Project. Working with fourth grade students at the same project school as Harel, the research focused on students as game designers, how students approached designing a game, and how students changed those designs over the course of a project. Kafai also investigated how students developed knowledge of fractions and programming language through game design. She found that students were able to handle the task of designing a game while significantly improving their knowledge of LOGO programming and fractions in the process. Students were very engaged in the project and continued to work on their projects for six months, especially enjoying the ability to create graphics, characters and story for their game. The Game Design Project allowed for students' personal interests and styles of thinking, learning and designing. The use of student created digital games in the classroom promoted not only a rich and complex learning environment but a learning culture as well. Students faced similar problems in designing and programming their games and could work alone or in collaboration with others. Kafai found the use of a game task had considerable impact on student learning and thinking but cautioned about task complexity. In comparison to Harel's research, Kafai found that programming tools incorporated into the instructional design instead of just game design led to a richer and deeper incentive for students to think through and create representations of fractions (Kafai, 1995). While Kafai's research strongly supports the use of a game task for mathematical learning, game design and programming at the elementary level, it also was not easily replicable for classroom teachers. There are many dimensions to Kafai's research that make it difficult to replicate. Many teachers lack familiarity with programming languages designed for children, struggled with how to

connect the programming software to content standards, could not manage the length of time devoted to the project or had an accessible, efficient way to assess the final game product.

In an additional study by Kafai and Yarnall (1996), fifth grade students created a game to teach younger students about the ocean environment. The findings from this study support Kafai's earlier research on the use of LOGO game authoring software for the development of student content knowledge and programming skills. Kafai, Ching & Marshall (1997) used LOGO to research student created interactive media to examine the design process on the development of student content knowledge on astronomy and programming skills. The results concluded that student development of multimedia was a rich context for concurrent learning of science, programming and collaboration. While the product analyzed in this study was not a digital game, there exist similarities including student design, student programming, and connection to content and social learning. As with previous studies, the teachers participating in the project were well versed in LOGO programming as well as the teaching and learning philosophies of the media lab at MIT.

Since Papert, Kafai and Harel's research was conducted after the development of LOGO, the focus on game based learning moved toward the development of commercial Edusoftware and the use of free or commercial games as a vehicle for student motivation, drill and skill of content, exploration of ideas and communication. LOGO software had an impact on the development of future tools for game construction and student friendly programming environments. The creation of the LOGO software for children provided a foundation for the development of block based programming languages used in Scratch,

LEGO robots, and several apps available for Apple and Android devices ("LOGO history," 2015). The simple drag and drop structure in block based programming languages allow children to easily design, create and explore with code. Several studies conducted on the use of game authoring software with children focus on after school programs and students who are of middle, high school or college age (Denner, Werner, & Ortiz, 2012; Repenning, Webb, & Ioannidou, 2010; Touretzky, Marghitu, Ludi, Bernstein, & Ni, 2013). Other studies examined the use of game authoring software and narrative development (Good & Robertson, 2004; Navarrete & Minnigerode, 2013; Robertson & Good, 2004, 2005; K. Salen, 2007); game authoring software and design (Navarrete & Minnigerode, 2013; Robertson & Howells, 2008; K. Salen, 2007); student acquisition of specific content through game development (Baytak, Land, & Smith, 2011; Calao, Moreno-Leon, Correa, & Robles, 2015); and a comparison of student motivation between student digital game development and student game play for learning (Vos, van der Meijden, & Denessen, 2011). In addition, several studies examine how student created digital games support the acquisition of computer science skills and computational thinking (Denner *et al.*, 2012; Johnson, 2014; Repenning *et al.*, 2015; Seiter & Foreman, 2013; Wilson *et al.*, 2012).

Student Digital Games and Computational Thinking

Wing (2006) introduced the idea of computational thinking suggesting it crossed all disciplines and are needed skills for the 21st century workplace. Computational thinking is the thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an

information-processing agent (Cuny *et al.*, 2010). It includes the dimensions of computational concepts, computational practices and computational perspectives (Brennan & Resnick, 2012). Organizations such as the Computer Science Teachers Association (CSTA), as well as universities such as Carnegie Mellon and Massachusetts Institute for Technology (MIT) have worked to develop resources for classroom teachers to better understand and teach computational thinking skills within the classroom ("Center for Computational Thinking," 2012; "Computational thinking with Scratch: Developing fluency with computational concepts, practices and perspectives," 2012; "CSTA Computational thinking taskforce," 2009). The International Society for Technology Education (ISTE) computational thinking toolkit and example lesson plans provide educators with some basic information on this emerging field and support classroom teachers who have no formal background knowledge in computer science (ISTE, 2011).

When considering how best to connect computational thinking to K-12 curriculum, researchers are examining how these skills connect to other STEM initiatives surfacing used in schools such as game-based learning. In the after school iGame project, middle school girls explored computational thinking through designing, programming and testing created games using Alice (<http://www.alice.org>), a free game authoring software from Carnegie Mellon (Lee *et al.*, 2011). Research conducted by Repenning *et al.*, (2015) examines the use of a program called Agent Sheets to develop a scalable game design program for the purpose of bringing computational thinking to the classroom.

Researchers also examined how the use of Scratch software to create digital projects, including games, supports the development of computational thinking skills in

children. The Progression of Early Computational Thinking (PECT) framework for understanding and assessing computational thinking skills in primary grades examined 150 student Scratch projects from teacher galleries posted on the Scratch website to gauge at what age certain computational thinking skills begin to surface (Seiter & Foreman, 2013). While this model provided a lens as to the types of programming children are using at different primary grades, the study included plans to conduct additional research with enough student projects for reliability and validity. A framework developed by Brennan and Resnick (2012) included three dimensions in assessing computational thinking in students using Scratch: Computational concepts, computational practices and computational perspectives. In addition, Brennan and Resnick suggested student assessment of computational thinking include project portfolio analysis, artifact-based interviews and design scenarios, noting this process takes time which may be a burden to educators. Moreno-Leon and Robles (2015) developed the Dr. Scratch software to easily analyze computational thinking skills within a Scratch project. Dr. Scratch automatically assigns a computational thinking score to uploaded projects in terms of abstraction and problem decomposition, parallelism, logical thinking, synchronization, flow control, user interactivity and data representation. While the examination of a single project may be limiting regarding the computational thinking skills a student possesses, the project provides a set of Scratch blocks typically used in each level of development for each computational thinking concept.

However, as Tyack (1990) has asserted assessment drives instruction. Until computational thinking is a set of knowledge and skills included in state mandated

curriculum and assessed as part of high stakes testing, educators and administrators will place the inclusion of activities designed to support the development on the backburner.

Can You Create a Game Challenge

The *Can You Create a Game Challenge* is a task designed around the occupations of children and grounded in constructivist, constructionist as well as social constructivist theories (Mazur & Prater, 2012; Prater & Mazur, 2014a, 2014b). By creating a game challenge based on content standards, teachers frame a set of “rules” for the task. When a player takes on and adopts these rules and agrees to follow them, play happens. Play is viewed as the opposite of rules, one being uncertain and improvisational while the other closed and fixed, however, in a game they find a common home (Zimmerman, 2007). Through the use of game authoring software, students are able to “play” and explore concepts in a realistic environment where they are free to make mistakes, try ideas and ask questions. The use of virtual blocks allows students to build a program and make a playable game. The use of constraints promotes creative problem solving and challenge students to “think” about new information, seeking the assistance of a more knowledgeable other to overcome hurdles in the learning process. This cycle of exploration, questioning and information-seeking leads to meaning making for the student. These theories also support the criteria for authentic learning for students in education.

The *Can You Create a Game Challenge* task consists of four parts: the deconstructed standard; the design constraints, design plan, and the student reflection. Teachers connect the knowledge and skills listed in the deconstructed standard that students need to demonstrate to either software mechanics or game structures. The

teachers translate these connections to the game task as game constraints, questions in the student game design plan or reflection. Complete information on the *Can You Create a Game Challenge* is in Appendix A. To assist teachers in thinking differently about how to use a game challenge as assessment, I created an accompanying flow chart (see Figure 5).

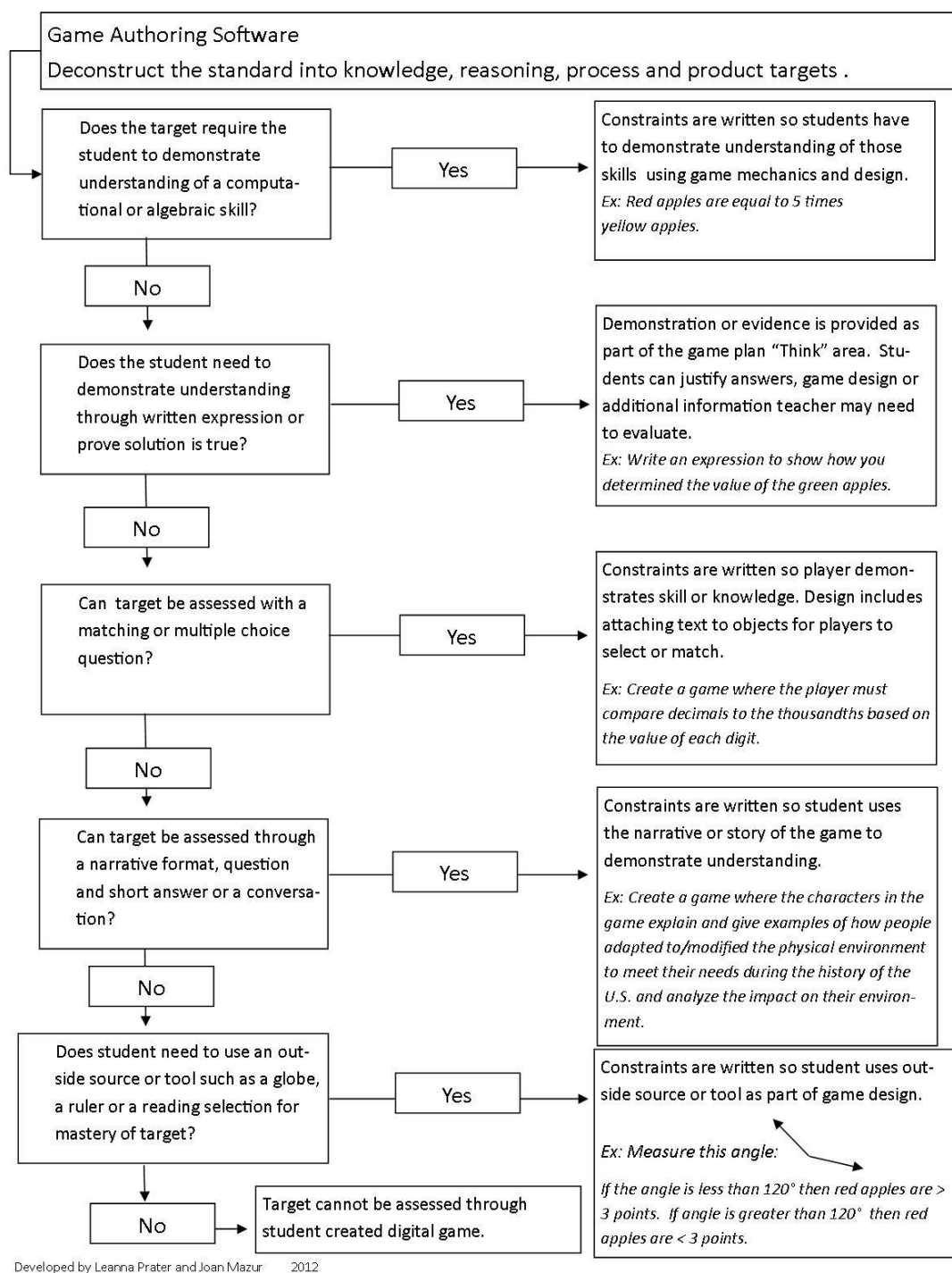


Figure 5. Flow chart for creating a *Can You Create a Game Challenge*.

Teachers begin with the deconstructed standard and consider how they would normally assess the components. The flow chart suggests ways in which a teacher can alter the traditional form of assessment to include in a game challenge. As teachers work through the flow chart, they may find that some standards are not well suited for inclusion in a game challenge. In addition, teachers design a rubric for assessment of student created game, specifically noting the standards included as part of assessment.

I conducted an initial pilot of the *Can You Create a Game Challenge*, presented at the Massachusetts Institute of Technology Scratch Gaming conference, with fourteen middle school students in a small rural school in the south central United States (Mazur & Prater, 2012). The pilot focused on the game task usability by students. Selected students had at least one semester of Scratch software programming prior to the task assignment. I designed tasks based on elementary Common Core math standards with the intent of avoiding math content struggles. Students could use resources available, including the web and classmates to complete the task. Students complete the game challenge with the given constraints, developed plans and reflected on the process. Feedback from the students and the classroom teacher included structure of the task, difficulty level and overall thoughts. Findings from this pilot include a fifty percent completion of the game challenge by the class, students struggling with the math content and variations of game genres among the completed games (Mazur & Prater, 2012; Prater & Mazur, 2014b). Using the new Common Core math standards to create the game challenge was a possible cause for student difficulty. The year I conducted the pilot was the first year students received instruction using the new standards providing the possibility of gaps in instruction.

To determine if students could complete a game challenge aligned to Common Core at the appropriate grade level, two elementary schools in the south central region of the United States participated in a second pilot. The schools selected different game authoring software to use, but both provided some basic instruction on how to program in the software prior to assigning the game challenge. Students in school A used the game challenge with Scratch, as part of an after school enrichment program while students in school B used KODU during a computer lab special class. Both schools implemented the game challenge after students received instruction on the content in the regular classroom. Findings from this pilot included the student use of modifications to existing games to fit game constraints and some introduction of computational thinking skills (Prater & Mazur, 2014a, 2014b).

A different elementary school special area STEM class, located in the south central region of the United States, served as the location for a third pilot, focusing on teacher game challenge development and implementation. The classroom teacher developed the game challenge on the topic of caves, using the Next Generation Science Standards as constraints for the task. The teacher introduced the task at the beginning of the unit. Students received basic instruction on Scratch programming prior to the game challenge assignment. Findings included students actively researching content for the game, asking classmates questions about programming and the use of features such as paint in the Scratch program to create graphics needed for the game (Prater & Mazur, 2014a, 2014b).

Initial use of the *Can You Create a Game Challenge* task suggest students can successfully create a game based on specific content standards using different game

authoring software. One teacher successfully constructed a game task and used the task with students. Teachers chose to implement the game challenge for different purposes within an instructional unit, indicating a need for additional research to determine if the game challenge is appropriate as an authentic form of assessment as well as how teachers use self-created content based game challenges within authentic instruction (Prater & Mazur, 2014b).

Conclusion

The conceptual framework and literature cited provide the theoretical lens for the inquiry and analysis of the study. The methodology described in Chapter Three presents the case method design, data analysis and procedures for the study.

Chapter Three

Methodology

In this embedded single-case study of elementary STEM teachers and the intermediate (4th or 5th grade) classes they teach in a large, south-central United States city, I examined the use of a teacher created, standards-based digital game based challenge and the student-authored games produced in a classroom setting. The goal of the study was to examine how teachers implemented the game challenge and how it affected classroom instruction, assessment and students' engagement.

The central research question for this study is:

1. How do elementary teachers use a game challenge specifically aligned with Common Core/Next Generation Science (NGSS) state standards for instruction?

Supporting questions for this investigation were:

2. How does the teacher's use of a digital game based challenge work as an assessment of elementary students' understanding of Common Core/Next Generation Science state standards?
3. How does the specifically designed game challenge affect other dimensions of classroom instruction, assessment and students' engagement?

Research Design: Embedded Single Case Study

Yin (1994) defined a case study as “an empirical inquiry that investigates a contemporary phenomenon within its real life context, especially when the boundaries between phenomenon and context are not clearly evident” (p. 13). Yin’s definition of case study, viewed in terms of the research process, differs from Merriam (1998) who defines a case study in terms of the end product. “A qualitative case study is an intensive holistic description and analysis of a single instance, phenomenon or social unit” (p. 27). Whether the researcher is examining the process or the end product, the defining characteristic of a case study is the case itself which is a unit with a boundary that the researcher studies and could include a child, a classroom or an innovative program (Merriam, 1998). Case studies are useful for educational research because they communicate directly with the implementers, relate clearly to daily experiences and allow for manageable aspects to be examined closely (Shaw, 1978). This case study is descriptive, seeking to reveal patterns and constructs in relation to theory; illustrating the people, places, processes and events happening without judgments (Tobin, 2010; Yin, 1994).

The phenomenon in this case is the elementary STEM teacher’s use of a game challenge within the context of actual classroom instruction. Studies suggest the use of game authoring software in the classroom leads to student learning of content and skills in design and programming. However, there is a lack of research that supports a replicable framework for teachers connecting a game task based on mandated state standards to authentic student learning. Multiple variables in the proposed study exist,

such as the teacher's knowledge of game authoring software, years of experience as a teacher, age, knowledge of authentic instruction and the manner in which classroom teachers design instruction. The study used multiple sources of evidence including classroom observations, interviews with teachers, student written reflections of the task and completed student digital games to answer the proposed questions.

Merriam (1998) identified three characteristics of a qualitative case study, (a) particularistic or focused on a particular situation, event, program or phenomenon; (b) descriptive, in terms of the end product being a thick description of the phenomenon studied; and (c) heuristic, illuminating the reader's understanding of the phenomenon. In addition, she notes three reasons why a research selects a case study over another research method:

- Case studies help answer “how” and “why” questions (Yin, 1994).
- Case studies are well suited for studying process (Reichardt & Cook, 1979).
- Case studies are essential for understanding the range or variety of human experience, including the upper and lower boundaries of the experience (Abramson, 1992).

The nature of this case study fits the criteria Merriam outlines in Table 4.

Table 4

Merriam's Case Study Criteria and Research Questions

Merriam Case Study Criteria	Research Study
Answers “how” and “why” questions	<p>Research questions:</p> <p>How do elementary teachers use a game challenge specifically aligned with Common Core/Next Generation Science (NGSS) state standards for instruction?</p> <p>How does the teacher’s use of a digital game based challenge work as an assessment of elementary students’ understanding of Common Core/Next Generation Science state standards?</p> <p>How does the specifically designed game challenge affect other dimensions of classroom instruction, assessment and students’ engagement?</p>
Well suited for studying process	The manner in which teachers negotiates the use of the game challenge within instruction is a process to be examined.
Help understand the range of human experience, including upper and lower boundaries.	To best answer the proposed question, research and data needs to be answered at both the upper boundary of the classroom as a whole as well as the lower boundaries of the teacher as the mediator of the tool and the student completing the task.

Embedded Single Case Study Design

Yin (1994) identified three rationales for using a single-case design: (1) The single case represents the critical case in testing a well-formulated theory, (2) the case is represents a unique or extreme case and (3) the case is revelatory or the researcher has an opportunity to observe and analyze a phenomenon previously inaccessible to scientific research. In addition, Yin (1994) states an embedded study is appropriate if the analysis

of a case study “includes outcomes from individual projects with the program and possibility even some quantitative analyses of large number of projects” (p. 44).

The study fits the rationale for a single case study because it is a representative case. The study included three elementary STEM teachers employed by a public school system located within a large, south-central United States city. Individual elementary schools in this school district fund STEM teachers using discretionary money, so not all elementary schools in the area employ a STEM teacher. All STEM elementary teachers see all students in their respective schools on a rotational basis as part of specials class, similar to art and music. Because schools typically employ only one STEM teacher, the STEM teachers from various schools meet approximately once a month in a professional learning community to share ideas, lessons and discuss issues relevant to their work. Because the case study focused on three STEM teachers in the same school district, a single context, it must be a single-case study. Individual teachers in the study vary in terms of years teaching, experience with game authoring software, and students they teach, however, the context in which they plan and implement lessons as part of a professional learning community is similar. The study is an embedded single case study because even though the teachers may plan and implement lessons in a similar fashion, the research will include the teachers as both an individual as well as part of a group of STEM teachers.

