USING SCRATCH FOR LEARNER-CONSTRUCTED MULTIMEDIA: A DESIGN-BASED RESEARCH INQUIRY OF CONSTRUCTIONISM IN PRACTICE

By

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A DISSERTATION PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

UNIVERSITY OF FLORIDA

2010

To Betsy and Ella

ACKNOWLEDGMENTS

I am so grateful to Mrs. H. for her willingness to collaborate with me on this research study. Her contributions made this work meaningful in so many ways. This dissertation would also not be possible without the support and insight of my committee including Kara Dawson, Cathy Cavanaugh, Fran Vandiver and Lynda Hayes.

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LIST OF ABBREVIATIONS

DBR	Design-based research
ILE	Innovative learning environment
LCM	Learner-constructed multimedia
RtI	Response-to-Intervention

Abstract of Dissertation Presented to the Graduate School
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August 2010

Chair: Kara Dawson
Major: Curriculum and Instruction

This design-based research study investigates the impact on learning when young learners design multimedia that demonstrates an understanding of math content. During this study, 5th graders used Scratch, a contemporary computer program designed for young people to create multimedia, to demonstrate their understanding of the properties of geometric solids. This process requires that young learners engage in content and think about how they can represent specific content in a Scratch multimedia artifact rather than simply memorizing the content for a test. The results of this study indicate that having 5th graders design multimedia using Scratch yields a mixed impact on learning depending on learning preferences of the individual learner. Though increases in content learning were not identified based on a traditional form of assessment in the two case studies presented in this manuscript, it is reasonable to acknowledge that this approach may serve as an alternative form of formative or summative assessment.

CHAPTER 1
INTRODUCTION

Research Problem

Increasing math achievement has remained a long-term concern of the American educational community (Forgione, 1998; Schoenfeld, 2004). Recently, initiatives focusing on improving science, technology, engineering and mathematics (STEM) education have expanded to ensure that students in the United States can compete with global peers (Fitzpatrick, 2007). A component of this renewed interest in STEM education is an attempt to increase math achievement for the K-12 student population. Ensuring that students have a deep conceptual understanding of standards-based math content is a goal of the American educational system (NCTM, 2006). Finding ways to engage and motivate youth, particularly academically at-risk youth, in extended engagement with math content is critical for ensuring deep content learning (Singh, Granville & Dika, 2002). One method for extending engagement with content places learners in the role of a multimedia designer; that is, learners create multimedia that represents their understanding of content. This practice forms the foundation of the concept of learner-constructed multimedia (LCM). Designing multimedia about content requires extended engagement with content, and contemporary multimedia design tools are intrinsically motivating and engaging for young learners. Previously, the National Council of Teachers of Mathematics has identified that an understanding of the properties of geometric solids is one of three curriculum focal points for 5th graders. Therefore, the purpose of this study is to identify learning gains when academically at-risk 5th graders design and construct multimedia that represents their understanding of the properties of geometric solids.

In this study, this researcher designs, implements and evaluates an innovative learning environment (ILE) in collaboration with a school-based practitioner that integrates LCM as a pedagogical strategy. Thus, this environment simultaneously features young, academically at-risk learners using computers as design tools, young learners learning and using a visual programming tool, Scratch, to design multimedia and young learners designing multimedia artifacts that represent their understanding of math content (i. e., the properties of geometric solids). This study uses design-based research (DBR) as its guiding framework. The goals of an educational researcher adopting DBR methods are to "engineer innovative educational environments and simultaneously conduct experimental studies of those innovations" (Brown, 1992, p. 141). Thus, this study attempts to design, implement and document an ILE that integrates LCM as a pedagogical strategy and features the properties identified above. This researcher also analyzes and evaluates this ILE as a pedagogical strategy for increasing content learning of the properties of geometric solids for young, academically at-risk learners.

Design-Based Research

DBR begins with a complex, real-world problem (Ma & Harmon, 2009). Then, through an iterative process, researchers in collaboration with practitioners design and study a solution to the problem. A key feature of DBR is its collaborative nature. A researcher does not provide a research protocol to a practitioner that should be implemented within the practitioner's context. Rather, researchers and practitioners collaborate to identify an educationally relevant problem then work cooperatively to design, implement and evaluate a solution to that problem in an educational context. This study provides a solution, collaboratively designed by a practitioner and researcher, to address the real-world problem of increasing math achievement for academically at-risk learners. DBR's foundation in education began with the concept of design experiments first articulated by Brown (1992) and Collins (1992). These design experiments in education were modeled after the design processes evident within other design fields such as aeronautics and artificial intelligence (Collins, 1992).

Several authors have articulated a call for DBR in the field of educational technology to create technology-based innovative learning environments (Reeves, Herrington & Oliver, 2004; Wang & Hannafin, 2005; Ma & Harmon, 2009). This call stems from a lack of usable knowledge to guide instruction, particularly technology's role in improving instruction (Reeves, 1995; Richey, 1998).

Characteristics of Design-Based Research

The Design-based Research Collective (2003) proposed 5 characteristics of appropriate design-based research. When using DBR as a research framework, this type of study:

- should promote the design of innovative learning environments and the development of learning theories;
- should be an iterative process consisting of 4 stages: design, enactment, analysis, redesign;
- should produce educationally-relevant knowledge for classroom applications;
- should provide rich descriptions of content and interactions; and
- should use appropriate research methods related to question.

For each of the characteristics, this researcher provides a brief summary followed by an explanation of how each characteristic is addressed in this study.

First, DBR should actively and simultaneously promote the design of innovative learning environments and the development of learning theories. In this study, the researcher documents the design of an innovative learning environment that places young learners in the roles of participants and producers rather than as spectators and consumers (Jenkins, 2006). Specifically, academically at-risk 5th graders actively participate in the design process to produce multimedia that is used to express what they know about the properties of geometric solids and could be used to teach others about the content. In addition, the researcher provides evidence to reinforce a constructionist approach to pedagogy that emphasizes that conceptual learning, in contrast to rote learning, occurs when learners construct personally meaningful artifacts that are shareable within a community of learners (Papert, 1993).

Second, DBR should be an iterative process with the following stages: design, enactment, analysis and redesign. These four stages articulated by the Design-based Research Collective (2003) represent a similar process to the steps portrayed in Figure 1-1. Reeves (2000) articulated the steps identified across the top row of boxes. Later, Ma & Harmon (2009) expanded on these steps and included additional sub-steps for each. The Design-based Research Collective's design stage corresponds to Reeves' and Ma & Harmon's steps 1 and 2: analysis of a practical problem by researchers and practitioners and development of a solution with a theoretical framework. The enactment and analysis stages combine to represent step 3: evaluation and testing of solutions in practice. Finally, the redesign stage corresponds to step 4: documentation and reflection to produce "design principles". During the design stage, the researcher in collaboration with the participating teacher designs the innovative learning environment ensuring that critical elements are included in the design. The enactment stage represents the implementation of the design with the participating teacher's students.

Data such as outcome measures, observational field notes and interviews are collected during this stage then utilized in the analysis stage. The analysis stage includes analyzing and evaluating the ILE as a pedagogical strategy. During the redesign stage, findings from the analysis stage provide insight into the next iteration of the design. A limitation of this approach is the amount of time spent documenting this iterative process. Because of time limitations associated with the school site's calendar, only a single iteration of this process was completed (Ma & Harmon, 2009). However, the attributes of the redesign stage are well documented, and future research opportunities will continue this process.