Participants and Subjects

Due to the limitations of time and travel, I selected research participants from a convenience sample of elementary STEM teachers currently working in a public school district with which I have a working relationship. Elementary STEM teachers (n=15)

working in this school district in the 2014-2015 school year received an email invitation from me to participate in the research study. Three elementary STEM teachers responded, indicating interest in participating (n=3). The participating teachers see all students enrolled in their schools on a regular basis throughout the year, typically have access to equipment needed for the research study and serve a wide range of students in reference to gender, ethnicity and socio-economic status. The three teachers who volunteered to participate in the study are teachers I am currently working with, have some familiarity with game authoring software and were part of a team working on a grant funded project to create and implement standards aligned Scratch tasks in the classroom. Each participating teacher identified one fourth grade or fifth grade class to invite to participate in the research project. A total of twenty five (n=25) 4th grade students and nine (n=9) 5th grade students participated in the study. I followed school district and university consent protocols and informed all study participants of the research process and confidentiality procedures. Additionally, I obtained necessary parental consent for students in the participating classes. In following confidentiality procedures, I refer to participants, including their school and school district, using pseudonyms. The IRB approval for this protocol is located in Appendix B.

Procedures and Instruments

Merriam (1998) stated data collection in case study research typically involves the strategies of interviewing, observing and analyzing documents. Usually, one or two strategies dominate the data collection while the others serve as a support to gaining a better understanding of the case. The study used qualitative methods through a combination of typical case study strategies: participant interviews, observations and

analysis of student written reflections and game products, as outlined in Table 5. In answering each question, the combination of strategies will both inform and provide support to gaining an in-depth understanding of the case. In addition, Yin (1994) suggests the use of case study question, or specific questions, the researcher needs to keep in mind during data collection.

Table 5
Research Questions and Sources of Evidence

Research question	Case Study Question	Sources of Evidence
How do elementary teachers use a game challenge specifically aligned with Common Core/Next Generation Science (NGSS) state standards for instruction?	What process do teachers use to determine the location of the digital game challenge within the instructional design of a unit? How does the teacher structure support for students designing a game challenge? Are there multiple ways the game challenge can be used for assessment?	Observations and interviews with classroom teachers Written game task and rubric
How does the teacher's use of a digital game based challenge work as an assessment of elementary students' understanding of Common Core/Next Generation Science state standards?	Do students solve the problem in the challenge creatively? Are there multiple demonstrations of the problem solution? Are there limitations to the use of the challenge for assessment? Do students view the game challenge as authentic?	Observations and interviews with teachers Student finished game Student written reflections Interview with teacher Student written reflection Classroom observation
How does the specifically designed game challenge affect other dimensions of classroom instruction, assessment and students' engagement?	How does a teacher's knowledge of game authoring software support successful implementation of a game challenge?	Interview with teachers Student written reflections Classroom observations Student digital games

Preliminary semi-structured interviews with teacher participants gathered information regarding teaching background, comfort level with technology, climate, instructional design and familiarity with, and use of, drag and drop programming in the classroom. Sample questions from the initial interview include: What do you currently teach? Could you describe a typical day for me? Describe your comfort level with technology? How did you become interested in game authoring software, or software like Scratch? See Appendix C for the complete set of questions asked during Interview 1.

The initial interview, which lasted approximately one hour, provided evidence to support a classroom observation focusing on criteria for authentic instruction. I conducted three classroom observations for two subjects and two classroom observations for one subject to corroborate data from the interview. Weather became a factor for scheduling a third classroom observation for the third subject prior to the end of the project, as noted in *Problems with Data Collection* section. Classroom observations took place at the beginning of the unit, middle of the unit and end of the unit. I included examples of the semi-structured observation protocol used in Appendix D.

To answer specific questions about the use of the *Can You Create a Game Challenge* task as authentic assessment, I conducted a second interview with teacher participants with questions regarding the examination of student work. Specific questions for this interview included: Describe any student solution which you consider to be exemplary, describe any student solution where you feel the student demonstrated creativity; please share with me some examples of where you felt the student showed mastery of those standards using the finished game, the game plan or the student reflection. The full protocol for Interview 2 is located in Appendix E.

I used additional data from the written student project reflection (see Appendix F), classroom observations and review of student work to gather evidence regarding both authentic assessment and perception of a game challenge as an authentic task. I recorded all interviews using a digital audio recorder on my cellphone and transcribed the data for analysis. I entered all data into a Microsoft Excel spreadsheet for the purpose of organization and analysis.

Table 6

Case Study Questions and Sources of Evidence

Case Study Question	Evidence from Interview (Specific Questions)	Evidence from Observation (focus)	Evidence from documents	Timeline
What process do teachers use to determine the location of the digital game challenge within the instructional design of a unit?	<p>When you get ready to design a unit, what steps do you take?</p> <p>Could you walk me through it?</p> <p>How do you decide when to use a game challenge as part of a unit of study?</p> <p>When thinking about the instructional design of a unit, when do you usually introduce a game challenge to the class, at the beginning of the unit, in the middle of the unit or at the end of the unit? What criteria do you use when deciding the best location?</p> <p>How do you see your role in you using game authoring software in the classroom?</p>	Classroom observation		Interview 1 Observations 1, 2 and 3

Table 6 (continued)

Case Study Question	Evidence from Interview (Specific Questions)	Evidence from Observation (focus)	Evidence from documents	Timeline
How does the teacher structure support for students designing a game challenge?	What plans do you have or use to structure support for students using programs like Scratch to complete a game challenge?	Classroom Observation		Interview 1 Observations 1, 2, and 3
Are there multiple ways the game challenge can be used for assessment?	In what ways do you use the game challenge to measure student progress on standards? How do you provide feedback to your students on a game challenge?	Classroom Observation	Student reflection Student game	Interview 1 and 2 Observation 1, 2, 3
Do students solve the problem in the challenge creatively?	Describe any student solution where you feel the student demonstrated creativity.	Classroom observation	Student reflection Student game	Interview 2 Observation 1, 2, and 3
Are there multiple demonstrations of the problem solution?	Describe any student solution which you consider to be exemplary.	Classroom observation	Student reflection Student game	Interview 2 Observation 1, 2, and 3
Are there limitations to the use of the challenge for assessment?	Please share with me some examples of where you felt the student showed mastery of those standards using the finished game, the game plan or the student reflection. You also developed a rubric to accompany the game challenge task. Describe how you used the rubric as part of your instructional design.	Classroom Observation	Student reflection Student game	Interview 2 Observation 1, 2, and 3
Do students view the game challenge as authentic?		Classroom Observation	Student reflection	Observation 1, 2, and 3

Table 6 (continued)

Case Study Question	Case Study Question	Case Study Question	Case Study Question	Case Study Question
How does a teacher's knowledge of game authoring software support successful implementation of a game challenge?	How did you become interested in game authoring software?	Classroom Observation	Student reflection Student game work	Interview 1 Observation 1, 2, and 3
	How did you hear about them?			
	What previous experience do you have with drag and drop software?			
	What previous experience do you have with Scratch software?			

Problems with Data Collection

Weather was a factor during the data collection period. The schools participating in the study missed seven complete days and one partial day due to school closures from winter storms. Because of the snow days, I was only able to conduct two instead of three classroom observations for teacher 1, Annie.

Another issue was archiving student-authored games for analysis. Saving student digital games was a hurdle for teacher 3, Susan. Susan used the web-based version of Scratch for student games. To avoid creating student accounts, Susan created one class account for students to use to log into the software and save projects to a class folder. While Susan had access to the completed projects for grading and sharing during interview 2, some games submitted to me for data collection were incomplete, more than likely due to student error in saving. In addition, some completed student games involved groups of students where one student did not have parental consent to

participate in the study. I did not include those games in the data analysis. While saving games was not a hurdle for teacher 2, Heather, retrieving completed games to submit to me for data collection was problematic. Heather's class used a downloaded version of Scratch software on laptop computers. Because Heather borrowed laptop computers from multiple classroom teachers, trying to locate the saved games on multiple devices was difficult. From the 34 students participating in the study, I was able to include games for 16 students, or 13 games, in the data analysis. Those 13 games were saved, completed games with consents.

Data Analysis

I analyzed the data using Hatch's (2002) typological analysis. Typologies are themes or categories generated from theory, common sense and/or research objectives (p. 152). The model for typological analysis consists of nine steps

1. Identify typologies to be analyzed
2. Read the data, marking entries related to identified typologies
3. Read entries by typology, recording the main ideas to entries on a summary sheet
4. Look for patterns, relationships, themes within typologies
5. Read data, coding entries according to patterns identified and keeping a record of what entries go with which elements of your patterns.
6. Decide if your patterns are supported by the data and search the data for non-examples of your patterns
7. Look for relationship among the patterns identified
8. Write your patterns as one-sentence generalizations

9. Select data excerpts that support your generalizations

Using this method, I selected typologies for data analysis from research objectives as well as criteria established in the theoretical framework for authentic instruction and authentic assessment. I created a column in the Excel spreadsheet labelled *initial typology* for coding of the data. The initial typologies selected were task, environment, process, product, role of teacher and assessment. Once I established the initial set of typologies, I read the data completely with one typology in mind, finding and marking those areas of evidence supporting the selected typology and entering the name of the typology in the designated spreadsheet column. I repeated this process for each identified typology. Next, I filtered the spreadsheet by each typology to read the associated data set, looking for emerging patterns. Next, for each typology, I wrote summary statements and analyzed for emerging patterns, relationships and themes. Emerging themes included physical space, social context of environment, collaboration, facilitation, co-learning, grouping, scaffolding, shared knowledge, modeling, shared authority, coaching, and authenticity. I created a second column in the Excel spreadsheet with the heading *initial sub typologies* for the emerging themes. I read the data again, coding as to hypothesized patterns, relationships and themes previously established (See Appendix H for examples). I evaluated data not coded, searching for non-examples, contradictory evidence or evidence leading to support other cases. Examples of this data include background knowledge of teacher, teacher perception of student gaming experiences, differentiation for students with disabilities and success for struggling students. I added the typologies of supports for teachers, computational thinking and obstacles.

The rationale for this analytic approach is based on the constant comparative method of data analysis developed by Glaser and Strauss (1967) as a means of developing grounded theory. This method of data analysis by Glaser and Straus is often used by researchers who are not seeking to build substantive theory (Merriam, 1998).

Next, I moved from individual analysis to look for connections across the group as a whole. As a final step I noted excerpts from the data for use in supporting broad analytical findings made.

Hatch (2002) notes the primary strength of a typological analysis is its efficiency through the use of pre-determined typologies, but advises a potential weakness of the strategy is missing other important dimensions in the data. By combining both deductive and inductive strategies, the researcher can examine data through the lens of selected typologies but also allow for other patterns, relationships or themes to emerge. After analyzing the data, if it appears the researcher did not account for important data, the researcher applies an inductive analysis procedure is to fill any gaps of data analysis.

Inductive analysis examines the particulars within data, and then looks for patterns across observations and makes a case for the pattern as having the status of general explanatory statements. Also rooted in ground theory, Hatch's model can be used "for more than the discovery of data-based theory" (p. 162).

To complete the inductive analysis, I printed off the data set without assigned codes. I read the data and searched for emerging patterns and themes. Additional themes which emerged from this analysis included student challenges, learning as identified by students, enjoyment of task, and student dislikes of task.

The strength of this type of analysis is the ability to obtain meaning from a large, complex set of data through a systematic approach (Hatch, 2002). Hatch (2002) argues this strategy provides a researcher with confidence in reporting an accurate representation of the studied social situation or participant perspective. I found that analyzing the data through the use of typological analysis, using an initial deductive approach with a follow up of an inductive analysis for any unaccounted for data of importance provided more thorough and accurate data analysis results. Additionally, the use of Excel aided in the organization of coding, ensured the inclusion of all data and eased the task of data analysis. Table 7 lists case study participants, their position and school as well as the types of data collected for each.

Table 7
Preparation of Data Analysis

Participant	Position	School	# of Interviews	Observations	Student work
T1-Annie	STEM Teacher	S1: Main Street	2	2	
T2-Heather	STEM Teacher	S2: Brookside	2	3	
T3-Susan	STEM Teacher	S3: Waterson	2	3	
1A	Annie's 5 th Grade Students	S1: Main Street		Included in general classroom observation	Reflections Games
1B					
1D					
1G					
1H					
1I					
1J					
1N					
1O					

Table 7 (continued)					
Participant	Position	School	# of Interviews	Observations	Student work
2D	Heather's 4 th Grade Students	S2: Brookside		Included in general classroom observation	Reflections Games
2J					
2L					
2P					
2Q					
2R					
2S					
2T					
2W					
2AA					
3A	Susan's 4 th Grade Students	S3: Waterson		Included in general classroom observation	Reflections Games
3B					
3C					
3D					
3E					
3F					
3G					
3H					
3I					
3J					
3K					
3L					
3M					
3N					
3O					

Case Study Quality

Yin (2009) identified three strategies for improving construct validity. These strategies include the use of multiple sources of evidence, asking key informants to review the case study report, and maintaining a chain of evidence. Multiple sources of data allow for data triangulation, support accuracy of case study findings and allow for a researcher to examine an audit trail for consistency of evidence across different data sources (Baskarada, 2014). The multiple sources of triangulating evidence collected for this case included participant interviews, classroom observations, game design task, game

design rubric, student written reflection and student created digital games. As a member checking strategy (Creswell & Miller, 2000), teacher participants reviewed the interview data and the report. Participants reported verbal and written feedback for needed corrections. The creation of a case study database provided a way to store all notes and data collected from the study and generated a way to maintain a chain of evidence, linking case study questions to evidence collected.

In addition to audit trail, triangulation of data and member checking, Creswell and Miller (2000) suggest the use of thick and rich descriptions and researcher reflexivity to improve trustworthiness of the study. Throughout the findings, I included detailed descriptions of the participants, and settings of the observations to help draw the reader close to the study. I addressed researcher reflexivity in the next section, Role of the Researcher.

Role of the Researcher

As per my job duties in the school district for which I am employed, I provided training and professional development experiences for elementary teachers for over ten years, including the teachers in this study, in the areas of creative computing, LEGO robotics and other STEM related topics. In addition, as part of a grant funded project, I trained teachers on the development of *Can You Create a Game Challenge* tasks and rubrics for use in the classroom. While I conducted research as an outside reviewer, I continued to be available to these teachers as an instructional support for technology integration.

Limitations

The intent of this case study is not to present findings that are generalizable to a wider population, but instead to provide an extensive and in-depth examination of a complex phenomenon. In this research study, possible limitations include research bias, availability of data, access to data and constraints of time. As the researcher, my role as a professional colleague of the study participants, interest in the area of creative computing and the use of coding in the classroom creates the possibility of research bias within the research process. Because I know that my professional relationship with these teachers may create an unintended bias, I used semi-structures protocols and self-questioning strategies to remain focused on the research questions. In addition, due to time constraints and availability of the teachers using Scratch in the classroom, the case study examined the use of a single game design task with accessible teachers. Knowing the limitations of both time and availability, I included three teachers in the study to provide access to a larger field of data for the study.

Summary

This embedded single case study focused on how a group of elementary STEM teachers implemented a *Can You Create a Game Challenge* aligned to Next Generation Science Standards within authentic instruction for assessment. Characteristics from the literature review of authentic instruction and assessment as well as the theories of constructivism, constructionism and social constructivism informs the study and will, in concert, provide a multi-faceted analytic lens for the case data analysis.

Chapter Four

Discovery cannot be setup; invention cannot be scheduled (Papert, 1993b).

In Chapter Four, I present descriptive narratives of the setting and teacher participants. Following the descriptions, I report research findings from the study by research question. All identifiable information, including names of the school district, schools, teacher and student names are pseudonyms.

Narratives of Settings and Teacher Participants

Woodlawn School District

Woodlawn school district, located within a large, south-central United States city, serves over 40,000 students and employs more than 5,000 administrators, teachers and staff. The system includes 35 elementary schools (grades K-5), 12 middle schools (grades 6-8), one middle/high school (grades 6-12) and 5 high schools (grades 9-12). Twenty-two district preschool programs, twenty of which are housed within elementary schools, provide educational services to identified special needs children between the ages of three to four years as well as children, age four, whose family qualifies for the federal free and reduced lunch program. Three technical centers located within Woodlawn school district provide career and technical education in areas such as pre-nursing, veterinarian assistance, equine studies, auto-mechanics, advanced gaming technology, multi-media production and culinary arts to participating area high school students. In addition to the traditional schools and technical centers, six non-traditional academic programs serve the needs of students who require a different learning

environment. Four secondary schools, including middle and high, offer specialized programs for students in technology, engineering, the arts as well as the International Baccalaureate program. Students identified as gifted and talented may attend specialized programs such as accelerated cluster, a school for performing arts, the Liberal Arts Academy or the Math, Science, Technology Center. Eight institutes of higher education, including community colleges and universities, offer continued educational opportunities for students and the community. Several of these institutions partner with the school district to offer dual credit and accelerated course opportunities for qualifying students (Woodlawn School District, school district website, 2015).

The student population of Woodlawn School District reflects diversity in ethnicity and socio-economic status. The racial composition of the district student body is 54.3 % Caucasian, 22.6% African American, 14.3 % Hispanic and 4.2 % Asian. The district instructs 3,789 limited English proficiency students who speak one of 80 native languages. During the 2014-2015 school year, 53.9% of students qualified for the federal free and reduced lunch program, which is an indicator used to determine the number of students living in poverty (Woodlawn School District, school district website, 2015).

Annie, Heather and Susan are elementary STEM teachers employed by Woodlawn School District. Each of these teachers work in a different school (Main Street, Brookside and Waterson) which vary in student populations, daily STEM class schedules and neighborhoods.

Annie, STEM Teacher at Main Street Elementary

Main Street Elementary is a suburban school nestled within a middle income neighborhood in the Woodlawn School District. The school sits along a busy road, near

two parochial schools, a church and a city park. Single-family homes line the surrounding streets, a proximity close enough for many students and families to walk to school. In addition to serving neighborhood children, the district buses students from an outlying upscale neighborhood to the school. In 2013, contractors completed a 15 million dollar renovation of the building, with upgrades to support the growing number of technology devices, expansion of the parking lot, additional classrooms and office space, a larger cafeteria and expanded library. With an enrollment of approximately 550 students in grades K-5, the racial composition of Main Street Elementary is 83% Caucasian; 4% African American; 5% Hispanic; 3% Asian and 5% other. In addition, 6% of the students are English language learners. Even though 29% of Main Street students receive free or reduced lunch, the school does not meet the qualifications for school-wide Title 1 funding and does not receive additional staff to support students performing below grade level. With a commitment to assist at-risk students with highly qualified interventionists, the school site based decision-making council (SBDM) elected to convert and combine money for classified assistant positions to full time interventionists. Main Street houses Woodlawn School District's only deaf and hard of hearing (DHH) elementary cluster program, consisting of two DHH primary classrooms, one DHH intermediate classroom and three DHH interpreters. In addition to a well-established parent-teacher association (PTA), the school has a strong base of parent volunteers, who donated 6,140 hours of service in 2013-2014 school year. In 2013, the school site based decision-making council decided to combine the computer lab and science positions to create a STEM lab teacher for the following year. The STEM lab

teacher would provide instruction to students in both the STEM lab and the computer lab as a special area class (Main Street, school report card, 2014).

The STEM lab at Main Street Elementary is a classroom space, recently renovated to include a large storage area, cabinets and counters. Long windows frame one wall, providing natural light to the room. Moveable furniture and stationary cabinets divide the classroom into specific work areas. Evenly spaced along one side of the room are large rectangular tables and chairs for work groups. Baskets of Crayola markers, worn crayons, school scissors and glue sticks placed in the center of each table provide students with resources needed for creative projects. The teacher desk, with the teacher computer and document camera, sits in the back corner close to the classroom whiteboard and wall mounted short-throw interactive projector. A large LEGO board with a Mars Rover themed mat and various student built LEGO structures, rests on tables in the other back corner, adjacent to the teacher desk. LEGO Mindstorm robots and clear plastic containers of different LEGO bricks and connectors line the counters between the LEGO board and class tables. Paper towel tubes, cereal boxes, plastic bottles and recyclable treasures fill the open shelves on the wall. Cardboard contraptions, soil filled plastic two-liter bottles and Matchbox racing sets support the project-based focus for many of the classroom STEM lessons. Large plastic bins of various colored LEGO bricks and donated materials for the STEM lab fill the classroom closet. The teacher computer is the only computer visible in the classroom.

Directly across the hall is the computer lab, a second space the STEM teacher uses for instruction. Designed for traditional instruction, the lab is equipped with a large white board and wall mounted short- throw interactive projector in the front of the room.

Opposite the whiteboard, floor space is available for students to sit in order to easily see and hear directions before moving to a computer station. Extending toward the back of the room are rows of desktop computers sitting on long tables, divided into two groups by a center aisle. The teacher's desk is located in the back of the room, beside a black metal shelf filled with partially built student LEGO WeDo robotics projects. Additional closets located behind the teacher's desk provide storage for items such as headphones, extra computer mice and keyboards. The teacher's computer has a wireless keyboard to make typing from any location in the classroom easier.

Annie, the current STEM teacher at Main Street Elementary, was a fifth grade classroom teacher at the school when the position of the STEM lab teacher became available in 2013. When discussion of moving a teacher from the classroom to this new role occurred during a school leadership meeting, Annie was the only teacher at the table eager to rise to the challenge of this newly created job. Her enthusiasm, technology skills and creative energy made her a top candidate for the position. At the start of this study, Annie was beginning her eighth year of teaching and her second year in the STEM lab, a role she is helping to define for her school.

Annie shared in her initial interview that teaching was her second career, with prior work experience as a bank teller, a preschool teacher and a teacher assistant before going back to school to acquire her teaching certification. Eventually, she obtained her Master's degree in elementary education with a focus on reading and writing. Her college course work, with a heavy concentration on the social sciences, lacked an emphasis on STEM topics. She describes herself as "very comfortable" with using technology in the classroom and willing to seek help if needed. "If I don't know how to

do it, I will figure it out, or call somebody who will tell me how to do it,” she said (Annie, Interview 1, March 3, 2015). To better understand STEM topics and instructional approaches for teaching STEM, she relies on a support group including a District Technology Resource Teacher, her school computer technician and other STEM lab teachers. “We share ideas,” she said, “and we are all brainstorming because at this point this class is kind of a learning groove, there is a learning curve with it,” referring to navigating the new STEM teacher role in schools (Annie, Interview 1, March 3, 2015).

Students at Main Street Elementary attend STEM class as part of the specials rotation, once every five days for approximately fifty minutes. It is important to note that a five day rotation is different than meeting once a week. Students attend STEM class every fifth day school meets. Over the course of the year, each homeroom class attends STEM class about 35 times. On a typical day, this energetic teacher sees a class of students in each of the six grades, meeting in the computer lab or the STEM lab depending on the lesson objectives and computer lab testing schedule. “I see all grade levels each day, so I’m on a five day rotation; I see all students in a 5 day period” (Annie, Interview 1, March 3, 2015). The DHH students attend STEM lab class with regular classroom students, so Annie makes accommodations as needed for them, including wearing a microphone and modifying assignments as necessary. Annie’s day does not end immediately following afternoon dismissal. In addition to teaching in the STEM lab, Annie coaches her school LEGO Robotics team after school as part of the Student Technology Leadership Program (STLP) and serves as her school technology coordinator.

Annie selected a class of 5th grade students (n=23), of which a group of sixteen (16) students agreed to participate. Many students in this class participate in the school band and orchestra program which meets during special class rotation time. School band and orchestra classes meet once a week on an established day (such as every Thursday) and time of the week for 50 minutes. Students attend STEM class once every 5th day school is in session. Students in band and orchestra miss STEM class when the STEM day rotation falls on the established weekday that band and orchestra meet. These students continue to miss STEM class until school is not in session. Table 8 outlines an example schedule.

Table 8

Example Special Class and Band/Orchestra schedule for Annie's Students

Monday	Tuesday	Wednesday	Thursday	Friday
Day 1 Rotation	Day 2 Rotation	Day 3 Rotation	Band Day 4 Rotation (STEM)	Day 5 Rotation
Day 1 Rotation	Day 2 Rotation	Day 3 Rotation	Band Day 4 Rotation (STEM)	Day 5 Rotation
NO SCHOOL	Day 1 Rotation	Day 2 Rotation	Band Day 3 Rotation	Day 4 Rotation (STEM)

Annie stated, "I might go for four weeks and they (students) aren't here because they go on a day of the week for something and if we don't have any days off from school, I see them every Thursday. If they have class, then I miss (seeing) those kids" (Annie, Interview 2, April 16, 2015). Some students who agreed to participate in the study could not due to scheduling conflicts with band and orchestra class. Thus, in addition to Annie, nine students (9), three (3) females and six (6) males, fully participated in the research study.

Heather, STEM teacher at Brookside Elementary School

Brookside Elementary is located in a diverse suburban neighborhood within the Woodlawn School District, with residents from different socio-economic and ethnic backgrounds. The homes surrounding the school include single family houses, townhomes and apartments. The school currently serves students from several homeless families, contributing to the transient population and a constant flow of new students coming and going weekly. Brookside's unique student population represents over thirty different nationalities with 16% of the students receiving English as a Second Language (ESL) services. The school uses interpreters to translate school to home communications into many languages, including Spanish and Arabic, as well as translate live for conferences and school programs due to the number of parents who are not fluent English speakers. Because of the high number of low socio-economic students, Brookside Elementary receives school-wide Title 1 funding and the school's demographics continue to change. During the 2013-2014 school year, 67% of the student population qualified for free/reduced lunch; an increase of nearly 25% over the past nine years. Since Brookside is a Title 1 school, they received additional support resources such as a part time social worker and a full time family resource coordinator. The racial composition of the school's 700 students is approximately 56% white, 22% African American, 12% Hispanic, 3% Asian and 7% other. The school serves students who are gifted and talented (G/T) as well as over 70 students identified as special needs. Parent involvement at Brookside includes not only parents, but grandparents and guardians who may also be foster parents. The school has an active PTA with about 175 members who help fund projects and programs at the school (Brookside, School Report Card, 2014).

In 2013, with the adoption of the new Next Generation Science Standards (NGSS), the school site-based decision-making council, like the one at Main Street Elementary, decided to add a STEAM teacher as a special area class for students. The STEAM lab teacher would provide additional instruction for NGSS standards as well as integrate the arts into projects.

The school houses the Brookside STEAM lab in a corner classroom at the end of a long hallway. Outside the STEAM lab door are blue plastic crates of cardboard tubes and other recyclable materials donated by teachers, staff, students and parents for use in hands on projects. Occasionally, the wall adjacent to the lab has tables filled with broken radios, malfunctioning printers, outdated laptop computers and miscellaneous discarded electronics for students to use in STEAM lab tinkering activities. Organized for collaborative work, the room has several tables where groups of three to four students sit to work on projects, take notes and complete assignments. The STEAM teacher labeled every table space with both a number and a word to easily assign roles for group work. In front of the classroom whiteboard and mounted projector rests a kidney shaped table with lesson materials and several crates of student work journals, arranged by homeroom teacher. Adjacent to the kidney table is the teacher desk, with access to the teacher computer and document camera. In the back of the room, a large blue rug and wooden rocking chair provides a space for children to gather for discussions and listening to the teacher share a story. Large windows on the back wall provide a pleasant view of the grass and trees growing in front of the school and allow natural light to fill the room. Three laptop computers plugged in to charge, lie on the bookshelf under one window. A narrow passageway beside the portable, rolling containers of LEGO bricks and stacked

books housed neatly on open shelves along the side wall, allow enough space for the teacher to navigate from student to student. A small aquarium filled with tropical fish stands on the counter next to three stale, untouched cupcakes, subjects of a class investigation on preservatives in food. The yellow wall cabinets overhead provide storage for additional materials for experiments. Student constructed LEGO WeDo robots rest on the island of tables along with other partially constructed student projects. Since the STEAM lab teacher has little access to computers in the classroom, she borrows laptop from other classes for lessons involving technology. Student work with technology in the STEAM lab always involves group work due to small number of computers available.

Heather, a veteran teacher beginning her 14th year, is returning to the STEM lab for a second year. Her principal recruited her from a primary class position for the STEAM lab in 2013, to help shape the STEAM lab experiences and curriculum for students. While the majority of course work in her undergraduate and graduate teacher education programs focused on literacy, mathematics and classroom management, she fondly remembered a couple of “incredible science professors” and the graduate professor who taught a required technology course. “He was a good touchstone because even after the class was over and I moved out of state, I was still able to ask questions and touch base back with this person” (Heather, Interview 1, January 15, 2015). In an interview with Heather, I asked her to describe her comfort level with using technology in the classroom. “If we’re talking about a scale, like a scale of one to ten, I would say I’m probably a six or a seven. I’m pretty comfortable with it because I think I know enough about it now that I know I’m not going to blow a computer up. I’m not going to make the software explode, but I’m not very confident as an explorer, meaning that if I

don't have someone directly teaching me the software, I'm not good to figure it out on my own. That's not strength, but I am good at taking it, after someone teaches it to me, and applying it. I'm very comfortable with that" (Heather, Interview 1, January 15, 2015).

In addition to her former technology professor, Heather often calls on her District Technology Resource Teacher or fellow STEM teacher, Annie, for questions not answered through a web search and for ideas implementing technology in the STEAM lab. For programs like Scratch, she uses online question forums specific to the Scratch program, found on the Scratch website (Heather, Interview 1, January 15, 2015).

Along with serving as the STEAM lab teacher, Heather promotes STEAM in the regular classroom and with families during after school activities. She assisted in organizing the school's Arts and Science day, bringing in several local businesses who work in the STEM field to share experiences with students. She worked with the 5th grade team to incorporate a unit on robotics into the math lesson, modeling instruction for teachers; hosted a storytelling with LEGOs indoor field trip for students and encouraged students to explore creative problem solving through a small inventor fair.

Students at Brookside Elementary attend STEAM lab once every six days for approximately 50 minutes, as part of the special class rotation. On a typical day, Heather will see one class from each grade, K-5. Class sizes range from 24-28 students per class. "I start with my oldest kids first and then go to my youngest kids. My schedule starts off as more of a facilitator position at the beginning of the day with the older children and then towards the end of the day, by the time I get to Kindergarten and first grade, my day

is much more modeling the hands-on thing, so that keeps me busy” (Heather, Interview 1, January 15, 2015).

For this research study, Heather selected a class of 4th grade student to participate (n=29). In addition to Heather, ten students from the class (n=10) agreed to participate in the study, including seven males (n=7) and three females (n=3). The unbalanced number of boys to girls participating in the study reflects the school population, according to Heather. “We have more boys in most of our grade levels, as a school I’m not sure how that happened” (Heather, Interview 1, January 15, 2015).

Susan, STEM teacher at Waterson Elementary School

Waterson Elementary School is located in the heart of several mature, yet low income neighborhoods in the south end of Woodlawn School District. The school, situated among apartment complexes, churches, townhomes, single family homes, a middle school and a golf course, has a diverse population of students, with 10% receiving English as a Second Language services. The racial composition of the 685 students enrolled in grades K-5 is 52% Caucasian, 27% African-American, 11% Hispanic, 3% Asian and 7% other. Waterson Elementary receives school-wide Title 1 services due to 67% of their students participating in the federal free and reduced lunch program. While the student population includes children from low, middle and upper income families, several students live in single parent households and most of the parents work during the day that creates a difficulty in parent participation for during school activities. To help boost parental involvement and accommodate working parents, Waterson Elementary hosts a monthly family night focused on topics such as math and Spanish Heritage. In addition to teachers and school administrators, the staff at Waterson includes a speech

pathologist, a diagnostician, a school psychologist, social worker and behavior specialist. In 2013, with the state adoption of the Next Generation Science Standards (NGSS), the site-based decision-making council at Waterson Elementary elected to create the STEM teacher position as part of a special class for students (Waterson, school report card, 2014).

Upon entering the school, the STEM lab is located down a series of meandering hallways, winding past the cafeteria, several classrooms and the computer lab. Round tables dot the floor and afford ample space for group work, assignments and projects. Plastic 2-liter bottles filled with soil wait for student observers beneath the windows along the side wall. The windows provide natural light for the room and a view of the outside yard, often used as an extension of the classroom. Wall cabinets and counters, partially filled with beakers, boxes and other science lab materials line the back wall of the spacious room. The teacher desk, with a computer and document camera sits opposite the windows and adjacent to the class whiteboard and projector. A large, blue square rug in front of the whiteboard provides a cozy space for classes to gather to watch a short video, hear a story or share projects. A four foot high wooden crate, with chicken wire windows, houses the class rabbits. A computer cart, laptops and a shelf containing various bottles, cereal boxes, paper towel tubes and other student donated recycled materials are located toward the door.

Susan, the STEM lab teacher at Waterson Elementary, is early in her teaching career. She spent one year as a substitute teacher before Waterson Elementary hired her as a reading intervention teacher. When her principal approached her about moving to the STEM lab in 2013, she anxiously accepted. Susan began her 2nd year in the STEM

lab in August, 2014. Even though she took a variety of coursework, including reading, math, science, special education and methods, her undergraduate program included one hour of technology in which she recalled creating a teacher blog. Though lacking intentional instruction in implementing technology in the classroom, Susan feels comfortable around a computer. “I feel like my comfort level is about where most teachers are” (Susan, Interview 1, January 29, 2015). Her role as the school technology coordinator (STC) continues to increase her knowledge of technology and innovative software programs available for use in the classroom. “It’s made my comfort level in the classroom better, like I’m not afraid to try things. If I don’t know everything about Scratch, I give it to the kids and just say ‘I don’t know. You figure it out’ and I’m ok with that, whereas some teachers need that control” (Susan, Interview 1, January 29, 2015).

Susan is establishing a network of people and resources to help her better understand Next Generation Science Standards (NGSS), technology integration and teaching elementary STEM. In addition to her district technology resource teacher, she relies on other elementary STEM teachers in the district, her Professional Growth and Effectiveness coach who is a former district technology resource teacher and simple Google searches. If she is trying a new tool out, she simply takes time to explore. “I just play around, for example if I’m using Audacity (digital audio recording tool) for something, I might just play around with it for an hour and I can learn more from that than someone showing me sometimes” (Susan, Interview 1, January 29, 2015).

When Susan is not in the STEM lab, she is troubleshooting technology issues in her school as the school technology coordinator or working with students in the Student Technology Leadership Program (STLP) before and after school. She developed and

founded the school-wide Invention Convention, held once a year, where students put their creative minds to the task of solving a real world problem with an innovative solution. In the summer, she runs the school Camp Invention program to maintain student interest and excitement in STEM topics. After school, students come into the STEM lab, feed the rabbits and let them out to hop about the room for a bit (Susan, Interview 1, January 29, 2015).

Susan begins her school day with several STLP students, working to air the morning news show. She shifts roles from news show producer to math intervention teacher where she spends the next 30 minutes working with students identified as needing specific math assistance. Following math instruction, she moves into her STEM teacher role, seeing one class per K-5 grade level for 50 minutes each day. Unlike other schools in the district with elementary STEM programs, Susan sees each class every day for five sequential days. She will not see the class again for approximately one month (Susan, Interview 1, January 29, 2015). For the research project, Susan selected a group of 4th grade students (n=24). In addition to Susan, fifteen of her students (n=15) agreed to participate in the research study, including six males (n=6) and nine females (n=9).

Participants and Initial Use of Scratch Software in the Classroom

The participants in the study tinkered with Scratch many times before considering its use in the classroom with students. For Annie, her first exposure to Scratch was at a teaching conference which gave her a small amount of hands on time but did not “touch it” when returning to the classroom. Later the next school year, she attended a professional development offering in her district on Scratch. Then a colleague mentioned the software to her, sharing some of the capabilities. For Annie, the turning point for her

to use Scratch in the classroom was when her District Technology Resource Teacher worked with her one on one and said “let me show this to you.” In an interview with Annie she summarized this transition in a statement. “It was kind of saw it, saw it and then somebody really showing me got me interested in doing it.” (Annie, Interview 1, March 3, 2015) Heather had a similar experience when it came to first using Scratch in the classroom.

The first time I think I got interested in game software was the very first “Woodlawn” county technology conference I went to. It was probably my second year here in the district and someone the year before, our technology teacher here before, said something like “you should go to a Scratch workshop, I think you would like it” and I went and I saw the Scratch gaming workshop there and it was supposed to be intro level but it wasn’t all the people around me were off and flying and doing things and I had no idea what was going on. So I attended almost that same session the next year and then got a little bit of an idea, better idea. Then with that little-itty bit of knowledge that I got from the technology conference, my daughter was in first grade and the STLP teacher at (her school) was looking for help with Scratch. I happened to mention to her that I had taken that one class and then all of a sudden I was there trying to help with that. So I sort of got thrown into it and then once I moved into this position I started using the robotics and I started figuring out what coding and programming was then, I think again, it was (my District Technology Resource Teacher) who introduced the idea of Scratch and then introducing it as a way to create games for kids. So I had these little bits of information that kept getting plugged together and then it

sort of came to fruition and I understood what that was. My first lesson was the lesson that (my District Technology Resource Teachers) came to teach my first day with my first fifth grade class and I had my little itty bitty limited amount of knowledge and I sat right there with my notebook and everything that (she) said, I just wrote down and then the next four classes I had to teach it to after that, what I learned from (her) that 55 minute time period that's what was my jumping point for everything else. So and being a part of the grant was huge because now it has really changed my thinking, every project I get I'm thinking could I use Scratch for this and is this something I can tell the classroom teachers about that they could do something. (Heather, Interview 1, January 15, 2015)

While Annie and Heather first experienced Scratch at a conference, Susan's first experience with Scratch happened during the Hour of Code, a week-long celebration of computer science in schools. Susan shared her experience during an interview.

Last year with the Hour of Code, when I signed up for that, I thought why not try it. It was our first year having STEM lab so we were still trying to figure out what that is and what STEM really looks like in elementary school. So we tried it out and the kids loved it, so, of course, I wanted to do more because the kids were so interested, definitely Hour of Code started it. (Susan, Interview 1, January 29, 2015)

For Susan, it took seeing the reaction from their students using Scratch to incorporate the program into the classroom. Annie and Heather needed multiple exposures and a support person explicitly showing the software or modeling a lesson with students before they began using Scratch as part of instruction.

District STEM Professional Learning Community and Grant Participants

Annie, Heather and Susan participate in a district STEM Professional Learning Community (PLC) with approximately twelve additional elementary STEM teachers. As a District Technology Resource Teacher, I organize and lead the STEM meetings. Initially, the STEM PLC met on a regular basis, discussing important issues such as scheduling, understanding of the new Next Generation Science Standards (NGSS), available resources, lesson ideas and assessment. During the 2014-2015 school year, the STEM PLC communicated through email discussions and did not regularly meet face to face. At the beginning of the 2014-2015 school year, I received a grant to develop Scratch tasks aligned to Common Core/Next Generation Science state standards and integrated with computational thinking skills and dispositions. Annie, Heather and Susan agreed to participate in the grant, meeting every other month to design, implement and share the success and struggles of implementing Scratch tasks into the STEM/STEAM lab curriculum. In addition to the small group meetings, the grant participants traveled to a Creative Computing workshop, two Scratch Educator Meetups, attended Scratch Day at the Massachusetts Institute of Technology and assisted in organizing a Scratch Educator Meetup for their area. While these teachers used block-based programming in the STEM lab, their overall experience with coding, Scratch programming software, and understanding of computational thinking skills, dispositions and language varied.

Research Question 1: How do elementary teachers use a game challenge specifically aligned with Common Core/Next Generation Science (NGSS) state standards for instruction?

Digital Game Challenge as Exploration and Application of Knowledge and Skills

Teachers in the study used the *Can You Create a Game Challenge* for students to explore, practice and apply knowledge and skills across different content areas. In September 2014, Annie, Heather and Susan worked together to design an initial *Can You Create a Game Challenge* for 5th grade students on the interactions between hydrosphere and geosphere. After implementing the task and attending a Creative Computing Workshop in New York City in October, 2015, the teachers decided to specifically include computational thinking skills as well as using a specific Scratch block in the next *Can You Create a Game Challenge*.

Assessment of Next Generation Science Standards.