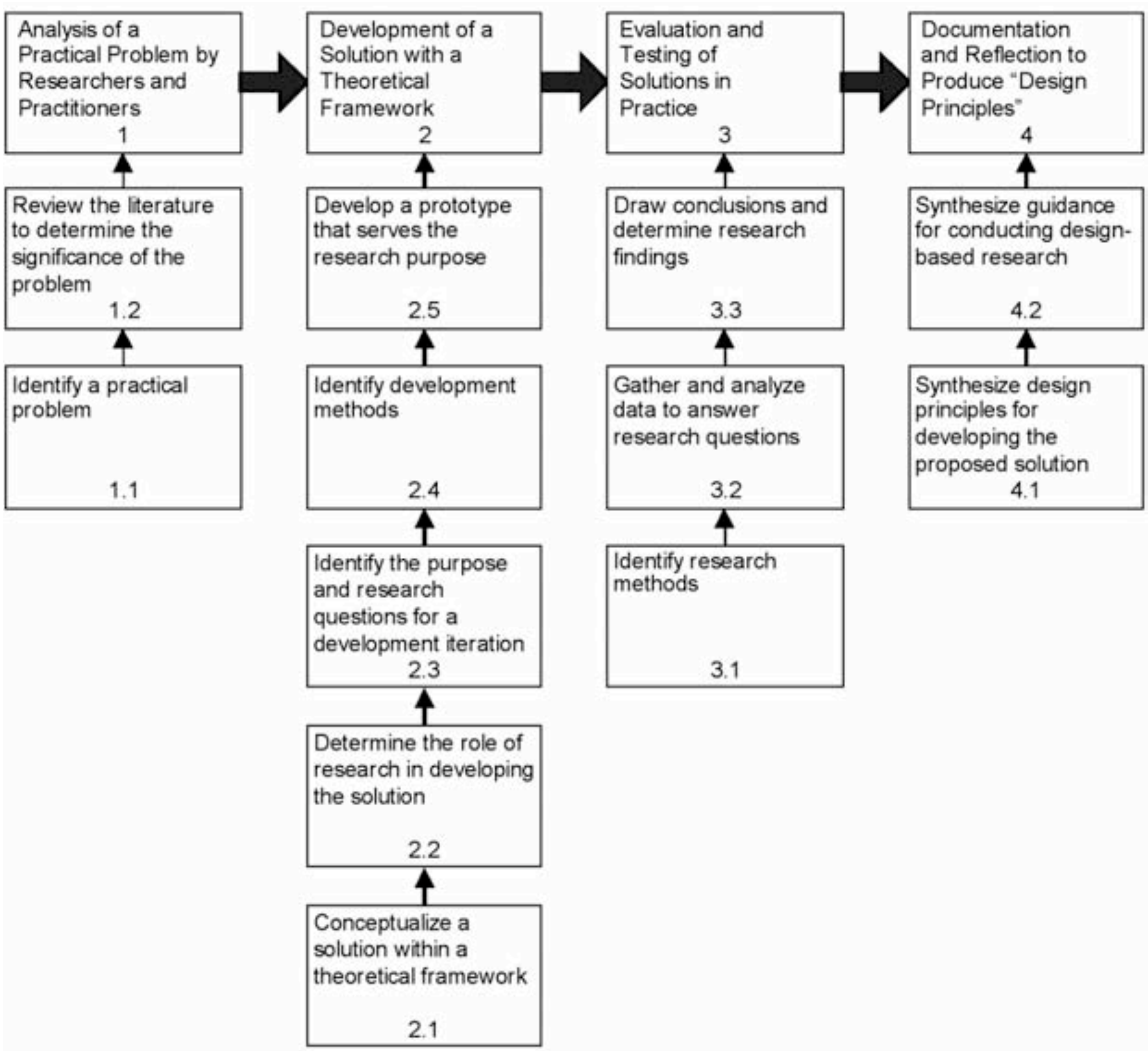


Figure 1-1. The design-based research process (Ma & Harmon, 2009)

Third, DBR should produce "usable knowledge" (Lagemann, 2002) that provides relevant impact for educational practitioners. Since this study takes place in a classroom context and not in an artificial laboratory setting, the outcomes documented represent authentic results that are readily usable for transfer to similar contexts. In addition, as part of the redesign stage, this study seeks to identify design elements essential for the next iteration of the DBR process. This knowledge of essential design elements provides an immediate impact for the design of future research whether conducted by this researcher or by others.

Fourth, DBR should provide rich descriptions of the context and the interactions that occur within the context. Rich descriptions of the context are necessary to ensure reliability and applicability for other contexts. Daily debriefing notes between the practitioner and researcher and daily researcher reflections while analyzing multimedia artifacts provide the rich descriptions. During the implementation of this study, the practitioner and researcher collaboratively debriefed after each class meeting to discuss and assess each participant's progress on the design task, to determine how either the researcher or practitioner could assist participants during the next class meeting and to assess the implementation of the research project. These debriefing notes provided a data source for analysis (see Appendix B for an example). The researcher also independently documented his daily reflection of participants' progress while examining each participant's multimedia artifact (see Appendix C for an example). These reflections also provide a data source for analysis. Collectively, these data sources provide rich descriptions of this study's context and of the interactions that occurred.

Fifth, DBR should utilize appropriate research methods. A researcher selects a research method based on how well a particular method addresses a study's research question(s). The research method, in turn, determines the sources of data. This study explores the following research questions:

- How effective is learner-constructed interactive multimedia at increasing learning gains in the properties of geometric solids for academically at-risk learners?
- What are the design principles for creating an innovative learning environment that integrates learner-constructed interactive multimedia for academically at-risk learners?

Based on these questions, this study was accomplished through case study methods (a qualitative research approach), and the data for this DBR study included observational field notes, participant-constructed artifacts, interview transcripts and outcome measures of content knowledge. Eight (8) academically at-risk 5th grade students participated in this study. Each participant completed outcome measures of math content knowledge about the properties of geometric solids in the form of pre- and post-tests to determine learning gains in math content. Each participant designed a multimedia artifact using Scratch that was analyzed by the researcher for evidence of math content. Two participants were identified through maximum variation sampling to serve as cases for in-depth case studies. The researcher conducted interviews with these participants to determine their perception of learning gains while designing multimedia that expressed their understanding of the properties of geometric solids. The researcher also conducted interviews with the practitioner to document the design principles integrated into this ILE. Another source of data that contributed to the design principles are the reflective field notes recorded by the researcher.

Conducting Design-Based Research

The five characteristics of DBR described above help generate an understanding of the DBR paradigm but do not necessarily provide a systematic process for conducting DBR. Reeves (2000) articulated a four-step process for conducting DBR:

- analysis of practical problems by researchers and practitioners
- development of solutions with a theoretical framework
- evaluation and testing of solutions in practice
- documentation and reflection to produce design principles

Reeves' four-step process is comparable to the Design-Based Research Collective's four-stage process for an iteration of DBR described above (design, enactment, analysis and redesign). Reeves' steps of analyzing a practical problem and developing a solution are integrated into the Design-Based Research Collective's design stage. In addition, the Design-Based Research Collective's stages of enactment and analysis are combined within Reeves' evaluation and testing step.