Annie, Heather and Susan collectively created the next game challenge for students to demonstrate understanding of the NGSS standard 4-PS4-3 by generating and comparing multiple solutions that use patterns to transfer information. Specific task criteria for the challenge asked students to use a code to create a secret word and to create a code to allow a player to hear each letter in your secret word. In the “think” section of the challenge, teachers asked students to think about how they used a pattern in Scratch to communicate a message to a friend. The teachers had previously taught the vocabulary and basic concepts of communicating with patterns. Susan included additional patterns used for communication including binary code (Susan, Interview 1, January 29, 2015). Annie wanted her students to develop a deeper understanding of the content by creating a

product using Morse code. “When I introduced Morse code, a lot of them knew what Morse code was, like they had heard it, but they couldn’t, like if I would have said define it for me, they couldn’t give me an example ” (Annie, Interview 2, April 16, 2015).

Teachers used the task criteria for NGSS to create an accompanying rubric to assess the standard. Heather described how the rubric design for the *Can You Create a Game Challenge* supports opportunities for students to continue to work beyond the minimum requirements.

I’ve tried to design the rubric so that everybody should just be in a middle ground and then those exceling and those picking up on it, there is room for them to grow and that is reflected on the rubric. I did that intentionally, so I could sort of watch for that. (Heather, Interview 1, January 15, 2015)

Measurement of enduring skills for engineering.

A new teacher evaluation system put in place by the state in which the teachers in the study work, required classroom teachers to select one class and one enduring skill for a specific content area to measure student growth over time. At the time of the study, this accountability measure was one of several used as part of the formal teacher evaluation used for recommending continuation of contract.

Heather added an additional rubric for evaluation of the *Can You Create a Game Challenge* to help measure student growth on a specific NGSS enduring skill in the area of engineering. She explained how she uses this rubric for every engineering assignment with students:

The rubric is the same rubric that we did with the other project. It is a rubric that they are already familiar with. They already know what it is that I am looking for

prior to the project even starting so this is something they have been seeing all year long, we use it for every project. So we talked more about how this rubric fits in with this project, like how engagement is going to look with this project, how creating solutions is going to look so if you got stuck with your code, this is how I should see you trying to do to solve it, trying things of that nature, so, the grade part for the game came from that rubric. (We use it) for any engineering project, every kid I have does. These are connected to the engineering standards, they aren't science based, but connected to engineering standard, the engineering standards that are linked in through the new science standards. (Heather, Interview 2, April 13, 2015)

Student name: Project Topic:		Intermediate Engineering Rubric		
	Ineffective (0 points)	Developing (1 point)	Average (2 points)	Above Average (3 points)
Engagement	Did not engage in activity	Engaged with prompting	Engaged independently	Engaged with further observations
Creating Solutions	Did not use prior knowledge	With prompting, used information to generate and compare solutions to a problem	Independently used information to generate and compare solutions to a problem	Independently used information to generate and compare solutions to a problem and analyzed how well solutions matched a problem
Model Design	Did not create a model	Created a simplistic model	Created a model to meet basic requirements	Created a model that extended beyond basic building requirements
Testing Design	Only restated previous information without creating a fair test	With prompting, created a basic testing design	Independently created a test with control, independent, and dependent variables	Independently created a test with control, independent, and dependent variables and applied test results to building model
Content	Not able to answer any content questions	Able to answer content questions with prompting and cues	Correctly answer content questions without prompting and cueing	Correctly answered content question using appropriate vocabulary and extend explanations

Figure 6. Heather's Engineering Enduring Skill rubric.

Common Core

Even though the classroom teachers did not intentionally include Common Core standards as task criteria or an assessment component, the data from the study suggest the inclusion of Common Core Standards for Math and English/Language Arts (ELA) within task development.

I observed students applying speaking and listening skills, specifically Common Core ELA standard 1: Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on *grade level topics and texts*, building on others' ideas and expressing their own clearly (Initiative, 2016a). While working on the project, students verbally communicated with peers and their teachers, posing questions or providing explanations to their teammates. Example of one-on-one discussions included conversations about specific help with programming blocks or game ideas (Annie, Observation 2, April 16, 2015; Heather, Observation 2, February 2, 2015; Susan, Observation 2, February 3, 2016). Student group conversations encompassed topics such as design elements and features discovered within the Scratch software program (Heather, Observation 2, February 2, 2015; Susan, Observation 2, February 3, 2016). Students discussed issues such as problems with play-testing and brainstormed solutions for coming to a consensus and the best sounds to use for their Scratch games (Heather, Observation 2, February 2, 2015; Susan, Observation 2, February 3, 2016).

As defined in the Common Core Math Practice 1: Make sense of problems and persevere in solving them, mathematically proficient identify the problem, look for an

entry point while analyzing given constraints, relationships and goals. Students often plan a solution, monitor and evaluate their progress and change course if necessary. They may ask themselves if the solution makes sense and can understand how others solved the problem in a different way (Initiative, 2016b). The *Can You Create a Game* task and the teacher implementation of the tool in the classroom allowed students the opportunity to practice developing Common Core Math Practice 1. The structure of the *Can You Create a Game Challenge* provided students with a space to plan a solution for the given problem. The trial and error process of creating the game in the Scratch program provided students a way to monitor and evaluate solutions to different problems in programming. While students in the study indicated the task was difficult, they continued to work towards a solution (Student Self Reflections).

Exploration of computational thinking skills using Scratch software.

In addition to task criteria in the *Can You Create a Game Challenge* supporting NGSS, the teachers added criteria for the computational concept of “events” as well as specific Scratch programming blocks to support user interactivity. Added task criteria included create an event to begin the Scratch game and use “Ask and Answer” to make the game interactive with a player. The Challenge asked students to test their game and make changes as needed, addressing areas of computational practices of experimenting and iterating; testing and debugging. The teachers added components to the rubric for assessment to address the criteria for computational thinking.

Because Heather, like the other STEM teachers, instructs students every year, she has the opportunity to see how students develop skills and dispositions as they progress from grade to grade. Through the use of multiple Scratch projects, Heather plans to

measure student progress in student use of Scratch and the development of computational thinking skills for her students, within the time span of one school year as well as across the years the student attends Brookside Elementary.

Now that I've gotten a Scratch game that I've done at the beginning of the year, I'm hoping to do another Scratch game with my 5th graders at the end and compare those rubric totals that I have to see if there was any kind of improvement. What will be exciting this year is I've started it with 4th grade and it will just be interesting to see if I hang onto those rubrics, it would just be interesting to see how they are doing in 4th grade compared to what they are seeing in 5th grade after they have had experience with the software already, hopefully I will see that climbing. (Heather, Interview 1, January 15, 2015)

Student practice of basic computer skills.

The teachers in the study used the task for students to practice basic computer skills for an authentic purpose, creating a digital game with a piece of software. Teachers reinforced the concepts of logging into a computer, logging off a computer, opening a file, naming a file, saving images from the Internet and saving a file to a specific location. Student questions to teachers during the project included "How can I save a picture from the Internet to use in my game?" (Annie, Observation 1, March 3, 2015); "How do we name ourselves?" (Annie, Observation 2, April 16, 2015); and "How do I save it?" (Susan, Observation 1, February 2, 2015).

Observational data showed that teachers gave students specific instruction for basic computer skills as well.

Before moving to the computers, Annie reminded students how to log into the computer and save their Scratch project. “Once you get to your computer,” she said, “sign on as yourself. Open the Scratch program and save to your folder. How do we save?”

The class responded, “File, save as” and, then, they continued repeating the steps needed to save the project to the H drive on the school server. (Annie, Observation 1, March 3, 2015)

While Annie had students practice logging into the computer and save a file to a server, Susan had students practice navigating to a website, logging in with a shared class account, correctly naming a file and, then, saving it to the Scratch project folder in Scratch.

The students got up from the floor and moved to their computers in the lab. Once seated, Susan began to give directions to get started on the project. “Go to the Scratch website. I want you to log in as the teacher, the username and password is on the board. I want you to click the word *create* and then *File, save as*, and save your game as *your teachers name_your name*. Are there any questions?” (Susan, Observation 1, February 2, 2015)

Students practice skills such as image searches using a search engine such as Google.

Heather noticed her students becoming efficient at locating desired images from the web, a task that previously took a long time for students to complete. “I think they

are learning more specific parameter words to put in there so they can find the information they need faster” (Heather, Interview 2, April 13, 2015).

Using *Can You Create a Game Challenge* for application phase of inquiry lesson.

All three teachers implemented the same *Can You Create a Game Challenge* in their classrooms. See Appendix A for digital game challenge and accompanying rubric. Annie, Heather and Susan decided to implement the task as an application of NGSS standards. Their reasons for placing the task at this point in the instructional sequence included time, behavior management and the scaffold of the learning activities. Annie prefers to design instruction using the *Can You Create a Game Challenge* by asking students to apply knowledge previously learned either in the STEM lab or in the classroom because of time. “I’m back to time efficiency, it takes so much time and I only see them about 28 times a year (Annie, Interview 1, March 3, 2015).” Using the *Can You Create a Game Challenge* as an application of skills helps Susan’s students focus on the work.

If I started with Scratch, I feel like they wouldn’t listen to me, they would be thinking about their game the whole time, so I’ve tried it both ways but I have found that I’m not going to tell them we are going to do a Scratch game until I need to tell them we going to do a Scratch game and then I tell them how to tie in what we have done earlier in the week. (Susan, Interview 1, January 29, 2015)

Placing the *Can You Create a Game Challenge* in the application phase of instruction allows Heather adequate time to pre-teach skills she feels are necessary for student success.

Right now with our 4th graders they are supposed to write a Scratch game in which they are creating some sort of sound pattern that then somebody else is supposed to try and figure out what their sound pattern is saying by looking at a code that they have created. So, I've already actually introduced Scratch to them prior in the year during the Hour of Code, so they already know that Scratch is some sort of video game that has sounds, it has cool characters and they can change it. So, they already have that background information. So, I've taught the content, the sound. We've done the vocabulary for what they need to know about sound waves. (Heather, Interview 1, January 15, 2015)

Teachers also used the task for students to apply previously learned science content and practice the basic computer skills while learning specific programming skills in Scratch. Heather described her interdisciplinary instructional approach in an interview.

When they (the students) figured out what they wanted their code to be, then my first step was introducing Scratch and we spent a day just importing sounds, making sure they knew where to save it, how to save it, how to pull it back up, how to close it, um, all of those different things and then the next lesson is going to be about how to put those sounds that they imported together to create the code and then after that the third lesson, hopefully is going to be how to use the ask and answer function so that after their sound code is written then someone can play it and listen to it and they are going to ask their user to try and guess the word and then let the user type the answer in to see if it's correct, it's broken down into very small parts. (Heather, Interview 1, January 15, 2015)

In the section below, I use criteria for authentic instruction determined through the literature review as common themes: environment, authority, role of teacher and shared knowledge (Callison & Lamb, 2004; Herrington *et al.*, 2003; Lombardi, 2007; Maina, 2004; Means & Olson, 1994; Newmann & Wehlage, 1993; Renzulli *et al.*, 2004).

Supporting a Collaborative, Social Learning Environment

Teachers in the study designed and implemented instruction with the intention of students working together and creating an environment conducive to collaborative work. The groupings in each class were varied based on access to technology, space, teacher preference and student preference.

Heather assigned students to work in pre-determined diverse groups, including mixed and same gender, upon entering the STEM lab. Students coming to the STEM lab form a line along the outside hallway wall, wait for Heather to assign them a table and then enter the room one at a time. Heather uses the seat numbers at each table for partnering up the students.

“Let’s find a face partner. Bridge a high five so I can see you have a partner,” said Heather. Students formed a bridge by high fiving another student directly across the table from them. “We are going to reflect with your face partner. What was not working well? Scratch game? Gallery walk? Or code? The partner with the highest seat number will be first person to share. Go.” (Heather, Observation 1, January 27, 2015)

While group work promotes student collaboration, Heather’s students work in groups on tasks involving technology based on the number of computers available (see Figure 7).

G	Laptop	G	G	Laptop	B	B	Laptop	B	B	Laptop	B
G	Group	G	B	Group	B		B	Group		B	
	A			C			E			G	
G	Laptop	B	G	Laptop	G	B	Laptop	G		Laptop	G
G	Group	B	G	Group		B	Group	G	B	Group	B
	B			D			F			H	

Front of the Classroom											
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Figure 7. Student seat placement and grouping for Heather’s STEM class. “B” represents a male student. “G” represents a female student.

Annie paired students for the project, assigning students at different academic levels together but permitted students to work independently. Even through the students were paired, each student created a project on an individual computer. Partners worked with the person sitting next to them, asking questions, sharing ideas and often creating identical games. Annie found collaborative work helps students with project management. “The ones (students) that are working in partners are learning to share the work load and not let one person do all the work” (Annie, Interview 1, March 3, 2015). See Figure 8 for student seat placement and grouping for the assignment.

Front of Classroom			
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Computer Group A	Computer Group A	Computer	Computer	Computer Group F	Computer Group F	Computer	Computer
B	B			B	G		
Computer Group B	Computer Group B	Computer Group C	Computer Group C	Computer Group G	Computer Group G	Computer Group H	Computer Group H
G	G	B	B	G	G	G	G
Computer Group D	Computer Group D	Computer Group E	Computer Group E	Computer Group I	Computer Group I	Computer Group J	Computer Group J
G	B	B	G	G	G	B	B

Figure 8. Student seat placement and grouping for Annie’s STEM class. “B” represents a male student. “G” represents a female student.

Susan allowed students to self-select partners for the project. During the first lesson, she introduced the task then verbally gave students the option of working with a group, a partner or alone. Students formed work groups in the computer lab on the first day of the lesson (Susan, Observation 1, February 2, 2105). On the second day of the lesson, the transition from rows of desktop computers in the lab to the round tables with laptops in the STEM room made it easier for students to talk, ask questions and share ideas with each other (Susan, Observational 2, February 3, 2015). See Figure 9 for Susan’s classroom arrangement.

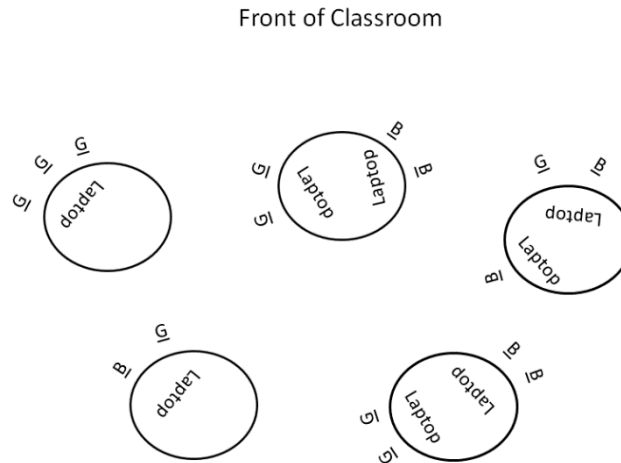


Figure 9. Student seating and grouping for Susan’s STEM class “B” represents a male student. “G” represents a female student.

The room arrangements allowed for each teacher to assist groups and individual students at tables or walk to the front of the room to gain attention and explain a concept to the entire class when needed. During classroom observations, Annie and Susan sat with students, joined the group for short periods of time and worked with them to solve a given problem. Heather moved among groups, standing or kneeling beside the table, but space limitations made it difficult for her to sit down to work with students. The movement of the teacher reflects the collaborative, social environment of the classroom. When possible, the teacher becomes a member of the team with students, physically sitting with them, listening to what they have discovered and helping think through solutions to problems.

Shared Authority

In all three classrooms, observational data found that students or groups of students who struggled with solving a problem sought out a more knowledgeable other to assist them. In some situations, the teacher was the more knowledgeable but often it was a fellow student. Even with the given content constraints, the structure of the game task allowed for student choice and decision-making for game construction. Students had direction over game genre, backgrounds, sprites, sounds and programming. Within groups, students negotiated with one another, listening to the ideas of fellow teammates and feedback from members of the class, including but not limited to the teacher.

It is the 3rd day of the game challenge in the STEM lab for students at Waterson Elementary school. Bursts of excitement in finding new features within the Scratch software to personalize games occasionally erupt in pockets of the classroom. Over in the back corner John calls another student by name, “Come over here, guys, look at this!” John shows them how the group has figured out the camera.

“How did you do that?”

“See this button? It lets you take a picture with the webcam.”

“Let me see.”

John clicks the button to open the webcam feature.

“I want to try.”

Eager to add their own picture to their game, the group rushes back to their computer to make edits.

Several minutes later, in another corner, a group of girls began rapping a song they made up. They lean over to the table next to them to share the newly discovered programming button. “Look, guys, we’ve figured out how to record.”

“How did you do that?” another student asked as he moves toward the computer.

“We found this microphone.”

They begin singing again. (Susan, Observation 3, February 4, 2015)

During my second observation at Main Street Elementary, Annie describes Gabe, a 5th grade student in her STEM class, as a kid who loves programming. As a member of the school’s robotics team, he was familiar with block based programming as well as the thinking involved. He just “thought that way” when solving problems with code. In the hallway before class, when going over STEM class directions and discussing ways to obtain help on a problem, a fellow student identified Gabe as a source of support. On the last day of the assignment, Annie asked Gabe to help answer questions for classmates struggling with the programming of the game. Gabe willingly transitioned between the roles of student and teacher aid, moving from classmate to classmate, asking questions and offering suggestions while using correct technical language.

Struggling to figure out how to program her game so a response appears to the player when typing in the correct answer, Jade raises her hand for assistance.

Gabe notices she needs some help and his teacher is working with another group, so he gets up from his seat to see if he can offer some support.

Jade: “How do I make something happen with the right answer?”

Gabe: “Are you using ask/answer?”

Jade: “yes.”

Gabe: “show me.”

Jade shows Gabe her program. “See right here,” she says, pointing to the screen.

“Oh yes, try putting the ask/answer here then it should appear over here on the other screen,” Gabe replies, pointing to Jade’s program.

“Oh, thanks,” Jade says as Gabe moves back to his seat. (Annie, Observation 2, April 16, 2015)

A few miles down the road, students at Brookside Elementary discovered the webcam in the Scratch software. The discovery is hard to contain to just members of the group, especially when neighboring students see and hear the excitement emerging from the end of their table.

At one end of a center table, students huddle around the laptop screen and appear to be posing for pictures. The students discovered the button that incorporates images taken from the webcam on the computer into the Scratch project. This particular group begins to take selfies to include in their game. The giggling and picture posing captures the attention of the students working beside them.

A student from the neighboring group asks, “How did you get your picture in there?”

A student from Group 3 replies, “If you click on the camera, you can use the webcam to take a picture for your background.”

Their teacher, Heather, walks over to the group, “Can I see your script, please?”

“I know you want to do the fun stuff, but you need to do this first, then you can play and add things on.” (Heather, Observation 2, February 2, 2015)

Even though students freely explored the Scratch environment, finding interesting capabilities of the software, Heather still felt a sense of responsibility to keep students on task. While students and teachers shared authority in the classroom, the teacher still maintained power, including the redirection of students. The game challenge was a class assignment. Students worked on specific task goals with criteria set by the teacher. The teacher created the timeline for when the products are due and then assigned a grade to the finished game. The teacher expected the students to adhere to routines such as entering the room, saving files or turning in assignments and classroom rules.

For Heather, the importance of shared authority is visible through skills such as learning task delegation. While it is easy for students working in a group to let the expert always assume a specific role such as programmer or artist, it is important for each child in the group to develop skills associated with each role. She encourages taking turns with each task and hopes students “are learning to make sure everyone has a turn instead of just one person focusing on the computer and letting each person work on it. “They are definitely figuring out who gets it right away and I’ll notice that person will get the computer sort of shoved to them because they know that person understands and they could get it done a little faster” (Heather, Interview 2, April 13, 2015). Through group work and encouraging students to assume different roles for the task, students in the group need to rely on those who know more, including members of the group, the class and the teacher.

Annie and Susan physically joined the student teams, moving from group to group. These simple unstated gestures gave a sense of community to the classroom and placed the teacher in the position of a learner among learners (Annie, Observation 2, April 16, 2015; Susan, Observation 2, February 3, 2015). As such, the students in both classes were comfortable moving around and asking another student for assistance. Heather still maintained a supervisory position, standing among a seated group of students, never fully joining the group as a member (Heather, Observation 2, February 2, 2015). While her students ventured out to a neighbor for assistance on a problem, Heather felt the children still viewed her as the trusted source of knowledge in the classroom (Heather, Interview 2, April 13, 2015).