Building on Reeves' process, Ma and Harmon (2009) refined a procedure for conducting an iteration of a DBR inquiry that includes additional details on this research process (see Figure 1-1). This researcher selected Ma & Harmon's process because it provides a structured process to conduct a single iteration of the DBR cycle. As an emerging scholar, it is helpful to have a research framework that provides support for engaging in research. This procedure provides the framework for conducting this research study on the impact of learner-constructed multimedia on learning for academically at-risk learners. In addition, this procedure provides the structure for this manuscript. The four steps first articulated by Reeves (2000) and adopted by Ma and Harmon (2009) are integrated into this manuscript.

Research Purpose

In the teaching and learning environment, whoever does the most work does the most learning. That is, whoever engages and interacts more with the content will learn more quantitatively and qualitatively. The 'sage on the stage' can spend numerous hours researching and preparing for a class lecture. This individual engages and interacts with the content and develops a sophisticated understanding of the content. However, the learners, the audience of the lecture, do not invest nearly as much cognitive skill to engage and interact with the lecture content, and therefore, develop only a superficial understanding of the content. Therefore, if an educator creates opportunities for learners to engage and interact with content in rich and complex ways, learners are more likely to develop a more sophisticated understanding of such content.

One such method for creating such opportunities is by learning through design. More specifically, learning through design refers to the process of learning content during a design task that promotes engagement with content. Thus, students design and create artifacts that demonstrate knowledge of the content to be learned. Artifacts can exist in multiple forms of media or multimedia: reaction papers, blog posts, videos, podcasts, etc. According to Sennett (2008), "making is thinking" (p. ix). The act of designing and creating an artifact that represents what a learners knows and can do related to some content may provide evidence of understanding and thinking about that content. In fact, this may represent more than just superficial thinking. Rather, it may reflect a deeper level of thinking that goes beyond memorization or recall and reaches into the realm of higher order thinking associated with Bloom's taxonomy of cognitive skills such as evaluating and creating (Bloom & Krathwohl, 1956; Anderson & Krathwohl, 2001).

Today's youth have unprecedented access to powerful multimedia-authoring tools. Deep, rich conceptual learning can occur when learners design multimedia that represents their understanding of content knowledge. This view is consistent with constructionist pedagogy, a pedagogical theory that emphasizes the construction of personally meaningful artifacts using technology that can be shared with others (Papert, 1993). For example, Kafai (1995) worked with 10-year-old youth to design games in Logo that would teach knowledge of fractions to younger students. She reported that these youth developed their own representations of fractions while learning programming concepts and strategies. This work epitomizes the potential impact that multimedia-authoring tools can have on young learners.

Research indicates that increasing learner motivation and cognitive engagement will promote achievement (Turner & Paris, 1995; Guthrie & Wigfield, 1997; Guthrie & Wigfield, 2000; Guthrie, 2001; Roe, 2001; Kamil, 2003). Today's young academically at-risk learners may not respond to traditional instructional approaches. Therefore, we must consider innovative approaches to motivating and engaging these young learners. One such approach places young learners in the roles of designers of multimedia.

Having learners construct multimedia is one strategy that facilitates the development of thinking skills (Spoehr, 1993; Lehrer, Erickson & Connell, 1994; Hay, Guzdial, Jackson, Boyle & Soloway, 1994). Yet, it may be an underutilized strategy in most schools. Only 43% of teachers who regularly use media in their classrooms highly value student-created multimedia (PBS, 2009). Tools for constructing multimedia typically include a steep learning curve or a high cost, which may indicate causes for the lack of diffusion of this strategy. Yet, Scratch, a contemporary design tool with a shallow learning curve and available for free, may provide greater opportunities for diffusion and integration into classroom contexts. Therefore, the purpose of this study is to identify learning gains when young academically at-risk learners design and construct multimedia using Scratch to express what they know about math content, particularly content addressing the properties of geometric solids.

Design of This Manuscript

The remaining chapters of this manuscript provide a detailed account of the design, implementation, analysis and findings for this study. Chapter 2 addresses the theoretical framework and situates this study within the existing literature. Chapter 3 documents the research methods used to conduct this study within a K-12 setting. Chapter 4 provides an overview of the evaluation and testing of a learning environment that integrates learner-constructed multimedia through the perspectives of two individual case studies. Chapter 5 provides documentation and reflection on the design principles necessary to implement learner-constructed multimedia as identified through the collaboration between the practitioner and this researcher. Chapter 6 summarizes this study’s findings, situates this study’s findings in the existing literature and shares implications for learners, teachers, schools and the research community.

CHAPTER 2
LITERATURE REVIEW

Introduction

This chapter provides an overview of the theoretical framework and background information necessary for understanding this study's context. This chapter also situates this research study in the existing education research literature. In addition, this chapter's content addresses Step 1.2 of the DBR framework: reviewing the literature (Ma & Harmon, 2009).

Theoretical Framework

Integrating multimedia is a contemporary strategy for engaging students in content. According to a recent survey of 1200 K-12 teachers, 76% use digital media frequently or regularly in their classrooms, and 43% of these media-using teachers highly value student-produced multimedia (PBS, 2009). Contrary to other approaches that integrate multimedia into classroom practice, learner-constructed multimedia (LCM) places learners in the roles of participants and producers rather than spectators and consumers (Jenkins, 2006). Integrating LCM is a pedagogical strategy for promoting content learning through the design of a digital artifact that expresses what a student knows. Specifically, learners participate in the design process to produce a digital artifact that represents their understanding of content rather than consuming content through instructional multimedia.

LCM can be understood through several perspectives: theoretical, pedagogical and historical (see Figure 2-1). From a theoretical perspective, LCM is grounded in constructivist theories of knowing. The use of the word 'theories' is intentional to acknowledge that there are multiple forms of constructivism (e. g., radical constructivism) evident within the education literature (Phillips, 1995). This study is concerned with how an individual constructs knowledge through experiences, such as the experience of designing multimedia that represents an understanding of content knowledge. Therefore, psychological constructivism, in contrast to social constructivism, forms the foundation for this study because the unit of interest for this form of constructivism is the individual (Richardson, 2003). Piaget's perspective has had considerable influence on contemporary views of psychological constructivism (Matthews, 2003). Piaget expressed "that knowledge does not result from a mere recording of observations without a structuring activity on the part of the subject" (Piaget, 1980, p. 23). Thus, making meaning for the learner entails developing schema, or mental models, that represent understandings of experiences. In an educational environment, learners can construct representations and understanding of content through a diverse range of experiences including teacher-delivered lectures or hands-on experiments.

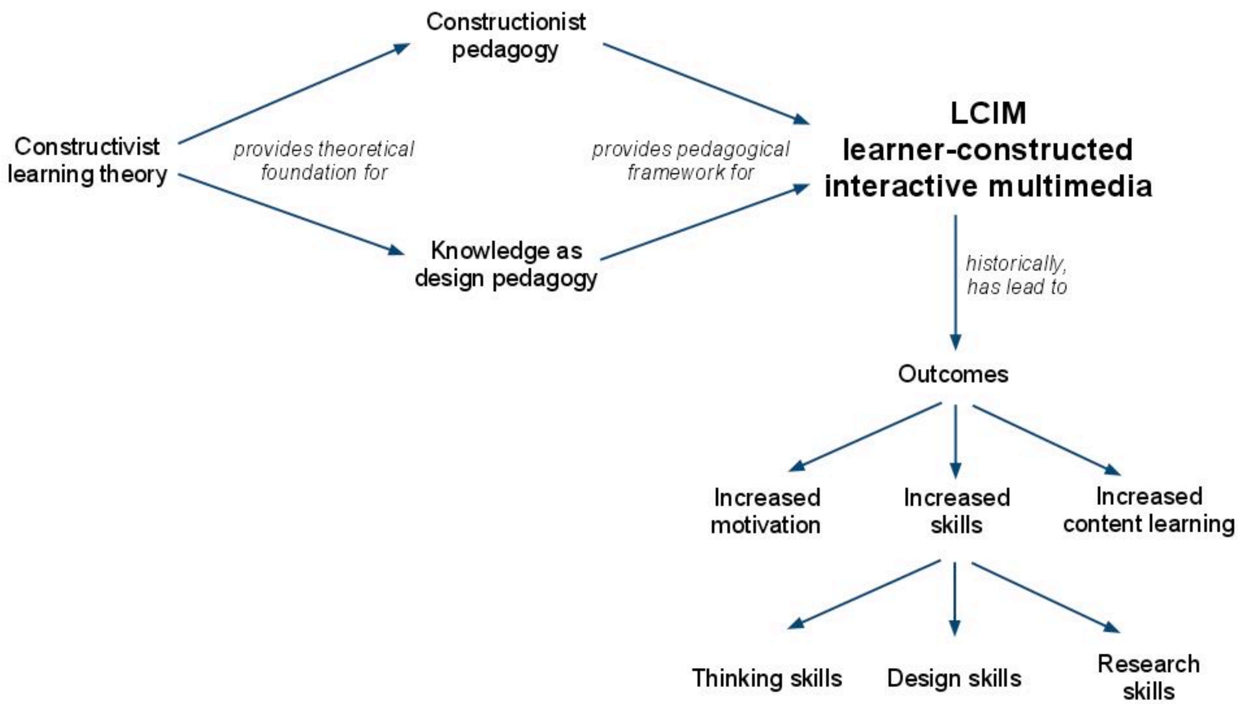


Figure 2-1. The theoretical framework for this study

Within a pedagogical framework, LCM has a foundation in constructionist pedagogy, which is an application of constructivist learning theory. Constructionist pedagogy emphasizes that learners develop an understanding of content especially well when given opportunities to design and construct a personally relevant and shareable artifact (Papert, 1991). Relatedly, LCM also has a foundation in the concept of learning through design. Perkin's knowledge as design pedagogy encourages an active use of knowledge through the creation of products to represent student understanding (1986). Student-created products about subject matter demonstrate students' ability to apply knowledge and synthesize understanding through the design of a product rather than simply regurgitating information on a test. Perkins argued that "students who spend most of their time consuming knowledge, however well served up it may be, are not constructing their own products of mind" (1986, p. 96). That is, students may acquire information (or consume it), but they may not be able to use knowledge for application purposes (or produce it in a design product). Perkins clearly articulated that designing a product that represents an understanding of knowledge promotes deeper understanding than consuming information then regurgitating it back on a test.

Historically, multimedia has been used as an instructional tool whereby learners consume multimedia to learn about content. Instructional designers or teachers create the multimedia content that learners consume. Jonassen, Wilson, Wang & Grabinger (1993) observed that designers of instructional materials learn the most from the materials. Thus, it seems likely that instructional designers and teachers learn more content through designing multimedia than learners do from consuming it.

> People who design materials are necessarily engaged in a deeper analysis and articulation of the subject in order to teach it, which results in their better understanding of the subject, as opposed to learners who only read or interact with the materials (Jonassen, Peck & Wilson, 1999, p. 153).

This notion forms the justification for creating opportunities for learners to construct multimedia that represents what learners know about content.

A Foundation in Constructivism and Constructionism

As described above, constructivism is a learning theory that posits that knowledge is constructed by the learner and not simply transmitted from teacher to learner. Constructivism is also referred to as 'discovery learning' to indicate that learning takes place through discovery as one individual leads another to discover concepts (Stager, 2002). It is often associated with the idea of 'learning by doing', which implies that the learner is active and engaged in the learning process. Constructionism, a pedagogical paradigm first articulated by Seymour Papert, extends this idea into 'learning by making' to emphasize the importance of generating a shareable artifact over simply engaging in an activity.

> We understand "constructionism" as including, but going beyond what Piaget would call "constructivism." The word with the *v* expresses the theory that knowledge is built by the learner, not supplied by the teacher. The word with the *n* expresses the further idea that this happens especially felicitously when the learner is engaged in the construction of something external or at least shareable…a sand castle, a machine, a computer program, a book. This leads us to a model using a cycle of internationalization of what is outside, then externalization of what is inside and so on. (Papert, 1990, p. 3)

Constructionism shares with the more familiar constructivism the belief that learning is the process of building knowledge structures through experiences. Constructionists extend this theory and argue that learning is particularly robust when learners have the opportunity to construct a shareable artifact (Harel & Papert, 1991). Constructionism contrasts with instructionism, a more dominant pedagogical approach in education.

> I like to formulate a major theoretical issue as "constructionism vs. instructionism." This does not suggest that instruction is bad or useless. Instruction is not bad but overrated as the locus for significant change in education. *Better learning will not come from finding ways for the teacher to instruct but from giving the learner better opportunities to construct*. (Papert, 1990, emphasis in original, p. 3)

In practice, constructionists provide opportunities for learners to design and construct shareable artifacts, and constructionism places the locus of control for learning with the learner. In contrast, instructionism maintains the locus of control for learning with the teacher. Thus, a teacher adopting a constructionist approach to learning would create opportunities for learners to design and construct artifacts that represent understanding of content. In addition, these artifacts could be composed using multimedia tools, and there is a reasonable amount of historical evidence to support this approach.

A Historical Perspective on Multimedia

Multimedia became widely regarded as an instructional tool during the 1990s (Brown, 2007). For the purpose of this study, this researcher defines multimedia as a digital artifact that shares information through multiple forms of media. Media commonly exist in auditory or visual forms such as text, speech, music, sounds, images or animations. Other researchers' definitions of multimedia and hypermedia form the foundation for the definition of multimedia used this study. Mitchell, Andreatta & Capella (2004) described multimedia as "an educational presentation made using audio and images" (p. 3962) and emphasized that the amount of text is reduced within multimedia. Erickson (1997) articulated hypermedia as "a way of authoring on the computer that combines text, graphics, sound, and animation" (p. 5). Wisnudel (1994) identified multimedia as "the coordinate use of several types of media" (p. 6) and compared and contrasted it with hypermedia.

> Hypermedia, like multimedia, incorporates symbolic expressions beyond texts, including graphics, animations, still images, and video. Hypermedia enables users to retrieve chunks of information on demand. Unlike multimedia, hypermedia environments contain an inherent structure, or network, with links, or connections and relationships between chunks of information. (p. 6).

Thus, multimedia and hypermedia share a common aspect: both integrate multiple forms of media to express information. They differ in their linearity: multimedia is linear, and hypermedia is non-linear. While this distinction may have been relevant in the past, contemporary tools allow users to construct both linear and non-linear artifacts. In addition, hypermedia and multimedia are often used interchangeably within the literature. In the current study, this researcher exclusively uses the term 'multimedia' to refer to the digital artifacts created by participants.