A collaborative, social environment supports teacher-student shared authority and changes the role of the teacher within instruction. These teachers, though more knowledgeable of science content and some aspects of block based programming, are not experts on many of the new tools used for creative computing, technical language associated with computer science or computational thinking skills. By sharing the role of the more knowledgeable other in the class, a teacher's role flows from lecturer, to facilitator, to coach, to co-learner.

Shared Authority and the Role of the Teacher

During the implementation of instruction, Annie and Susan viewed their role within the lesson as that of a facilitator, designing instruction and guiding students along the learning journey (Annie, Interview 1, March 3, 2015; Susan, Interview 1, January 29, 2015). In an interview with Heather, she saw herself as something similar to a facilitator,

but also recognized her role in this type of learning environment as different from mere facilitation and acknowledged she is not the expert in the room:

I would see myself more as a facilitator role, meaning that all I can show the kids is kind of the experience I've had and what I know what to do with the software and that I want them to be able to reflect those same things back and then figure out what else they can add to it later on. It's not a teacher role, it's a very different role when we are doing the gaming software, it's a very different feel than when you are sort of the expert and know what is going on or you have the ability to quickly find the answer and that doesn't happen with Scratch. I don't know always have that capability to find the answer, so it is a different role than what we are used to. (Heather, Interview 1, January 15, 2015)

The conversation with Heather revealed an important detail evident across the classrooms, the changing role of the teacher when implementing a game challenge with limited personal knowledge and experience with programming software. While not the expert or always the most knowledgeable person in the room in regards to programming in the Scratch environment, the teachers were experts in problem solving strategies when they did not know an answer. Annie's introduction of the game task illustrates how she made her thinking visible to her students through personally creating a game based on the task she assigned:

Annie gathered the students on the carpet in front of the large, interactive display on the board. As part of the lesson, she wanted to share her experience working through the challenge herself and explicitly show students how to find and use the help feature for the programming blocks within Scratch. She quickly moved the

computer mouse to locate and launch the Scratch program. “I did the challenge myself,” she says to the group of 5th graders in front of her, “It took me off and on for two hours and ten versions but I’ve had lots of time to think about it. What is your favorite game to play? Think about what you like about the game. Do you think the game designer started out that way, with that version? No, it was probably basic and they added to it.”

Annie proceeded to introduce the Scratch challenge to the students, sharing ideas about what sounds a dot or dash might be in the Scratch program. She grasps the wireless mouse, pointing to the file button and then selecting open. Click. She navigates to a folder and opens it on the screen. Click. A list of multiple versions of her game she created appears. She opens the game she identifies as version one to show students how she began, a version that was far from perfect, but simply a start. “I can now make my cat play a sound,” she says, showing her students the programming blocks she used to figure it out. “You all have played with them but haven’t used the questions. Let me show you what I started with and what I ended with. After version one, I noticed my player had no direction.”

Annie’s students play through her version one game as a group and appeared anxious to provide her feedback. Knowing version one of her game needed much work, Annie asked the children, “what was wrong?” Answers from students began to pop in the air:

“It was too fast.”

“It was boring.”

“It didn’t do anything.”

Annie nodded in agreement, “This is why I have ten versions. Here is my program for what you just saw. After I played, I realized I didn’t have any directions. So, the next version, I added directions.”

Annie clicks the mouse again, to open version two of her game. “Is that better? Do you know what a clap and a dash sounded like?”

The students nodded.

“Ten versions to get to this. You may start out with one and it may not be your best. So far is this better?”

“Yes,” replied the class.

“This is only four letters that I’ve given you. Doing it a step at a time made it easy. I had no idea how to do this here,” Annie says, pointing to the ask/answer block. “Let me show you what I did.” She right clicks on the block, demonstrating how the user can locate the help feature in Scratch. “See the help block, every single block you need help with is here and will walk you through it.” Suddenly, another menu appeared on the right hand side of the screen, offering a step by step scaffold for any user struggling with that particular programming block. “Some of this I don’t know and when I went to New York I was still learning things.”

(Annie, Observation 1, March 3, 2015)

Through the sharing of version after version, explaining her thoughts along the way and how she sought out help when needed, Annie modeled her thinking for her students. She revealed to her students the iterative process of game design and

programming. She let her students see how she managed to break the large problem of creating a game with several constraints into small problems to solve, making changes to improve the game for the player along the way. She demonstrated the dispositions of a computational thinker. In a later classroom visit (Annie, Observation 2, April 16, 2015), I observed Annie modeling her thinking once again as she struggled with providing a guiding answer to a student programming problem:

The student used the ask/answer block and programmed the game to inform the player when the answer is correct but struggled to figure out how to program the game to inform the player when the answer is wrong. Annie asked the student to articulate the specific problem as well as the steps she had taken to figure the problem out. Without knowing the answer to the programming problem, Annie sat next to the student and as a team, they worked together brainstorming ideas. After a few minutes, Annie stopped to see if a more knowledgeable other in the room had a solution by simply asking the class, “has anyone figured out how to get something to appear on the screen when the answer in the game is wrong?” No one replied, but several other students expressed interest in finding a solution to this problem as well. Annie and the young girl beside her worked through several ideas; would two “if” programming blocks work or would a loop help. They verbalized their thinking allowing for others to hear their thoughts, moving a finger along the screen to read the program as it executed. Annie finally turned to me, as I observed the struggle of solving this programming problem. “Do you know of a block that would be if this or if that?” I replied, “Do you mean *if*,

else?” Two pair of eyes lit up immediately, “Yes, yes, I bet that would work.

Let’s try that!” (Annie, Observation 2, April 16, 2015).

In addition to modeling, the teachers showed their students that even when they did not know, they still continued to seek a solution. Not only did the teachers participate in this type of problem exploration, but coached students to do so as well. Susan illustrated this coaching technique during an observation:

Susan moved from table to table, working with individual and small groups as needed. One student seemed to have trouble getting a sprite to move a specific way on the screen.

“I want my sprite to start here, how I do that?” asked John, pointing to the screen of the laptop.

Susan replied, “How have you tried to solve the problem?”

“I tried this block, but that isn’t working.”

Susan paused for a moment, “Mmm,” she said, “that’s not working. See if you can try a different solution. I’ll stop back by in a couple of minutes to see how you are coming.”

Susan turned and walked to assist another child in the room. A few minutes passed and she walked back to the still struggling student.

Susan offered a little bit of information to John. “Well, do you see these x,y numbers down here,” she said, “They tell you where things are on the stage.” She pointed to the screen, moving her finger for a visual explanation as she continued speaking. “The x number goes this way and the y axis this way. Together they are called coordinates. Maybe you can use the x,y axis and

coordinates to help you place the sprite.” (Susan, Observation 2, February 3, 2015)

This coaching technique used by Susan provided the struggling student time to test out different ideas to solving the problem while suggesting confidence in his ability to find a solution. Noticing he was still struggling, Susan gave the student with a small bit of information, explaining the mathematical content he needed without giving a solution to the problem. Susan communicated two types of knowledge with this student: the definition of the x,y coordinates and the unspoken guidance of problem exploration by providing a scaffold for the student to independently solve the problem without explicitly providing step by step directions to the student.

Shared Knowledge

Tinzmann *et al.*, (1990) identified one characteristic of a collaborative classroom as shared knowledge, where knowledge flows among all members of the classroom, including both teacher and student. Because Annie, Heather and Susan recognized a personal lack of expert knowledge on Scratch programming, they did not always have a solution in mind to guide a student having a problem on the game challenge. One resource the STEM teachers utilized was the knowledge and experience of classroom members.

Annie relied on students to help classmates troubleshoot and discover new tools within the software:

Students from the 5th grade classroom lined up alongside the hallway wall, one tile block apart from one another. Annie liked to give directions to the class prior to entering the computer lab at Main Street Elementary. After a quick reminder

regarding the amount of time left to finish the project, Annie engages the class with a question about finding assistance when they are stuck on a problem:

“Where can you go for help?” she asked.

One student replied, “You.”

Another answered, “Gabe.”

Annie responded, “Yes, me, a friend or neighbor. Don’t forget about help in Scratch. Right click and go to HELP for things like ask and answer.” (Annie, Observation 2, April 16, 2015)

During instruction, Susan answered many student questions with phrases such as “I don’t know, you tell me” or “how have you tried to solve that problem?” Students working in pairs continued to talk through the problem or sought answers from a neighbor. Susan observed the importance of student sharing of knowledge while working on the game challenge, noting a peer often became a first source of information for a student and new ideas. “For the most part I think they would use each other, they would notice like ‘oh, that’s cool’, ‘how did they do that’, they like to look at each other’s projects” (Susan, Interview 2, April 13, 2015).

Heather, however, stated her students did not initially share ideas and information outside their work group, using her and the software as the only resources. The inclusion of a gallery walk provided students the opportunity to see and play games created by other groups, sparking an interest.

I think when they were actually, initially doing the game themselves, they were just within their group and they didn’t even have a thought of going to another person yet. Once they had walked around and had seen what other people had set

up and had done, they were able to go and ask their friend, but their friends almost had to prove that they had something to teach or something to show, because I don't think that was a thought. When it is all so new, the only person I think they really trust is the teacher, the person who supposedly knows it. (Heather, Interview 2, April 13, 2015)

When asked how they sought help when struggling with a game task problem, students across all three STEM classrooms who acknowledged they needed assistance, tried to problem solve, ask a partner or team member, another student or teacher. See Table 9 below.

Table 9

Sources of Help from Students Working on the Can You Create a Game Challenge

Identified Source(s) of Help by Student	Number of Students from Participating Classes Requesting Help (n=25)
STEM Teacher	N=4
Student	N=4
Partner/Team	N=6
STEM teacher or student	N=1
STEM teacher or partner/team	N=1
Attempted independently, then teacher	N=1
Attempted independently, then student	N=4
Used the Help feature in Scratch	N=3
Attempted independently by thinking like the STEM teacher	N=1

While the STEM students in the study identified peers as a source of knowledge when faced with a problem on the task, the recognition by the teacher offering validity to student responses is important. Annie's clear directions and expectations set prior to students entering the classroom provided them with the understanding that asking for help from a source other than the classroom teacher is both permissible and encouraged. By including a friend or neighbor as a resource for help when needed, Annie verbally acknowledged and valued the knowledge of the students in the class. Susan acknowledgement to her students that she did not have a simple solution to a task problem encouraged them to seek help from each other. Inclusion of time for students to play classmates' games provides students with an opportunity to explore how other groups attempted to solve the problem as well as the use of different programming blocks and features of the Scratch program. Once a student viewed the success of another group and the teacher acknowledged students as a reliable source of information, students felt comfortable asking a friend or neighboring group for help.

Members of the classroom shared explicit knowledge through written and verbal factual information and directions. Information shared among class members included facts such as the combination of dots and dashes for the letter "H" in Morse code (Annie, Observation 2, April 16, 2015), how to locate the help feature on a Scratch block (Annie, Observation 2, April 16, 2015; Heather, Observations 1,2,3; Susan, Observations, 1,2,3) or which button to click to transform the white background canvas into a colorful masterpiece (Heather, Observation 2, February 2, 2015; Susan, Observation 3, February 4, 2015). Through all of the formal language, established processes and documents,

another type of knowledge flowed, creating a web-like work environment, which was spontaneous and open to sharing. Class members shared tacit knowledge through stories of how they discovered a feature, why they selected a sprite and how they solved a programming problem. The use of the game task within instruction became a mediating tool used by class members to share the typical classroom knowledge of facts and routines, as well as the flow of thinking, problem solving and dispositions. A graphic (see Figure 10) illustrates how knowledge flowed in the classrooms among members.

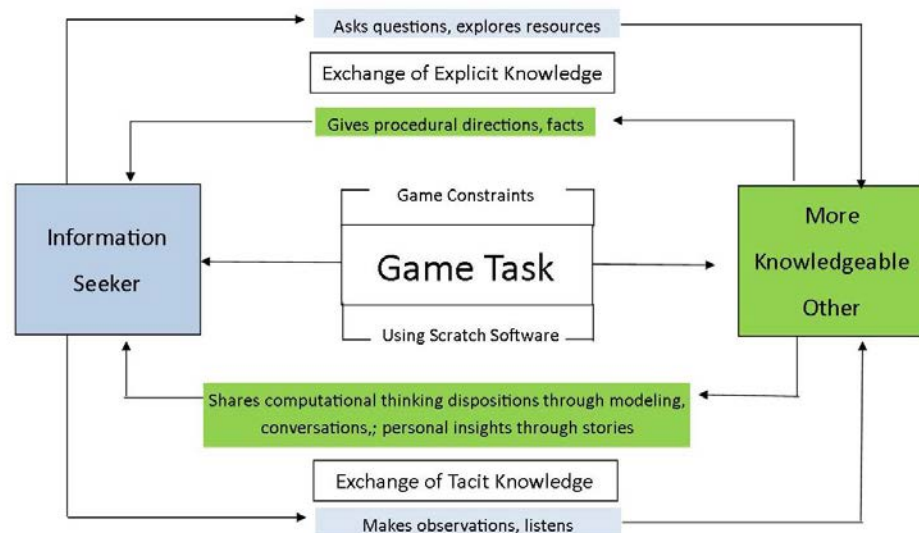


Figure 10. Flow of knowledge in the classrooms

The collaborative structure of the classroom supports the social construction of knowledge. The person seeking information asks questions to a more knowledgeable other or explores available resources for answers. The more knowledgeable other responds with specific directions or facts. The information seeker observes and listens to the more knowledgeable others in their group or class, obtaining tacit knowledge through

conversations, modeling and stories. While this discussion occurs between the information seeker and the information provider, others in the classroom community benefit from the exchange of knowledge. With all members of the class working on the same challenge, the game task anchored the exchange, providing a purpose through the use of constraints and a platform for creative problem solving through programming. The exchange of knowledge extends to students in the classroom but not part of the initial discussion.

In a conversation with Annie, she describes a student who used information gained from listening and observing the others around her:

She paid attention to when we were problem solving using *if and else*. She quietly just listened and then implemented it into her project, so she was paying attention to what we were doing instead of needing to ask me the same question again, because I asked her if she had figured it out or if she had listened and she said I listened to what you said and I just did it. To me that is a good skill.

(Annie, Interview 2, April 16, 2015)

The exchange of knowledge between Annie and the student extended to peripheral students in the class (see Figure 11).

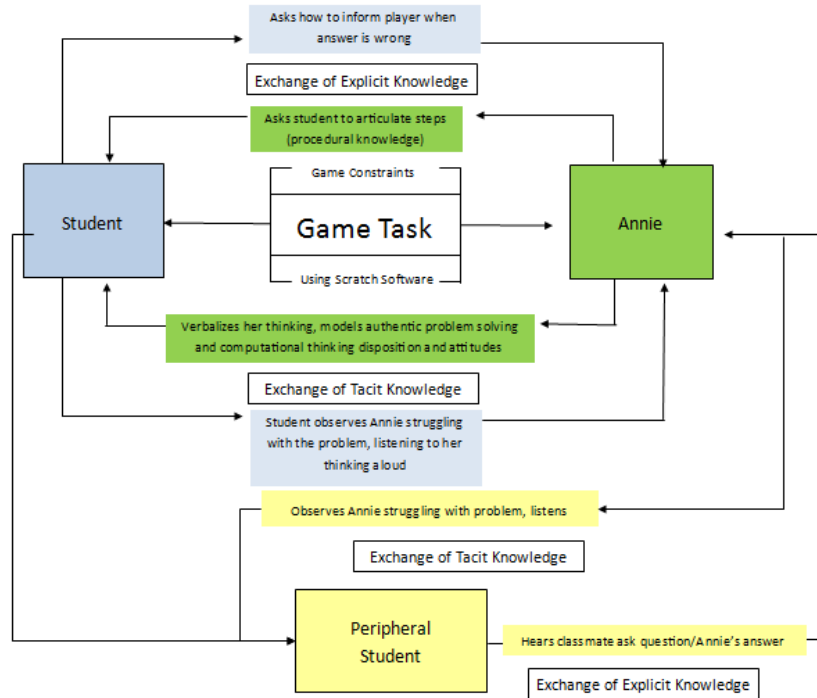


Figure 11. Flow of knowledge in “Annie’s” classroom with peripheral students

From a traditional social perspective on learning, discourse in the context of a shared relevant task introduces novices to a community of knowledge (Driver, Asoko, Leach, Scott, & Mortimer, 1994). Within the case study classrooms, learners have access to the community of knowledge around them including the cultural tools of language, rules and dispositions exchanged through different means. Members of the classroom constructed knowledge through the social conversations and activities of the shared game challenge.

Supporting Question 2: How does the teacher’s use of a digital game based challenge work as an assessment of elementary students’ understanding of Common Core/Next Generation Science state standards?

Role of Assessment

The use of real world, cognitively demanding tasks is one criteria of authentic assessment derived from the literature review. Digital game play is an activity shared by almost every adolescent in America. According to a PEW study, 97% of American youth, ages of 12 to 17 and across racial, ethnic and socio-economic spectrum, play computer, console, portable or cell phone games (Center, 2008). Digital game play is a real world activity for students in elementary grades as well. In interviews with teachers, all believed the students in their classroom had prior experience with video games or game apps regardless of access to other types of technology or software.

Heather in her first interview stated her students’ previous technology experiences included “anything with video games or video game software, like PSP, Wii, I don’t know all the brands. I’d say that most of the software that they are used to is like a video game format.” Likewise, Annie made a similar statement in her first interview as well, noting her student came to school with multiple technology experiences, including game play, but lacked productivity skills needed in school such as typing:

The kids all know apps... they can do all that stuff. Games, video games, but not what I call the more academic stuff, like being able to sit down and type something which is required in Common Core, that you have to type so many pages in one sitting, they can’t, it’s a struggle. (Annie, Interview 1, March 3, 2015)

Likewise, Susan believed her students came to school with prior digital game play experience, but mentioned how she noticed a level of student engagement when she incorporated a connection to digital games into learning experiences for her students. “Kids will beg (to play digital games), like I’m just going to go home and play video games and not do homework, that’s their goal. So like last year when Hour of Code had Angry Birds, it was more exciting to them because of the theme of the game and they didn’t realize what they were learning” (Susan, Interview 1, January 29, 2015).

Perceptions of Authenticity of Assessment

Student reflections of the game task suggest they believed the task to be real world. From the completed student reflections (n=33), students acknowledge the ability to play their own games (n=26), play a friend’s game (n=21) and viewed themselves as a game designer in the experience (n=22). One student from Waterson Elementary still viewed themselves as a game designer despite the ability to play their own game or a friend’s game. Reflective statements from students who viewed themselves as a game designer

- indicated feelings of ownership (n=16): “We programmed a game and we had a free choice on what the characters were and sounds and backgrounds”,
- identified as a game designer (n=11): “Game designers mess up sometimes, and I messed up a couple of times”,
- identified as a programmer (n=6): “I programmed everything that happened”,

- difficulty of task/felt accomplished (n=4): “I have never accomplished something like this by myself. Working together with my friend's that’s what made my happy”,
- identified as a learner (n=1): “because it help me learn more and I love designing”; and no reason (n=1).

A chart (see Figure 12) provides a visual representation of the number of students who could play their own game, a friend’s game and identified as a game designer by participating STEM school.