Learning Through Multimedia Design

The metaphors of student-as-designer and learner-as-designer have been used throughout education literature (Harel, 1991; Ehrmann & Balestri, 1992; Beichner, 1994; Lehrer, Erickson & Connell, 1994; Liu & Rutledge, 1997; Wilhelm, Friedemann & Erickson, 1998; Chen & McGrath, 2003; Kimber & Wyatt-Smith, 2006). Indeed, this literature has identified multiple benefits when learners participate in the design process, and there are numerous studies that identify positive outcomes when learners design hypermedia or multimedia artifacts (see Table 2-1). Notice that there were no appropriate studies found past 2007. This researcher identified these studies through an exhaustive review of specific journals such as the *Journal of Educational Multimedia and Hypermedia* and of the university's library databases. Search terms included "multimedia", "construction", "student created", "learner created", "student constructed", "student designed", "multimedia design", "multimedia designer" and "multimedia construction". In addition, once a suitable article was identified, this researcher used Google Scholar to follow the citation trail of the article to identify more current articles that cited the previously identified article.

Table 2-1. Overview of benefits of learners designing hypermedia/multimedia

Author(s)	Summary of benefits
Carver, Lehrer, Connell & Erickson (1992)	Students develop design skills; students demonstrate high mental effort and involvement
Spoehr (1993)	Students organize knowledge in an expert-like manner
Lehrer, Erickson & Connell (1994)	Students demonstrate high mental effort and involvement; off-task behaviors are reduced; students develop skills to search for, interpret, articulate and communicate information
Hay, Guzdial, Jackson, Boyle & Soloway (1994)	Students create multiple representations of content

Table 2-1. Continued

Beichner (1994)	Design process motivates students, especially when designing for an external audience; students deeply engage in content while analyzing, evaluating, synthesizing and representing content-related information
Erickson (1997)	Students develop research and design skills
Liu & Rutledge (1997)	Students exhibit motivation to learn, increase on-task behaviors, are willing to spend additional time outside of class and increase self-efficacy
McGrath, Cumaranatunge, Ji, Chen, Broce & Wright (1997)	Design process motivates students; students take interest in content and increase responsibility for their learning
Liu & Pederson (1998)	Design process motivates students; students increase content knowledge and develop design, collaboration and metacognitive skills
Orey, Fan, Scott, Thuma, Robertshaw, Hogle, Tzeng & Crenshaw (2000)	Design process motivates students if task is not too structured; students develop collaboration skills
Liu & Hsiao (2002)	Students develop design skills; students develop collaboration skills
Chen & McGrath (2003)	Students represent content in multiple ways and develop metacognitive and reflective skills
Mitchell, Andreata & Capella (2004)	Students engage in course content
Brown (2007)	Design process motivates students; students develop multiple higher-order thinking skills
Garthwait (2007)	Students increase writing skills

Carver, Lehrer, Connell and Erickson (1992) developed a design skills model that places learners in the roles of hypermedia authors. These design skills included project management skills, research skills, organizing and representation skills, presentation skills and reflection skills. The researchers collaborated with secondary teachers to develop teaching units that integrated these skills during hypermedia design projects. Based on an analysis of student discourse, Carver et al. reported that students became autonomous with respect to design skills over the course of the project. In addition, student questionnaires revealed increased “mental effort and involvement, interest, collaboration, planning, and individualization" (p. 394). This study contributes evidence to support the view that designing hypermedia develops design skills. In addition, this study demonstrates that students deeply engage in content when designing about the content as they search, analyze, evaluate and synthesis information related to the content.

Spoehr (1993) documented benefits when high school students reported results from research projects using hypermedia. She identified that students developed "a proficiency to organize knowledge about a subject in a more expert-like fashion" (p. 9) when given the opportunity to construct hypermedia. This is a significant finding as educators seek to find meaningful ways for learners to develop representations of content. The ability to organize knowledge in a sophisticated manner when designing hypermedia provides evidence that this approach has a considerable impact on learning content.

Lehrer, Erickson and Connell (1994) asked 9^{th} grade students to construct a hypermedia presentation on an American history topic with the intent that the hypermedia presentation could be used by peers as an educational tool. In teams of 5, student groups used HyperAuthor to construct their hypermedia presentations. The researchers reported that students demonstrated high levels of mental effort and involvement, which indicates a high level of engagement with content during the design process. Another indicator for a high level of engagement among students was evident in a remarkable decrease in off-task behaviors over the duration of the design process (from 30% in the beginning to 3% at the end). In addition, researchers observed that students developed several useful skills that could transfer to other contexts: "finding and interpreting information, articulating and communicating knowledge, and using computers as cognitive tools" (p. 248). These skills were not intentionally encouraged as part of the design process, but they are a beneficial outcome of the design process. Of most significance, the researchers noted that students observed that knowledge was "a result of their constructive efforts rather than as a set of givens from their teacher and text" (p. 248). Thus, designing hypermedia (or multimedia) is a constructionist task rather than an instructionist one. Learners construct knowledge representations of the content addressed in their hypermedia (or multimedia) during the design process rather than the teacher or textbook providing representations for learners to memorize.

Hay, Guzdial, Jackson, Boyle and Soloway (1994) analyzed 83 multimedia documents created in MediaText by high school students to meet assignment expectations in four different courses. Though the expectations for the multimedia documents varied across courses, the researchers reported that learners developed a "richer understanding of the concepts" (p. 315) of the course assignments because learners were able to provide multiple representations of content using multiple media formats in their multimedia compositions. Therefore, learners may create more meaningful representations of course content by representing content in multiple forms through the use of various forms of media. This study generates relevant implications for the current study by emphasizing that learners may create meaningful representations of content as they construct multimedia that represents the content.

Beichner (1994) observed nine middle school students as they learned science content through designing and creating multimedia information screens for a local zoo using hybrid software of HyperCard and SuperCard. Because students were designing multimedia for an external audience, Beichner reported that students found the task motivating because it “had importance outside the classroom” (p. 67). Throughout the design process, students engaged in science content then identified the essential aspects of that content to share within the multimedia product for the intended audience. This process develops skills associated with Bloom’s taxonomy of cognitive skills such as analyzing and evaluating (Bloom & Krathwohl, 1956; Anderson & Krathwohl, 2001). Analyzing, evaluating and synthesizing information with the intent of sharing it with an audience requires extended engagement with content. Beichner encouraged this type of student work because “students will learn content, enjoy the learning process, and recognize that they have created something worthwhile—that is, worth their time and effort” (p. 67). This study demonstrates that the design process motivates students, particularly when students design for an external audience. In addition, the design process requires that students engage with content in meaningful ways; students construct representations of content as they analyze, evaluate and synthesize information.

Erickson (1997) observed middle school students and their teachers in a classroom structured as a “community of designers” (p. 5). This environment included several aspects that fostered the design community: students worked on sustained hypermedia design projects; students shared, discussed and reflected on their hypermedia projects; and, teachers became decentralized and “distributed instruction, evaluation, and knowledge across the classroom community” (p. 6). Erickson focused her research on the perceptions of the teachers with regard to student learning within this environment rather than measuring student learning directly. Participating teachers acknowledged that students “demonstrated growth over the year in the cognitive skills of research and design” (p. 20). Teachers perceived that students developed skills in finding, organizing and representing information while designing hypermedia documents. This study provides several design principles for implementing a design community within a classroom, and these design principles contribute to the design of the innovative learning environment implemented in the current research study.

Liu and Rutledge (1997) assessed the impact of a learner-as-designer environment on high school students, 60% of which were considered academically at-risk. The researchers compared student motivation between a control group of students in a computer application class and a treatment group of students in a similar class that was structured as a learner-as-designer environment. This environment created opportunities for students to design multimedia that would be used by external audiences such as the school or a local museum. Liu and Rutledge reported that motivation for learning was significantly higher in the treatment group. These students also exhibited more on-task behaviors and were willing to spend additional time outside of the regular class time to work on multimedia projects. In addition, self-efficacy significantly increased for the treatment group. This study contributes additional support to the notion that designing multimedia is an intrinsically motivating process. An increase in on-task behaviors and a willingness to work on design projects outside of scheduled class time provides considerable support for integrating multimedia design projects to encourage engagement with content.

McGrath, Cumaranatunge, Ji, Chen, Broce and Wright (1997) completed several case studies of science-related multimedia projects integrated into elementary and secondary classrooms. The researchers reported on three aspects of these projects: learning and attitudes, gender and responsibility. McGrath et al. found that students were motivated and enthusiastic about designing multimedia and demonstrated high levels of interest in the science content related to their projects. However, students' attitudes about science were not impacted as a result of designing multimedia. As a result of designing multimedia on science topics, students learned science but also developed planning, researching, writing and collaboration skills. McGrath et al. also found that gender had no impact on enthusiasm for the project or on learning of content or skills. In addition, the researchers reported that students demonstrated increased responsibility for their learning. Evidence for increased responsibility included students willing to work on multimedia projects outside of the school day, students willing to persevere when frustrated during the design process, students concerned with how their multimedia projects would appear to an external audience and students realizing that others were relying on their efforts. Overall, this set of case studies provides evidence that the process of designing multimedia not only encourages engagement with content to promote learning of content but supports the development of meaningful skills that will have value throughout students' lives.

Liu and Pederson (1998) compared motivation and learning of design knowledge for two classes of fourth graders: one class was identified as the designer group while the other was identified as the non-designer group. While both groups authored hypermedia projects on science content, students in the designer group worked collaboratively to construct hypermedia while students in the non-designer group worked independently. Liu and Pederson reported no significant differences between groups for most aspects of motivation, which is a consistent finding within the research literature. Generally, students find hypermedia authoring motivating. However, the designer group demonstrated increased ability to make judgments independent of the teacher. In addition, both groups completed a pre- and post-test of science content knowledge, and both groups significantly increased their science content knowledge over the course of the project. Students in both groups developed the ability to use hypermedia-authoring tools, but students in the designer group also developed "skills such as planning, project management, reflection (getting feedback from the peers and the audience), and working in groups to achieve a common goal" (p. 177). Not surprisingly, students in the designer group demonstrated "significantly better understanding of planning and collaboration" (p. 177). This study provides evidence that designing hypermedia is motivating, leads to increased content knowledge, produces hypermedia-authoring skills and develops collaboration and metacognitive skills.

Orey, Fan, Scott, Thuma, Robertshaw, Hogle, Tzeng and Crenshaw (2000) shared several anecdotes about young learners designing multimedia in classrooms for gifted and academically at-risk students. The researchers reported that designing multimedia motivated students. Students were willing to work on multimedia projects before and after school and on school holidays. This extended engagement requires motivation. However, students demonstrated less motivation during more structured activities. The researchers attributed this phenomenon to a lack of choice or control evident within structured activities (Turner & Paris, 1995). Of significance, academically at-risk students also demonstrated motivation while designing. Orey et al. also reported that students developed collaboration skills.

Liu and Hsiao (2002) observed increased understanding of the design process when middle schools students became multimedia designers. Student designers could articulate the significance of the stages of a design process: planning, designing and testing. Student designers also increased their peer learning skills. Students collaborated with peers through the design process and came to rely on their peers to distribute efforts for the design tasks. This study provides evidence that collaboration skills and design skills develop as students design multimedia.

Chen and McGrath (2003) observed tenth-grade students designing hypermedia documents using *Storyspace 1.2*. Pairs of students worked together to produce a hypermedia document about water to meet assignment expectations for a science course. Chen and McGrath reported that students preferred hypermedia construction to traditional ways of representing information because it appealed to individual learning styles. Students articulated that they could choose multiple ways to represent content. Chen and McGrath also found evidence of deeper learning based on student comments that demonstrated metacognition and reflection. In addition, the authors reported that students in the roles of hypermedia designers developed “effective cognitive and knowledge representational skills” (p. 57). This study provides evidence that when students design hypermedia, they develop important metacognitive and reflective skills and learn to represent content in multiple ways.

Mitchell, Andreata and Capella (2004) asked students in 5 different courses of an education doctoral program to design a multimedia learning experience for future students who would be novices in the content of the courses. Students designed a multimedia product using LiveSlideShow that integrated an audio track explaining course material with images. After conducting student interviews to determine perceptions of the value of integrating learner-constructed multimedia, Mitchell, Andreata and Capella reported that this experience led to increased student engagement with course content. According to the researchers, this engagement stemmed from increased motivation through students creating personal connections to course content and through an appropriate level of challenge. Because students recorded their voice as part of the multimedia product, they articulated a more personal connection to the product over traditional ways of expressing information (e.g., writing a paper). In addition, students reported that the challenge of integrating audio and images to communicate course content was motivating because they were required to think about new ways of delivering information. This study highlights how learner-constructed multimedia increases engagement with course content for students as they negotiate ways to express essential information within the multimedia product. Though this study reports on evidence obtained from doctoral students, it is a reasonable assumption to conclude that students on the opposite end of the educational continuum may similarly benefit from increased engagement with content.

Brown (2007) also found increased engagement and motivation along with demonstrated higher order thinking skills when elementary students and pre-service elementary teachers constructed multimedia using HyperStudio. Across both populations, Brown noted that “[h]igh task engagement was evidenced by extended periods of involvement beyond class” (p. 106). A willingness to engage in expanded learning time particularly beyond traditional class time is an indicator of high levels of motivation for the prescribed task, which leads to a reasonable assumption that constructing multimedia may be inherently motivating for learners. Brown also described evidence of higher-order thinking as described by Resnick (1987). She reported that students:

> followed a non-algorithmic path, faced knowledge, skill and process complexity, generated multiple solutions, coped with uncertainty, demonstrated nuanced judgment with media selection and adaptation, were required to self-regulate their thinking, and put considerable effort into structuring information (Brown, 2007, p. 107).

This is an impressive list of skills, and teachers would be quite pleased if students developed these skills during any learning experience. These higher-order skills were not explicitly taught as part of the multimedia construction process but are significant by-products of it. This study provides support for integrating multimedia construction as a pedagogical strategy since motivation increases and higher-order thinking develops as learners construct multimedia.

Garthwait (2007) reported increased writing skills in middle school students after designing hypermedia projects for younger students. 7th grade students used HyperStudio to create a hypermedia document about African animals for 2nd grade students. Garthwait observed that 7th graded students became adept at writing for a specific audience. This study highlights how additional skills (i.e., writing skills) develop as learners design hypermedia.

Collectively, these studies indicate evidence for using multimedia construction to produce a variety of outcomes (see Table 2-2). These outcomes include increasing motivation to learn, which promotes increased engagement with content, and developing a number of skills including research, design and thinking skills. Of significant importance, students represent content in a more expert-like manner and have opportunities to represent content in multiple ways when designing multimedia. Through the act of designing a multimedia artifact that represents a student's understanding of content, s/he deeply engages in content and develops multiple skills that will have long-term potential benefits.