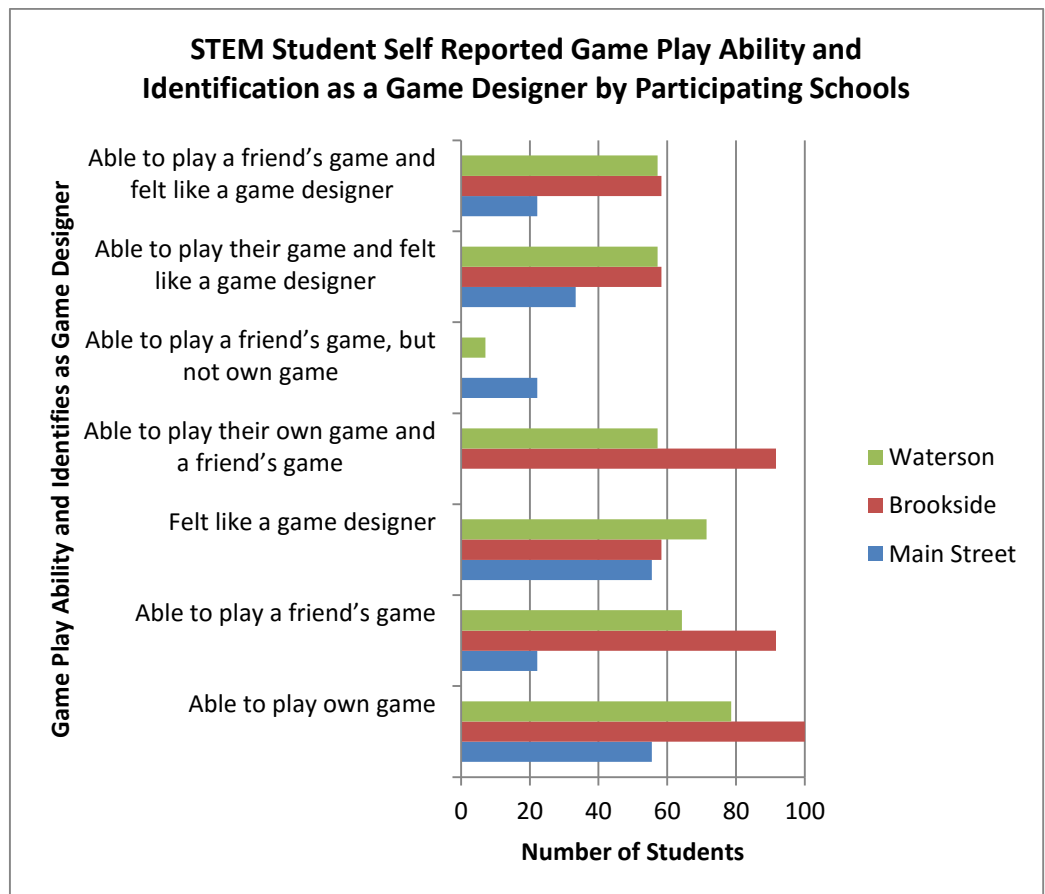


Figure 12: STEM student self-reported game play ability and identification as a game designer by participating schools.

The high number of students reporting the ability to play their own game as well as a friend's game at Brookside could be from the inclusion of a gallery walk, an experience intentionally planned for within the teacher's unit design. This instructional technique encouraged students to have a playable game for others to explore as well as play-test classmates' games.

Not all students indicated they felt like a game designer while completing the challenge. Student comments from those who did not feel like a game designer included reasons such as it was an assignment (n=2), "felt like regular 4th grade"; inauthentic task based on perceptions of game designers (n=2), "not really because I was not spending a lot of time on it compared to a real game designer"; inauthentic task based on perceptions of commercial digital games (n=2) "no because it's not going to get popular or heard"; difficulty of task/not accomplished (n=4), "no because it was a little difficult, but when I get used to it, I will"; and no reason (n=2) (Student Self Reflections, 2016).

In an interview with Annie, she believed her students developed a deeper understanding of computer animation and the thinking required by game designers to create a good game. "The animated things that they watch all the time on TV and video games, what is really behind it, that is not just the magic of a computer but it is somebody having to think it through and draw and create it and put it in order" (Annie, Interview 2, April 16, 2015).

Cognitive Demand

Comments from the written student reflection indicate the task was cognitively demanding and required problem solving, application of content and creative thinking.

Students (n=22) used the word “hard” or “difficult” to describe the task but included comments suggesting the importance of a social-collaborative work environment in persevering on difficult assignments. Remarks included “we did it as a team;” “two heads are better than one;” and “it was hard and easy at the same time.”

Students who indicated the task was challenging found difficulty in areas such as game design elements (n=10); game play/play-testing (n=2); specific Scratch blocks/programming (n=4), basic computer skill (n=1), iterative design process of testing and debugging (n=5); time consuming (n=2) and group decision-making (n=2) (Student Self Reflections, 2016).

Teachers felt the student use of creative computing in Scratch to create the Morse code game added a level of complexity to the task. When asked to describe exemplary student projects, the teachers highlighted games where students had figured out difficult programming features and were able to reuse parts of code they had figured out or worked beyond the basic requirements of the rubric.

In a conversation with Heather discussing exemplary projects, she stated, “My friends who were able to load their background and load their character, perhaps get their character to move along with the sound, friends that extended beyond the minimum rubric requirements, those are the ones I would say are exemplary” (Heather, Interview 2, April 13, 2015).

Susan shared a similar view when discussing exemplary projects. She said, “the ones who I think are exemplary are the ones who correctly did the “ask and answer” where they were able to type in an answer if they got it right. It would have a correct response like “good job” and if it was wrong, like “try again”. The ones that used the

blocks that fit inside the blocks and all that, I think that was exemplary. This was the first time they had even seen Scratch, they went above and beyond my expectations” (Susan, Interview 2, April 13, 2015).

While Annie felt all of her student projects were beyond her initial expectation, she felt her students with disabilities really shined on this project. “Well I showed you the one earlier that was differentiated, for my deaf and hard of hearing students, so that was excellent because they had to figure out something on their own that we hadn’t talked about in class and then it was a matter of helping them tweak the little details to make it work the way they wanted it to” (Annie, Interview 2, April 16, 2015). Because the task included sound patterns, Annie’s students with hearing disabilities needed an alternative way to demonstrate communicating with patterns. These students figured out they could use the graphical representations of dots and dashes in Morse code to create sprites in the Scratch sprite editor feature of the software and write a program to communicate a message in Scratch, demonstrating how people communicate with patterns.

Forms of Assessment

Teachers in this study used several forms of assessment for both Next Generation Science Standards and components of computational thinking. Teacher created rubrics with assessment criteria reflected the task criteria based on the NGSS standard and specific computational thinking skills and Scratch programming blocks for the *Can You Create a Game Challenge*. Teachers made expectations for the project clear to students with explicit criteria in the rubric. In addition, students played active roles in assessing

their own work and their peers' work. These assessments included formative and summative measures, and peer feedback through a gallery walk.

Formative Assessment

Teachers assessed the process of designing games using Scratch software and the final game product. During the game design process, teachers and students used feedback to guide each other in the creation of the game, discussing game design elements, including user controls, rules, game structure as well as the computational concepts of sequence, events and conditionals. Heather used the rubric as formative assessment, providing specific feedback to students with the option to improve their game and project grade based on rubric criteria:

I introduce the rubric to them at the beginning of the project and I show them that this is what I'm going to be using to evaluate you. This is the area that you want to live," pointing to the proficient area of the paper rubric. "This is your average, this is where I expect everybody to be and if you went beyond that then these are the things that would need to happen or things that I would be looking for. So for this year, a lot of what happened, like when I gave that cutoff point that the game was due and I was grading, that was sort of that midpoint touch because some of them, including some of them that thought they had done a really nice job on their game, when we actually looked at it and it reflected a number they realized they didn't label much of their game or they didn't show this content area, how it fits together so they got a low score on that so it was their chance to go back then and fix and rework and bring it back to me again and I would adjust the grade.

(Heather, Interview 2, April 13, 2015)

Susan provided just in time feedback to students during the game creation process describing it in an interview as a “live verbal feed” and asking students, “what about this or what do you think about that, how can you make this part better (Susan, Interview 2, April 13, 2015).” Observational data supported her statements:

Susan walks over to a group of students to playtest their game. On the computer screen, a question appears with a box to type in an answer. Susan enters her answer to the question while the students watch over her shoulder.

“I answered the question he was asking, is it what you want?” she asked.

“No,” replied one of the group members.

“Well,” Susan says, “what question should he ask? He asked me, ‘do you have any friends?’ Are you saying I don’t?”

“No,” replied another group member.

“Is this question going to give you the answers you want?” Susan asks.

(Susan, Observation 2, February 2, 2015)

Susan didn’t offer a solution to the group, but her feedback provided guidance to solving the problem on their own.

Annie used the rubric for the game project as a formative assessment tool as well. In an interview with Annie, she explained how she provided students with the rubric and criteria at the beginning of the lesson:

When I introduce it, they have the rubric and what they are required to have in their program. It was the minimum requirements and they had those to check themselves as they worked. I kept those (rubrics), and they would drop them off and pick them up during class but they knew they had to have things; it had to be

visually appealing, it had to have a four-letter or smaller word, that is what we were working toward. It had to have controls to start and sprites. I will have to go back and look at exactly what they had to have, but they knew they had to have certain things and they could check them off, so when I go back through them, they knew exactly what was expected at a minimum. (Annie, Interview 2, April 16, 2015)

Annie then shared her process of monitoring student understanding of both content knowledge and computational thinking skills:

Once they finish, we will get to a certain point and I'll go back and just do a formative assessment and just look at what they've made so far. It's literally just a check list and I go around and make little notes, like instead of starting with one command, if they had six different controls unnecessarily. So obviously they don't understand that concept or you know, they couldn't understand how to do a change of background after I showed them twice and then showed them once on the computer. They still aren't getting it, so I do that at different points. (Annie, Interview 2, April 16, 2015)

Student Conversations as Evidence of Learning

The physical and social structures of the classes provided a platform for rich discussions. Proximity to other students and working in groups allowed students to easily communicate about the task. Student conversations included the language of the Scratch environment and computational thinking, game design elements as well as the science content to communicate about the project (Heather, Observation 1, January 27, 2015;

Annie, Observation 2, April 16, 2015; Susan, Observation 3, February 4, 2015).

Observational data from the classroom found teachers and students using terms from the Scratch environment such as sprite, costume, background, broadcast, wait button, and ask/answer button (Heather, Observation 2, February 2, 2015; Annie, Observation 2, April 16, 2015; Susan, Observation 1, February 2, 2015). Gabe, the 5th grade student in Annie's class, used correct technical language when providing assistance to his peers (Annie, Observation 2, April 16, 2015). This practice of using correct terminology within an authentic environment allowed students and teachers the opportunity to develop language specific to the Scratch environment, making the conversation/dialogue authentic to the programming design task.

In an interview with Susan, I asked for examples regarding how her students demonstrated understanding of communicating with patterns, she identified conversations between students as a type of formative assessment:

Conversations, absolutely, because I could hear them talk about how coding is kind of like communicating with patterns and how not only did they get Morse code in here, but they got the computer coding of binary and how computers think things, like you have to put things in exactly or the computer isn't going to know what you are thinking- um, I think they got that. (Susan, Interview 2, April 13, 2015)

Gallery Walk as Peer Assessment

Student groups or individuals created realistic products demonstrating knowledge of both content for assessment as well as computational thinking skills as a product for assessment. During the learning process, teachers often reminded students to think about

the player because they were creating a playable game. The inclusion of a gallery walk provided students an opportunity to play test games and provide feedback to the class as a whole. Heather used the Gallery Walk at Brookside during an observation:

Heather gained the attention of the class, and then gave instructions. “Game will be ready when in projection mode. You need to click on the button that looks like a square with legs. Stand up with paper and push chair in, we are going to spend three minutes at each computer to play test.”

The students moved as a team to the computer next to them, attempting to launch the game and solve the mystery word. Students wrote the mystery word for each team’s game on an answer sheet.

One young girl leaned toward a teammate, “Did you put the sound on?”

“Yes,” she replied.

“Did you program 10 seconds in between?”

“No,” she said.

A similar conversation occurred with the group next to them.

“Is *Teate* a word?” one young boy asked.

His teammates flipped through the notebook accompanying the game for help. When all else failed, they stopped the game to look at how the group had programmed the game.

Heather walked from group to group, asking questions such as “Did you click the green flag?” or “Wonder why the game said, ‘Sorry, try again’?” She also made comments such as “Here is what I see happening,” if students encountered game play problems.

When time was up, and all teams had play-tested all of the games, students moved back to their seats. Heather read the correct word and students marked their responses as correct or incorrect. Heather directed the students to find a face partner to debrief about what went well and what did not. Then students shared to the group their findings.

One student said, “Someone circled code word in book” (anyone could guess)

Heather shared one of her findings, “The code, it was hard to guess, the handwriting hard to read, someone wrote in cursive.”

Another student mentioned, “When we got the word right it only went *dog* *dog*, we didn’t know if it was right.”

A classmate offered a solution to that problem, “Maybe they could put in a different word.”

Heather responded, “That is a programming issue.”

Additional responses included:

“One group didn’t have complete handwriting.”

“The sound didn’t come on.”

“Some games used a flag to start, some used the space bar. We needed more instructions on the screen.”

“Some forgot sec (block) or 5 sec (block) to wait, we couldn’t figure it out.”

Heather used the gallery walk as a way for students to improve their games, thinking about the player experience. “Playing each other’s games gave

us some great ideas on how we can make our games better. Some need to have directions, some need to check how many seconds you placed between letters and sounds; some need to write their guide neater for the players” (Heather, Observation 3, February 12, 2015).

Assessment of Computational Thinking

Along with the Next Generation Science Standards for assessment, teachers included the computational thinking skill of user interactivity as task criteria. Students used an event block in their Scratch game design to launch the game as well as the ask/answer block to promote player interaction. In both the formative and summative assessment of the games, teachers evaluated the student use of these blocks using the rubric.

Heather made a point to remind students during the gallery walk to click the green flag to launch the game as a way to formatively assess if the game met that criteria stated in the rubric. Following the Gallery Walk, she reminded students of the criteria again, mentioning several games did not start with the clicking of the green flag (Heather, Observation 3, February 12, 2015). Susan also play-tested student games to help students troubleshoot and to see if the rubric criteria for using the ask/answer block worked in the student game as intended (Susan, Observation 3, February 4, 2015).

Annie shared a project with me during her second interview. This student had demonstrated understanding of interactivity through the use of the ask/answer block but she also demonstrated the creative computing practice of expressing through her creativity and connecting by using the knowledge of the people around her:

It is not perfect, but she used more creativity in things that she was not requested of her to use. Her backgrounds and sprites are drawn completely on her own and made up in paint, but in addition to that, she animated her sprite to make the wings flap, which was something ... so this one worked out well. It's not the most perfect program, but to me she went about it well and even though it isn't perfect it worked out well. (Annie, Interview 2, April 16, 2015)

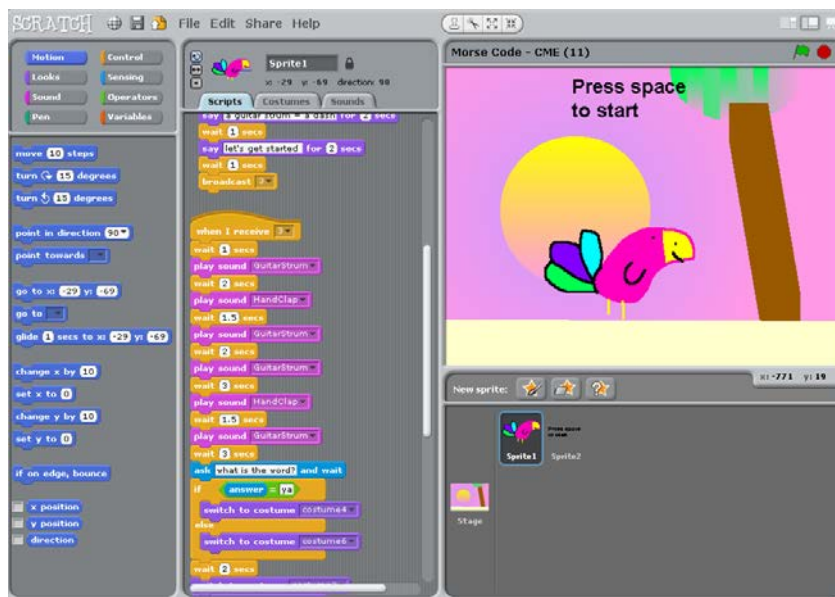


Figure 13. Screen shot of game identified by Annie as creative.

Susan identified a project where a pair of students went above and beyond the computational thinking criteria provided in the Challenge:

I think they had to actually understand how things actually worked, because it's a two way thing. It's not just the video saying "look at this", the player had to interact and type in the answer and how would you decode that answer they put in ... they were able to do more of the complex if/then, then say this, if they get it

incorrect, and say this, if they get it correct, I didn't expect them to be able to do that. I think that some of them kind of taught each other the same thing. (Susan, Interview 2, April 13, 2015)

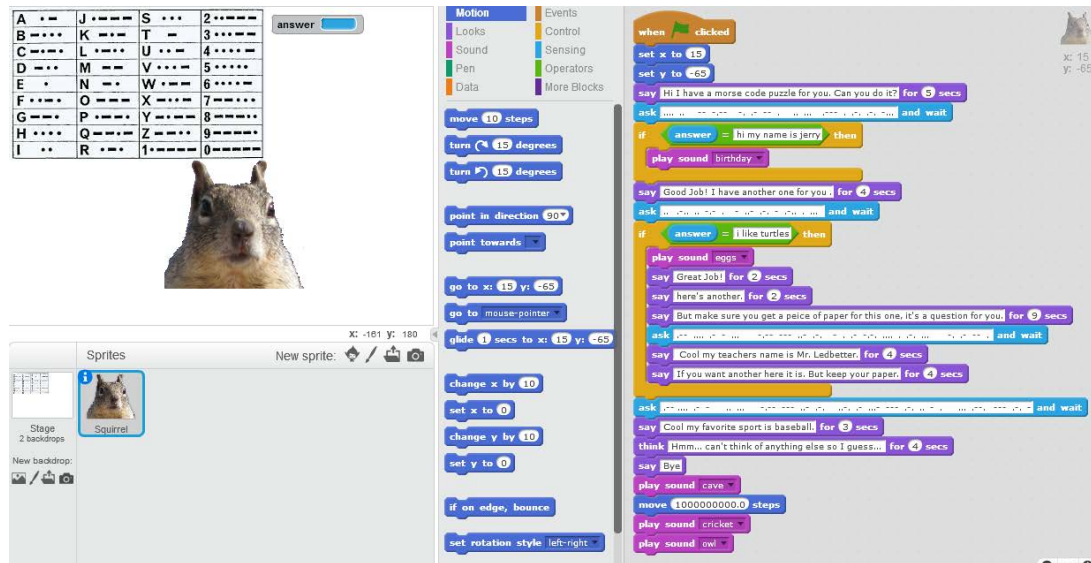


Figure 14. Screen shot of student game identified by Susan as complex.

Teachers did not formally assess the computational thinking skill *debugging*. However, evidence suggests students developed the process through the game design challenge. Annie mentioned students demonstrating debugging in an interview, the students “realize all their commands are coming on top of each other, so I need to go back and put a wait in. So, they can debug and if they have a glitch, what I need to do to stop it and finding it on their own” (Annie, Interview 2, April 16, 2015).

Game Design

While the games students in the study created for the *Can You Create a Game Challenge* differed in terms of delivery of Morse code patterns to the player, sprites used

and programming, all of the completed student games submitted for the study (n=13) produced used an instructional drill and practice game design for the project. The game design required the player to either listen to or read patterns and answer a question. A correct answer would provide a positive comment and in some games, and would advance to the next level. An incorrect answer would provide a negative comment, such as try again or you lose.

Teachers in the study played student games to assess for interactivity and a game goal of the player correctly solving the mystery word created with sound patterns as per the rubric. In addition, teachers formatively assessed students' knowledge of game design concepts such as player feedback, rules and win through questions during the game design process in class. Heather engaged her students in a conversation about player feedback during an observation:

Heather asks her class, "What happens in a video or computer game if you get the answer wrong?"

"It says please try again," the students reply.

"Do you think we could get our game to do that? Look at your code, what do you think we could add?"

The students begin to share ideas, "we could record our voice."

Heather tells the class, "This is your next challenge, I'm going to give you three minutes and the 1st group to get it will come to the front to share." (Heather, Observation 2, February 2, 2015)

While Heather play-tested a group's game, she gave the students feedback about communicating a win to the player. The group had inserted a sound, but the

communication of winning the game was unclear to the player. Heather used the situation to help guide student understanding:

After play-testing the game, Heather asked the students, “How will the person playing the game know if they’ve won? There is a flaw because they (the player) won’t know what the sound means.” The students began to problem solve as a group. “We could make signs or give directions (when a particular sound plays, you have won the game).” Another student suggested, “Maybe we had the same sound for any game,” indicating all of the games created in the class could use the same sound to communicate a win to the player. (Heather, Observation 2, February 2, 2015)

Annie gave similar feedback to students when play-testing games during the game design process as well, encouraging her students to consider how the player will interact with their game. “I hear that you have two sounds, but they both sound a little long. Do you think your player will be able to tell the difference between a dot and a dash? What could you change to fix that?” (Annie, Observation 1, March 3, 2015).