Table 2-2. Summary of outcomes when learners design hypermedia/multimedia

Outcome	Author(s)
Students become motivated.	Beichner (1994); Liu & Rutledge (1997); McGrath, Cumaranatunge, Ji, Chen, Broce & Wright (1997); Liu & Pederson (1998); Orey, Fan, Scott, Thuma, Robertshaw, Hogle, Tzeng & Crenshaw (2000); Brown (2007)
Students spend additional time outside of class to work on projects.	Liu & Rutledge (1997)
Students develop research skills: finding, analyzing, evaluating and synthesizing information.	Lehrer, Erickson & Connell (1994); Beichner (1994); Erickson (1997)
Students represent content in an expert-like manner.	Spoehr (1993); Liu & Pederson (1998)
Students represent content in multiple ways.	Hay, Guzdial, Jackson, Boyle & Soloway (1994); Chen & McGrath (2003)
Students develop metacognitive and reflective skills.	Liu & Pederson (1998); Chen & McGrath (2003); Brown (2007)
Students develop design skills	Carver, Lehrer, Connell & Erickson (1992); Erickson (1997); Liu & Pederson (1998); Liu & Hsiao (2002)
Students engage in content.	Lehrer, Erickson & Connell (1994); Beichner (1994); McGrath, Cumaranatunge, Ji, Chen, Broce & Wright (1997); Mitchell, Andreata & Capella (2004)

Table 2-2. Continued

Students reduce off-task behaviors.	Lehrer, Erickson & Connell (1994); Liu & Rutledge (1997)
Students increase self-efficacy.	Liu & Rutledge (1997)
Students take responsibility for their learning.	McGrath, Cumaranatunge, Ji, Chen, Broce & Wright (1997)
Students develop collaboration skills.	Liu & Pederson (1998); Orey, Fan, Scott, Thuma, Robertshaw, Hogle, Tzeng & Crenshaw (2000); Liu & Hsiao (2002)
Students develop writing skills.	Garthwait (2007)

The outcomes identified by the studies in Table 2-2 provide the foundation and rationale for designing an ILE that integrates learner-constructed multimedia as a pedagogical approach. Step 2 of Ma and Harmon's (2009) DBR process is the development of a solution with a theoretical framework. Integrating learner-constructed multimedia serves as the solution for this DBR study. Next, it is important to consider the tool that learners will use to construct multimedia.

Multimedia Construction Tools

There are a number of tools that have been used for multimedia construction. These include HyperCard, HyperAuthor, HyperStudio, Microsoft PowerPoint, Inspiration, Adobe Photoshop, LiveSlideShow, Macromedia Director, iMovie, Windows MovieMaker and Adobe Dreamweaver. All have their affordances and limitations. One tool of considerable interest is Scratch. Scratch was developed by the Lifelong Kindergarten Group at the MIT Media Laboratory as a means for producing interactive multimedia through the use of a simple, visual, free programming tool (see Resnick, 2006; Peppler & Kafai, 2007a; Maloney, Peppler, Kafai, Resnick & Rusk, 2008).

Scratch. This research study uses Scratch as the design tool for multimedia construction. Scratch was designed for use by children age 8 and up, though adolescents and adults may also find that is a valuable design tool. The Scratch interface is kid-friendly (see Figure 2-2). Designing in Scratch involves adding sprites (objects that represent characters, props and other elements) and editing the stage (background). In Figure 2-2, there is a cat sprite on a stage that consists of a solid white background. Creating actions for the sprites or stage consists of dragging command blocks from a palette and stacking them together. A stack of command blocks forms a script, and the script describes the actions or behavior of a sprite (see Figure 2-3). The script portrayed in Figure 2-3 shows 9 unique command blocks. The command blocks are color-coded to represent different types of commands. For example, the palette of motion commands is displayed on the left-hand side in Figure 2-2. In Figure 2-3, there are five different types of command blocks: control (yellow), looks (purple), sensing (light blue), sound (pink) and operators (green). Reading through the command blocks helps the user understanding which behavior or action will occur. The command blocks represent lines of code found in traditional computer programming languages. However, Scratch replaces the text of other programming languages with graphic blocks, and each block represents a specific command.

The script in Figure 2-3 begins when the space key is pressed. Pressing the space key acts as a trigger to begin the script. The ‘show’ block ensures that the sprite with this script is visible. The ‘say’ block states the entered text in the form of a talk bubble above the sprite. The text remains visible on the screen for 5 seconds as identified in the block. The ‘repeat until’ block ensures that the stack inside the block continues to loop until a specific condition is met. In this case, the stack will repeat until a user of the project enters a value of 1 when prompted. The ‘ask’ block creates a text box at the bottom of the stage where a user can use the keyboard to enter a response. The typed response is stored as a variable called ‘answer’. Notice that if the correct response is entered, a sound plays followed by two separate text bubbles. If an incorrect response is entered, the user is encouraged to try again using a text bubble.