In reflecting upon the use of the *Can You Create a Game Challenge*, thinking about ways the teacher could modify instruction to improve the learning outcomes;

Heather mentioned an intentional focus on some game design elements:

(I would) make them (the students) more aware that their game needs to have instructions because you’re thinking that your game is working but it looks different to somebody on the outside coming in to play your game, so you have to make sure that you have everything organized and labeled and explicit so that the user knows exactly how to play your game or how to use your game. So maybe I

would add that and talk about that because it was something I didn't even realize until the first class did their gallery walk and I realized there were friends who didn't activate their game by pressing the space bar, they chose something else, which was fine, but they had no way of telling anybody what that other way was and I didn't even realize that until we got into it and their game wasn't working and I had to go back and look in their script to see what had happened, what had gone wrong. So maybe I would have made that more of a teaching point.

(Heather, Interview 2, April 13, 2015)

Supporting Question 3: How does the specifically designed game challenge affect other dimensions of classroom instruction, assessment and students' engagement?

Student Need for Creative Expression in Instruction

Students indicated enjoyment in the ability to express creativity in their games. Based on answers from the student written reflection gathered from all participating classes:

- students enjoyed the opportunity to create or make something (n=10)
- liked creating a game (n=5)
- liked creating game design elements such as sprites and backgrounds (n=5)
- liked creating the sound code (n=3)
- creating the code for use in their game (n=1)

One student from "Annie's" class shared a desire for more time on the student written reflection, "I liked the least how we didn't have enough time! I loved all of it and enjoyed creating it!" I saw students wanting time to create during classroom

observations, including the use of the image editor/paint feature in Scratch (Susan, Observation 1, February 2, 2015).

Teachers expressed students wanting time to create sprites and backgrounds as well.

Annie mentioned her students had “drawn their own sprites and added movement”

(Annie, Interview 2, April 16, 2015). Placing time at the end of the project was

something Heather planned for because “that is when those special creative things come

into play” (Heather, Interview 2, April 13, 2015). While Susan noticed some of her

students used the same sprites or game idea, such as making the background an image of

the Morse code letters, she still found some students wanted more time to work on the

creative elements instead of focusing on the content of the game. “I think we had to

spend too much time on the aesthetics” (Susan, Interview 2, April 13, 2015).

Additional Skills Students Learned

In addition to NGSS standards and computational thinking, the teachers expressed additional skills they believed students developed through the *Can You Create a Game*

Challenge experience. Students developed skills for independent learning. In an

interview with Annie, she observed students finding solutions to different problems on

their own instead of asking her for assistance. “I think they get tired of me asking them

twenty questions, so they figure it out on their own, not all of them, but a lot of them”

(Annie, Interview 2, April 16, 2015). Susan made a similar discovery in her classroom.

“They got really use to me not telling them the answer,” she said, “like kids want you to

tell them the answer all the time, and I won’t do that unless they are really, really

desperate or days behind” (Susan, Interview 2, April 13, 2015).

Logical or sequential thinking is another skill teachers noticed students developing while working together on the challenge, the “step by step” process (Annie, Interview 2, April 16, 2015). Heather included students thinking through the pieces and parts of the program or game design elements needed to complete the task, but not included on the rubric. “You need other parts of things, like you need instructions added or there are certain parts that aren’t explicitly listed in a rubric or anything that you have on a to-do list, but you need that component for the game to be successful” (Heather, Interview 2, April 13, 2015).

The STEM teachers shared how students learned to work together, reflecting the computational thinking perspective of connecting. “Helping each other and being cooperative,” Susan said, “like collaborating with each other, like when they found out that I wouldn’t help them, they went somewhere else, they had to use their resources” (Susan, Interview 2, April 13, 2015).

Sticking with the task, even when students struggled, showed perseverance. Annie said her students stuck “to our school standards - staying determined, not quitting. I had one today that wanted to be done, but staying focused with it.” Similarly, Susan noted her students developing perseverance and seeking out time to work on the project outside of the classroom:

It takes some time to get this. Some kids pick it up really quickly and some kids it takes some time because you are really having to think through what you are doing, you can’t just put something down. If the computer doesn’t do what you think you’ve told it to, why doesn’t it, we have to figure this out and stick with it ... I think you could probably tell which ones worked on it outside of class, like

they would work on it in Dolphin Club after school in the after school program, um, I didn't have to do anything to get them excited about it, it was just there. I could say Scratch in the hall and kids would say, "I want to do it" and I thought you don't even know what Scratch is yet, but ok. (Susan, Interview 2, April 13, 2015)

Obstacles for Teachers

The STEM teachers participating in the study noted several obstacles in implementing the *Can You Create a Game Challenge* in the classroom. Teachers identified access, interruptions and knowledge of Scratch software as difficulties faced during the case study.

Student access to working computers or the Internet created issues for Susan. In addition to the occasional network connectivity issue at school or a school computer malfunctioning, students who wanted to work on the Scratch project at home found difficulty accessing the program with no computer or Internet connection. "A lot of kids want to do it at home, but some of our kids don't have access to those at home, like they probably have iPhones and iPads but you can't do Scratch on your iPhone so that was another problem, they wanted to do it but they may not have the capabilities at home" (Susan, Interview 2, April 13, 2015).

Heather mentioned her knowledge of the Scratch software as an obstacle to quickly assisting students in the classroom. A student might offer an idea of a game element they would like to include and Heather could picture what the program should do in her head, but not know how to order the Scratch blocks to write the program:

I'm not very good at right there drawing on the spot in class and there are a lot of times where I have had to say in six days, because I only see them every six days, I'll tell you in six days, so give me six days to figure it out. I wish I was a little more, well I guess that is just experience, but I wish I had a little more knowledge that I could immediately come back with some faster ideas about how to do things or different ways to do things, so they could get to it right then and there when it was in front of them instead of them having to wait. (Heather, Interview 2, April 13, 2015)

For Annie, the constant interruptions during the project became a challenge for students remembering basic computer skills like logging into the computer to the time it takes to catch up on the project after missing class. "Kids getting pulled for other things, absences, a lot of times it is just kids missing we get a lot of kids that move in and then move out and the kids that move and come back, so it's a lot of catch up time and to get them where they can even work with somebody." (Annie, Interview 2, April 16, 2015)

Chapter 5

Discussions, Implications and Further Research

Discussion

The initial question driving this study was: How do elementary teachers use a game challenge specifically aligned with Common Core/Next Generation Science (NGSS) state standards for instruction? Supporting questions for this investigation were: How does the teacher's use of a digital game based challenge work as an assessment of elementary students' understanding of Common Core/Next Generation Science state standards and how does the specifically designed game challenge affect other dimensions of classroom instruction, assessment and students' engagement?

For many teachers, the purposeful integration of new technologies within instruction and assessment is a challenge. Even though Annie, Heather and Susan acknowledged their lack of expertise in Scratch software, the use of the *Can You Create a Game Challenge* task within instruction created a learning environment rich in knowledge-building for all members of the classroom and supported the teacher's view of their role in the classroom. The teachers in the study used the *Can You Create a Game Challenge* as an instructional tool to support student understanding of NGSS skills and knowledge, development of computational thinking skills and dispositions and practice of basic computer skills. The flexibility of the *challenge* allowed for multiple forms of assessment and permitted students interested in adding more to their game to work beyond the requirements outlined in the teacher-created rubric. While the task was not enjoyable for every student in the study, the challenge of working together to create a

digital game product for a real audience brought authenticity to the lesson with many students indicating they felt like an actual game designer or programmer.

Several findings from this study could be used to support authentic instruction and authentic learning environments, as well as help educators rethink the types of assignments typically given for the purpose of standards assessment.

Role of the Teacher

Within authentic learning environments, the role the teacher assumes is a catalyst in the student creation of their own understandings of the world around them. As indicated in the findings, the teachers in the study believed their role in the classroom is that of a facilitator, not to tell but to guide students along the intended learning journey. Annie and Susan described facilitating as walking around, answering student questions and providing assistance when needed. Heather indicated how the facilitation of instruction is different when using programs like Scratch in the classroom but had difficulty in expressing why it was different. Typically, in instructional settings, the classroom teacher knows not only the answer, but the path to finding the answer. Having this information allows a teacher to quickly answer a student question or provide a scaffold to the end target. *The Framework for Teaching*, by Charlotte Danielson(2013), used as a basis for teacher evaluation for the teachers in this study, supports the assertion that a proficient teacher is an expert on the subject matter they teach as well as an expert on how to teach it. Teachers, who have a command of their subject matter, can anticipate student misconceptions, predict learning obstacles, vary instruction for students at different levels of understanding during instruction and know the pedagogy to teach content in a meaningful way. How does learning in the classroom change when a teacher

is not an expert? For the teachers in the study, the experience of using Scratch in the classroom in some ways changed how they facilitated instruction. They relied on the students to help discover solutions and in turn share those findings with others in the classroom. The teacher became a co-learner and partnered with students to investigate solutions to programming problems. This collaboration in the study helped create an environment of shared authority, a flow of knowledge and prompted students to take ownership of their learning.

Heather's feelings in regards to her role in the classroom when using programs like Scratch is similar to those found in other studies previously conducted with LOGO and Scratch. Seymour Papert (1993b) describes an observation where a class of elementary students worked to solve a LOGO debugging challenge with their teacher. At a point in the problem solving process, a student realized his teacher did not know how to debug the problem and asked her, "Do you mean you really don't know how to fix it?" (p. 115). Papert notes that teachers try to collaborate with students to solve a problem but usually the material itself does not generate research problems. When a teacher tells a student, "Let's work on this together," usually the teacher knows the answer and guides the student to the solution. In essence, they are not truly working together to solve an unknown problem together, instead the teacher is simply providing guidance to a known solution. But using programs like LOGO or Scratch, the teacher and the student frequently experience new situations and the teacher does not know the answer and in turn models authentic problem solving to the student. Papert's statement sums up the experiences observed in the classroom. "Discovery cannot be setup; invention cannot be scheduled" (p. 115).

Karen Brennan (2013) had similar findings for teachers negotiating how to facilitate Scratch in the classroom for instruction. She referred to the role of the teacher as a cognitive guide where teachers are “helping students to pursue their goals through metacognitive support, by asking questions, providing helpful resources, breaking down problems into smaller problems, and reframing problems”(p.151). In the study, while Annie, Susan and Heather were not Scratch experts and did not quickly respond with a solution for students, they did model their thinking with a real problem while demonstrating persistence until they found a solution. In addition, they asked students to do the same when problem solving together. At times, a student in the classroom became the cognitive guide, helping classmates through questioning and clarifying.

Beyond the Task

In the book, *Creating Cultures of Thinking*, Ritchhart (2015) states in order to understand learning we need to look beyond what students are asked to produce, what teachers require student to do and how they are asked to use the resources around them to get to that end product. Instead, it is what students are mentally doing that matters (p. 45). While the game task provided a way to connect content standards to creative computing software in a manageable way for a teacher, the students in the study had to think and apply knowledge to produce a game as an artifact of their learning. Though the task was cognitively demanding, it provided opportunities for students to explore and work beyond the initial task constraints while enjoying the process of game creation. When the task is enjoyable, the goal is clear, the problem at hand is challenging but attainable, a person enters a state of flow (Aguilar, 2012).

Mihaly Csikszentmihalyi, a noted positive psychologist, has studied the notion of “flow” or when an activity highly focuses and immerses a person. Those activities include art, play and work. Csikszentmihalyi (2004), studied people all over the world who enjoyed their work and regardless of their culture or education, similar conditions seemed to exist when a person is in flow

- there are clear goals;
- the person knows exactly what they want to do from one moment to the next;
- there is immediate feedback;
- the person believes what they need to do is possible to do, even though difficult;
- sense of time disappears
- there is no worry of failure; and
- self-consciousness disappears.

Csikszentmihalyi says when the conditions are present, then the task the person is doing becomes worth doing for its own sake. While not all students in the study worked within these conditions, findings suggest that students working beyond the minimum requirements of the task may have done so because they were in a state of flow. These students had clear goals established in the game challenge and created personal goals when working to figure out specific game design elements. Students verbalized ideas they wanted to include in their game and believed it was possible to do, even when they faced challenges. By working in the Scratch program, the students could test out different programming combinations and create sprites and background, then receive

immediate feedback when they executed their program. The Scratch software provided a safe environment, allowing for multiple edits, without fear of failure. They expressed a need for more time and were excited to share their findings with others.

Teacher Expectation and Actual Student Performance

While student flow is one possibility for why students worked beyond the minimum requirements of the rubric, another may be a mismatch between teacher expectations and actual student performance. Heather indicated in the findings how the teachers designed the rubric for the students performing in the middle, the average of what they expected students to be able to do in the Scratch program. When examining student work, the teachers shared specific examples indicating the inclusion of complex programming or creativity in the design of the game. Because there is not an established K-5 curriculum for Scratch software nor are there elementary computational thinking standards for assessment, it may be difficult for teachers to establish appropriate learning targets in the area of programming as well as ascertain the abilities of students at particular grade levels with using creative computing software. The teachers in the study had previously used Scratch in the classroom with students, but their own unfamiliarity with the program may have caused them to unintentionally underestimate what the average 4th or 5th grader could accomplish when using Scratch.

Finding a Balance

By including the *Can You Create a Game Challenge* in the classroom, teachers struggled with finding the balance between making the content in the game a priority and students wanting time to create and explore in the Scratch environment. Teachers have a set amount of time with students each school year to teach and assess a specific set of

grade level standards. For Annie, additional school related interruptions made it difficult for students in her classroom to complete hands on projects. For Susan and Heather, the responsibility of teaching specific content standards to mastery became a concern when students wanted to spend time adding “special creative elements” or “aesthetics.”

Students in the study acknowledged they enjoyed the creative aspects of using Scratch and wanted more time. By placing the task at the application phase of the instructional sequence, the teachers anticipated they would save time by pre-teaching the content used in the game and then provide time toward the end of the project for students to add special creative elements. However, when the students opened the Scratch environment to begin working on the project, they wanted to spend time on making sprites or exploring the features of the program.

Brennan (2013) shared a similar finding from her research on teachers using Scratch in the classroom. In her study, teachers indicated a desire to create opportunities for students to explore and build a basic understanding of Scratch software while negotiating classroom limitations. Open-ended projects take time and teachers need to make decisions in regards to what aspects of the project they need to be direct and what parts can be exploratory for students.

For teachers using the *Can You Create a Game Challenge* in the classroom, providing time for students to create in the program may be beneficial. In addition, exploring options for students to access their projects outside of the classroom may provide students time they need to create and explore Scratch.

Designing a Space for Collaborative Computing

The physical classroom space is an area teachers need to consider when deciding to use a *Can You Create a Game Challenge* in the classroom. Susan's classroom with round tables and laptop computers provided ample space for students to collaborate, move from location to location with their device and allow for Susan to sit down with students to discuss ideas or collaboratively problem solve. The limitations of technology access for Heather created a need for students to work in groups of four on the project. While this group size made it difficult at times for students to come to an agreement on design elements of the project, working with a team when designing a game is authentic. The long, rectangular tables in Heather's classroom made moving among groups difficult at times and left Heather to either stoop down beside students or tower over them when problem solving and giving feedback.

Overcoming Hurdles

Research shows teachers struggle with using new technologies in the classroom (Jen-Hwa *et al.*, 2003; Laffey, 2004; Li, 2007). Initially two of the teachers in this study struggled to implement Scratch immediately in the classroom as well. Both Annie and Heather needed multiple exposures to the Scratch software prior to using it in the classroom. For Annie, a one on one discussion and the modeling of a Scratch lesson in her classroom was the assistance she needed to think about how to use creative computing as part of her instruction. For Heather, learning more about Scratch became a necessity when her daughter's teacher became interested in using it with students in an afterschool program. In addition, having a her District Technology Resource Teacher model a lesson with students provided the scaffold Heather needed to gain confidence in

teaching Scratch and using the program in projects with students. Susan, however, became interested in using the software after she saw the reaction from her students. Their level of engagement prompted her to explore ways to include opportunities to use creative computing in the classroom.

This finding is important for those interested in helping teachers use new technologies in the classroom. While teachers often attend conferences and professional development offerings to learn about new tools and ideas, the teachers in this study needed to see another teacher model a lesson with students or use the tool with students to see their reaction prior to including the tool within instruction.

Areas of Further Research

Using the *Can You Create a Game Challenge* with Exceptional Students

In this case study, I did not collect data indicating students with a disability, learning or behavioral disorder or those receiving intervention services for other subject areas. However, students in Annie's classroom who struggled in other content areas or were students receiving DHH services found success in using the *Can You Create a Game Challenge* and the Scratch software program. The Scratch software program requires students to think in a different way when attempting to solve a problem, provides students a way to test and debug combinations of programming blocks and requires very little reading in the English language to successfully program. The Scratch software program has a language feature built so a user has the option to change the language displayed on the programming blocks to a different language, including those spoken in

Asian, European, South American and African countries. Additional research is needed in examining the use of a digital game task as an assessment for students with disabilities, non-English speaking students or students who struggle in other content areas but seemed successful in creating projects with programs like Scratch.

Using the *Can You Create a Game Challenge* with Other Content Areas

This study examined the use of a *Can You Create a Game Challenge* aligned to NGSS standards. The structure of the *Can You Create a Game Challenge* design supports the use of the challenge in different content areas such as language arts, math, social studies, art and music as well as multi-disciplinary projects. In addition, this study examined the use of the *Can You Create a Game Challenge* at the 4th and 5th grade level. Additional research is needed in how the use of a *Can You Create a Game Challenge* can be used to support instruction and assess student understanding of knowledge and skills in additional content areas, interdisciplinary units of study and with students at different grade levels.

Professional Development for Teachers: Game Design

The artifact produced in the classroom using the *Can You Create a Game Challenge* was a digital game. The teachers asked the students to focus on the player and to make the game interactive, but did not specifically teach game design terminology or principals to students. Instead, they allowed students to reflect on their own personal experiences with digital games when creating their project. Though student games varied in terms of sprites, patterns created for communicating a secret word and levels, all of the students created versions of a question/answer game. With additional professional development, teachers may be able to use correct terminology and design game

challenges with constraints based on game design elements allowing for a wider variety of student game genres. Additional research needs to be conducted to examine how teacher training in game design affects how teachers design and implement the *Can You Create a Game Challenge* in the classroom as well as student game development.

Professional Development for Teachers: Computational Thinking

The teachers in the study did not have prior coursework in computer science or computational thinking skills as part of teacher preparation. Though the teachers sought out professional development opportunities to learn Scratch software to use with students, teachers need to have dedicated time to develop these skills and dispositions as well. Findings from the study suggest teachers learned terminology and programming concepts with the students. While the co-learning environment provided a rich learning experience for students, additional research needs to be conducted on how professional development opportunities for teachers in the area of computational thinking affect the social, collaborative environment of the classroom for teachers using the *Can You Create a Game Challenge*. Research is also needed to determine if teacher professional development to improve teacher proficiency with the software used for the *Can You Create a Game Challenge* affects the role of the teacher, shared authority and flow of knowledge in the classroom.

Conclusion

This embedded, single case study provided insights into how three elementary STEM teachers implemented a *Can You Create a Game Challenge* into their instruction, including the assessment of standards. The use of the challenge in the classroom helped teachers move towards an authentic learning environment and allowed them to engage in

intellectual collaboration with students. The findings suggest considerations for teachers using digital game challenges in the classroom as well as areas of need for future research for classrooms using the *Can You Create a Game Challenge* and creative computing tools.



Waves and Information Can You Create A Scratch Game?

Can you make a game with these conditions:

- Use a code to create a secret word
- Create an event to begin the Scratch game
- Create code to allow a player to hear each letter in your secret word
- Use “Ask and Answer” to make the game interactive with a player

1. Brainstorm ideas:

Use a piece of paper and plan out your game.

- 2. Create your game on the computer**
- 3. Test your game, does it work? If not, make changes and test again.**

4. Think:

How did you use a pattern in Scratch to communicate a message to a friend?

4-PS4-3 Generate and compare multiple solutions that use patterns to transfer information



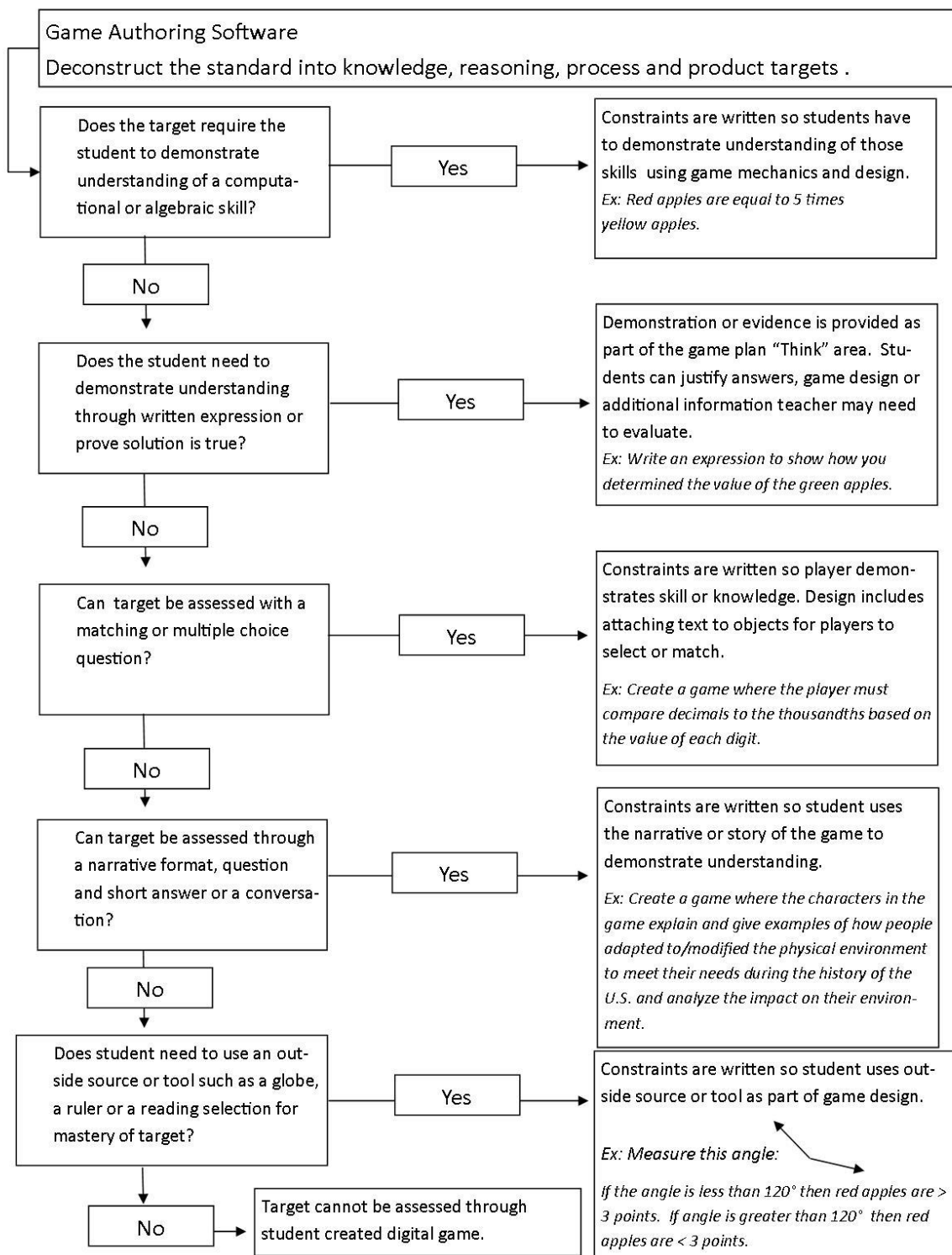
Waves and Information Can You Create A Scratch Game?

Project Rubric

Rating scale: 0= Incomplete 1= Attempted 2= Meet requirements 3= Exceeds requirement

Requirements	Points Earned
Use a code to create a secret word	
Create an event to begin the Scratch game	
Create code to allow a player to hear each letter in your secret word	
Use "Ask and Answer" to make the game interactive with a player	

Appendix A



Developed by Leanna Prater and Joan Mazur 2012

Appendix B



Initial Review

Approval Ends
November 4, 2015

IRB Number
14-0741-P4S

Office of Research Integrity
IRB, IACUC, RDRC
315 Kinkead Hall
Lexington, KY 40506-0057
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TO: Leanna Prater
Education Curriculum & Instr
1717 Abbingdon Hill
Lexington, KY 40514
PI phone #: (859) 271-3856

FROM: Chairperson/Vice Chairperson
Non-medical Institutional Review Board (IRB)

SUBJECT: Approval of Protocol Number 14-0741-P4S

DATE: November 11, 2014

On November 5, 2014, the Non-medical Institutional Review Board approved your protocol entitled:

Can You Create A Game: Student Authored Digital Games as Authentic Learning

Approval is effective from November 5, 2014 until November 4, 2015 and extends to any consent/assent form, cover letter, and/or phone script. If applicable, attached is the IRB approved consent/assent document(s) to be used when enrolling subjects. **[Note, subjects can only be enrolled using consent/assent forms which have a valid "IRB Approval" stamp unless special waiver has been obtained from the IRB.]** Prior to the end of this period, you will be sent a Continuation Review Report Form which must be completed and returned to the Office of Research Integrity so that the protocol can be reviewed and approved for the next period.

In implementing the research activities, you are responsible for complying with IRB decisions, conditions and requirements. The research procedures should be implemented as approved in the IRB protocol. It is the principal investigators responsibility to ensure any changes planned for the research are submitted for review and approval by the IRB prior to implementation. Protocol changes made without prior IRB approval to eliminate apparent hazards to the subject(s) should be reported in writing immediately to the IRB. Furthermore, discontinuing a study or completion of a study is considered a change in the protocol's status and therefore the IRB should be promptly notified in writing.

For information describing investigator responsibilities after obtaining IRB approval, download and read the document "PI Guidance to Responsibilities, Qualifications, Records and Documentation of Human Subjects Research" from the Office of Research Integrity's IRB Survival Handbook web page [<http://www.research.uky.edu/ori/IRB-Survival-Handbook.html#PIresponsibilities>]. Additional information regarding IRB review, federal regulations, and institutional policies may be found through ORI's web site [<http://www.research.uky.edu/ori/>]. If you have questions, need additional information, or would like a paper copy of the above mentioned document, contact the Office of Research Integrity at (859) 257-9428.

A handwritten signature in blue ink, appearing to read 'M. Van Tuley', followed by 'PhD/sh'.

Chairperson/Vice Chairperson

Appendix B



Office of Research Integrity
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Continuation Expedited Review
Modification Approved; Extension; Closed to Enrollment

Approval Ends
October 6, 2016

IRB Number
14-0741-P4S

TO: Leanna Prater
Education Curriculum & Instr.
1717 Abbingdon Hill
Lexington, KY 40514
PI phone #: (859)271-3856

FROM: Chairperson/Vice Chairperson,
Non-medical Institutional Review Board (IRB)

SUBJECT: Approval of Protocol Number 14-0741-P4S

DATE: October 13, 2015

On October 8, 2015, the Non-medical Institutional Review Board approved your protocol entitled:

Can You Create A Game: Student Authored Digital Games as Authentic Learning

Approval is effective from October 8, 2015 until October 6, 2016 and extends to any consent/assent form, cover letter, and/or phone script. If applicable, attached is the IRB approved consent/assent document(s) to be used when enrolling subjects. [Note, subjects can only be enrolled using consent/assent forms which have a valid "IRB Approval" stamp unless special waiver has been obtained from the IRB.] Prior to the end of this period, you will be sent a Continuation Review Report Form which must be completed and returned to the Office of Research Integrity so that the protocol can be reviewed and approved for the next period.

In implementing the research activities, you are responsible for complying with IRB decisions, conditions and requirements. The research procedures should be implemented as approved in the IRB protocol. It is the principal investigator's responsibility to ensure any changes planned for the research are submitted for review and approval by the IRB prior to implementation. Protocol changes made without prior IRB approval to eliminate apparent hazards to the subject(s) should be reported in writing immediately to the IRB. Furthermore, discontinuing a study or completion of a study is considered a change in the protocol's status and therefore the IRB should be promptly notified in writing.

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Chairperson/Vice Chairperson

Appendix C

Preliminary Interview for Participating Teachers

Thank you for agreeing to participate in this research project. Your participation is appreciated. As a researcher, I am interested in how elementary teachers use game challenges as a part of authentic instruction. Your responses will help me help me understand the process that you take when deciding how to incorporate a game challenge into a lesson. When I write about your experiences in my research, I will not use your name, the name of your school or school district. If you do not want to answer a question, you do not need to do so. You may request to stop at any time during the interview as well. To make it easier for me to focus on the conversation, I would like to record this interview using a digital voice recorder. Do I have your permission to record it? *If no permission is granted, make a note and then take written notes.* Do you have any questions? *Answer questions, if any.*

Current Position

What do you currently teach? How long have you been in your current teaching position? Could you describe a typical day for me?

Teaching Background

How many years have you been teaching? What previous teaching experiences have you had? What did you study while in school?

Technical Background

Describe your comfort level with technology? Describe any experiences or people you consider helpful to your use of technology in instruction (people, classes, professional development, and online resources)?

Game authoring software

How did you become interested in game authoring software? Describe your experiences with drag and drop software? What types of drag and drop software do you use in lessons with students? Describe your experience with Scratch software? Describe the students using the software in your classes?

Unit/Lesson Design

When you get ready to design a unit, what steps do you take? Could you walk me through it?

How do you decide when to use a game challenge as part of a unit of study?

When thinking about the instructional design of a unit, when do you usually introduce a game challenge to the class, at the beginning of the unit, in the middle of the unit or at the end of the unit? What criteria do you use when deciding the best location?

How do you see your role in you using game authoring software in the classroom?

What plans do you have or use to structure support for students using programs like Scratch to complete a game challenge?

In what ways do you use or plan to use the game challenge to measure student progress on standards?

How do you provide feedback to your students on a game challenge?

Appendix C

Thank you so much for taking the time to talk with me. Do you have any additional information you feel would be important to this research that you would like to share? Thanks again for your time.

Appendix D

Classroom Observation Instrument

Classroom Observation 1: *The purpose of the first structured classroom observation is to collect data on scaffolding support, role of the classroom teacher and teacher feedback to students toward the beginning of a unit.*

Date:

Teacher observed (pseudonym)

Grade taught:

Context: Activity observed; duration of activity

Description of physical learning environment:

Description of the learning activity:

Description of teacher/student and student/student interaction:

Description of scaffold support for students:

Description of the actions of the teacher, including feedback:

Appendix D

Classroom Observation Instrument

Classroom Observation 2: *The purpose of the second structured classroom observation is to collect data on scaffolding support, role of the classroom teacher and teacher feedback to students toward the middle of a unit.*

Date:

Teacher observed (pseudonym)

Grade taught:

Context: Activity observed; duration of activity

Description of physical learning environment:

Description of the learning activity:

Description of teacher/student and student/student interaction:

Description of scaffold support for students:

Description of the actions of the teacher, including feedback:

Appendix D

Classroom Observation Instrument

Classroom Observation 3: *The purpose of the third structured classroom observation is to collect data on scaffolding support, role of the classroom teacher and teacher feedback to students toward the end of a unit.*

Date:

Teacher observed (pseudonym)

Grade taught:

Context: Activity observed; duration of activity

Description of physical learning environment:

Description of the learning activity:

Description of teacher/student and student/student interaction:

Description of scaffold support for students:

Description of the actions of the teacher, including feedback:

Appendix E

Interview Protocol

Interview 2: Questions for Teachers

Thank you again for agreeing to participate in this research project. Your participation is appreciated. As you are aware as to our previous discussion, I am interested in how elementary teachers use game challenges as a part of authentic instruction. Your responses will help me help me understand the process that you take when deciding how to incorporate a game challenge into a lesson. When I write about your experiences in my research, I will not use your name, the name of your school or school district. If you do not want to answer a question, you do not need to do so. You may request to stop at any time during the interview as well. To make it easier for me to focus on the conversation, I would like to record this interview using a digital voice recorder. Do I have your permission to record it? *If no permission is granted, make a note and then take written notes.* Do you have any questions? *Answer questions, if any.*

Digital Game Challenges and Student Work

I understand that you have recently used a digital game challenge in your classroom. I would like to examine some student work with you. In looking at samples from participating students in your class, compare how students solved the digital game challenge task. Describe any student solution which you consider to be exemplary. Describe any student solution where you feel the student demonstrated creativity.

You wrote the digital game challenge based on specific content standards. Please share with me some examples of where you felt the student showed mastery of those standards using the finished game, the game plan or the student reflection.

You also developed a rubric to accompany the game challenge task. Describe how you used the rubric as part of your instructional design.

Appendix E

When students are working on a digital game challenge, what resources do they have available to them?

Climate

What is the attitude of your school staff, in general, in regards to technology use in the classroom? What is the attitude of your students in using technology in the classroom? What is the attitude of your students in using programming software in the classroom?

Describe a classroom that has successful integration of game authoring software?

What obstacles have you had to overcome in trying to use game authoring software in your classroom?

What tools or resources have you found helpful in trying to use programs like Scratch in your classroom?

Thank you so much for taking the time to talk with me. Do you have any additional information you feel would be important to this research that you would like to share? Thanks again for your time.

Appendix F

Student Reflection for *Can You Create a Game*

Directions: Please answer each question listed below.

1. What did you like most about creating a game with Scratch?
2. What did you like least about creating a game with Scratch?
3. What was easy about creating a game?
4. What was hard about creating a game?
5. How did you find help when you were stuck on a problem?
6. Were you able to play your game?
7. Were you able to play a friend's game?
8. A game designer is a person who makes games, sometimes as part of their job. Did you feel like a game designer when you made your game?

Appendix G

Heather's Engineering Enduring Skill Rubric

Student name:

Intermediate Engineering Rubric

Project Topic:

	Ineffective (0 points)	Developing (1 point)	Average (2 points)	Above Average (3 points)
Engagement	Did not engage in activity	Engaged with prompting	Engaged independently	Engaged with further observations
Creating Solutions	Did not use prior knowledge	With prompting, used information to generate and compare solutions to a problem	Independently used information to generate and compare solutions to a problem	Independently used information to generate and compare solutions to a problem and analyzed how well solutions matched a problem
Model Design	Did not create a model	Created a simplistic model	Created a model to meet basic requirements	Created a model that extended beyond basic building requirements
Testing Design	Only restated previous information without creating a fair test	With prompting, created a basic testing design	Independently created a test with control, independent, and dependent variables	Independently created a test with control, independent, and dependent variables and applied test results to building model
Content	Not able to answer any content questions	Able to answer content questions with prompting and cues	Correctly answer content questions without prompting and cueing	Correctly answered content question using appropriate vocabulary and extend explanations

Screenshots of Typological Data Analysis

Initial Typology ▾	Sub Typology ▾	Sub Typology ▾	Sub Typology ▾	Teacher ▾	Source ▾	Data
Environment	physical space	arrangement	access to technology	Annie	Observation 1	Students entered into the computer lab at the school and were seated on the floor. The classroom teacher sat in front of the group at a large interactive white board. The classroom teacher sat in front of the group with a wireless keyboard. Computers were located behind the students, in rows, with four computers placed in a line with an aisle separating them. The teacher's desk was at the back of the classroom. WeDo kits and other LEGO materials were on a shelf in the classroom adjacent to the teacher's desk.
Environment	physical space	grouping		Annie	Observation 1	See image (notes) for physical arrangement of space
Environment	physical space	arrangement		Heather	Observation 1	STEM classroom Tables are placed end to end allow for two sets of four students on each side. Teacher desk is placed in the front left side of the classroom, facing the school hallway. Teacher computer sets on desk and is connected to projector. Projector is on ceiling, pointed to white board for display. Teacher also has document camera.
Environment	physical space	arrangement	access to technology	Susan	Observation 1	Students were seated on the floor of the computer lab, toward the front of the room, directly at a white board used for computer projection. The STEM lab teacher and the computer lab teacher were present for the lesson. Behind the students, rows of computers, organized in the shape of a "W", based on the shape of the room. Rows of computers were lined against that wall, and two groups of computers were placed back in the center of the room.
role of teacher	cognitive apprentice	scaffold		Annie	Observation 1	Teacher: "This is only four letters that I've given you. Doing it a step at a time, I don't have no idea how to do this here-(points to ask/answer block) let me show you how to do it. Every block, every single block you need help with is here and will walk you through it. I don't know- when I went to New York I was still learning things."
role of teacher	guiding instruction	student-teacher interaction	procedures	Annie	Observation 1	Teacher: "Once you get to your computer, sign on as yourself. Open the Scratch project to your folder. How do we save?"
role of teacher	guiding instruction	student-teacher interaction	procedures	Annie	Observation 1	Students: "File, save as...(steps to saving to H drive)"
role of teacher	facilitator	procedure		Annie	Observation 1	Students get up from floor and move to computers. Students work with the teacher on the project. Directions for saving are posted on the wall for reference.
Process	introduction of task/modeling	activating prior knowledge		Annie	Observation 1	Teacher: "In 4th grade- who remembers learning about sound waves? Our project is about using Morse code- we are going to watch a quick YouTube video about morse code."
Process	introduction of task/modeling	activating prior knowledge		Annie	Observation 1	Teacher show video on the history of Morse Code, including the technology that has been used throughout history.
Process	introduction of task/modeling	activating prior knowledge		Annie	Observation 1	Student: "oh now I remember"
Process	introduction of task/modeling	activating prior knowledge		Annie	Observation 1	Student: "oh yeah"

Screenshots of Typological Data Analysis

Typology	SubTypology	Summaries	Patterns/Relationships/Themes	Possible Connections
environment	Social Space	students spent time working in groups in all classrooms with a few working independently. As students discovered features in Scratch or programming blocks, they shared the information with members of the group and groups around them. Information flowed from student to student in groups, group to group in classes, teacher to student, teacher to group. Information shared varied from topics such as how to save, blocks available in scratch, content and thought processes/problem solving strategies. Students sitting on the peripheral of conversations used information they saw/heard to improve their projects.	Flow of Knowledge	flow of knowledge (Explicit and tacit)
Task	authentic	many students viewed the task as challenging, not in regards to content but in the thought process/programming aspect. Many students felt the task we "real world" with others having sharing personal insights as to the difficulties faced by real game designers. While the task centered on NGSS content, I observed the students using ELA standards through communication, math standards through programming, art/music through addition of background, sprites, etc and computational thinking skills. The task was student centered - students had choice and software was age appropriate	Blooms Taxonomy (task would be towards the top) Depth of Knowledge? Cognitively Demanding?	Cognitive demand of task/technology skills and cognitive apprenticeship, authentic learning

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Academic Degrees

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Work Experience

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1997-2002	Linlee Elementary Fayette County Schools Lexington, Kentucky
1995-1997	Teacher National Academy Lexington , Kentucky
1993-1994	Substitute Teacher Kanawha County Schools Charleston, West Virginia
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Scholastic and Professional Honors

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LEGO Education Advisory Panel Member, 2014-current
KY Student Technology Leadership Program Ambassador Award, 2013
KET Mission US Honorable Mention Teacher of the Year, 2011

Publications

Peer Reviewed Conference Proceedings

Prater, L., & Mazur, J.M. (2014). Embedded standards-based digital gaming assessments: Pilot study with teachers. Proceedings of IEEE Computer Games: AI, Animation, Mobile, Multimedia, Educational and Serious Games (CGAMES). Louisville, KY. July, 2014.

Publications Under Review

Mazur, J.M., Prater, L., Walker, S. (under review). Digital game design tasks for Common Core Common Core Standards-based performance assessments. Submitted to Educational Technology Research & Development.