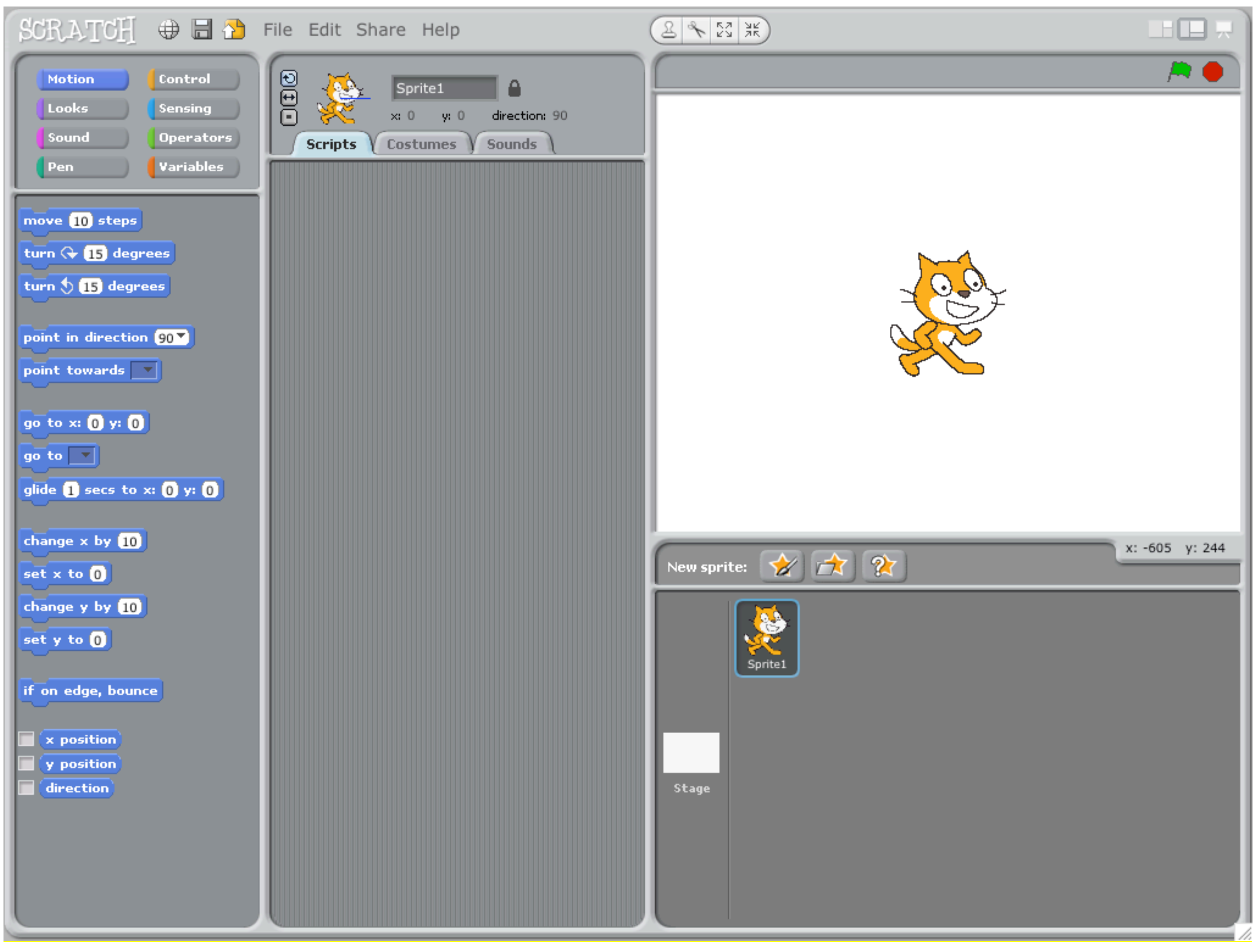


Figure 2-2. The Scratch interface

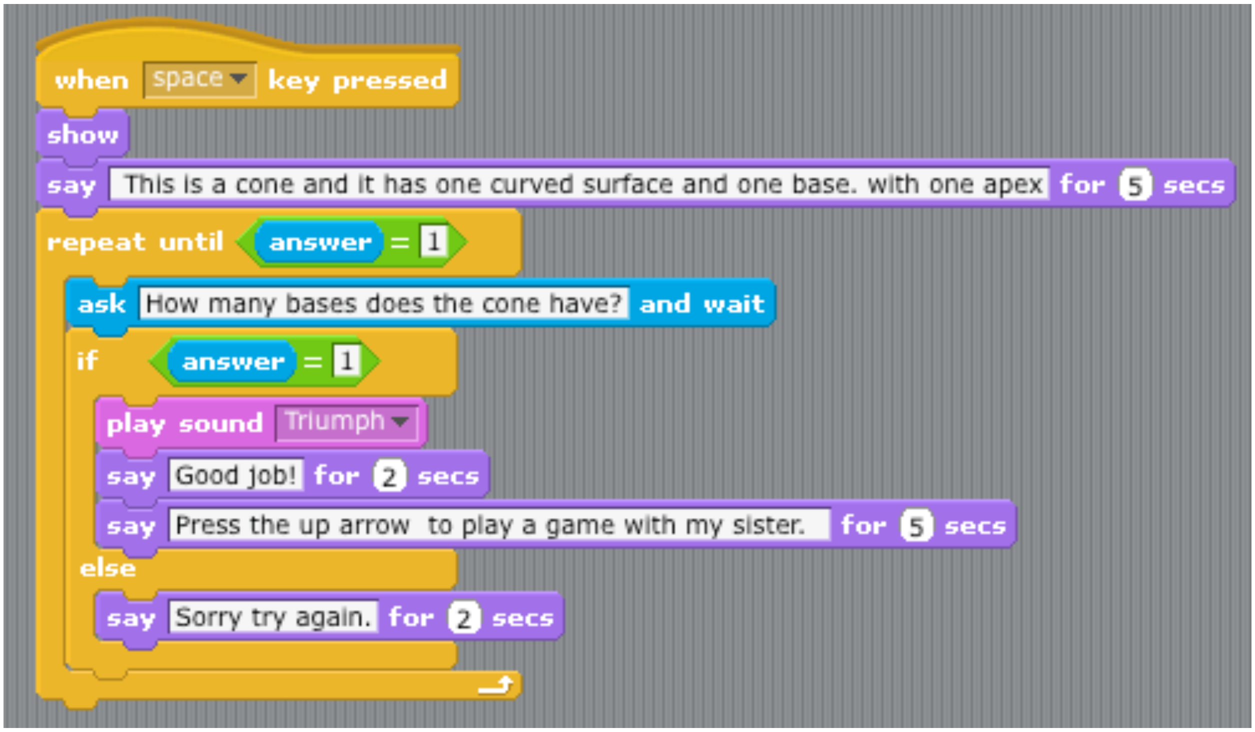


Figure 2-3. A script created in Scratch

As stated on the Scratch website, "[a]s young people create and share Scratch projects, they learn important mathematical and computational ideas, while also learning to think creatively, reason systematically, and work collaboratively." Based on this description, it is reasonable to assume that when learners use Scratch to design multimedia, they will develop thinking and collaboration skills.

The use of Scratch is well documented in after school programs and community technology centers (Peppler & Kafai, 2005; Kafai, Peppler & Chiu, 2007; Peppler & Kafai, 2007a; Peppler & Kafai, 2007b; Maloney et al., 2008). There is an online community associated with Scratch, and this feature of Scratch separates it from other kid-friendly programming tools such as Squeak or Alice. Documenting ways in which the community of Scratch users engage with Scratch and collaborate with each other is also evident within the literature (Monroy-Hernández & Resnick, 2008; Blau, Zuckerman

& Monroy-Hernández, 2009; Resnick, Maloney, Monroy-Hernández, Rusk, Eastmond, Brennan, Millner, Rosenbaum, Silver, Silverman, & Kafai, 2009). However, little documentation exists for using Scratch in formal K-12 classroom environments to promote gains in content learning and not just programming skills. The Scratch website includes a research page that identifies research articles and conference presentations that document how young learners use Scratch. Yet, no listed manuscript documents the use of Scratch in classroom contexts. In addition, an exhaustive search of the university's library databases did not reveal any articles documenting Scratch's use in a school-based classroom. The current research study attempts to contribute to this dearth of available literature documenting Scratch's impact on content learning in K-12 classrooms. More specifically, this study seeks to identify learning and motivation gains when 5th graders design multimedia about the properties of geometric solids using Scratch.

Properties of Geometric Solids

Developing an understanding of the properties of geometric solids is an expectation of the 5th grade curriculum (NCTM, 2006). Students should be able to describe three-dimensional shapes by their number of faces, edges and vertices. In addition, students should be able to calculate volume and surface area of such shapes. Understanding surface area and volume may be problematic for students if a learning goal for this content is reduced to memorizing formulas to calculate either quantity (Ben-Chaim, Lappan & Houng, 1985; Battista, Clements, Arnoff, Battista & Borrow, 1998). Creating opportunities for learners to design a multimedia artifact using Scratch that expresses the properties of geometric solids may serve as an effective pedagogical approach that ensures that learners are not limited to memorizing this content. While designing in Scratch, learners must consider how they will represent the properties of geometric solids. They must make decisions about what they will include in their Scratch artifacts and determine how they will represent these properties. This requires that learners actively engage with the specific content. Using Scratch may also motivate reluctant learners to engage in this content because Scratch may be intrinsically motivating for young learners.

Summary

Based on previous studies that have identified multiple outcomes when learners design multimedia, this study seeks to further understand the impact of LCM on learning and motivation when learners use Scratch, a contemporary design tool. This study created an opportunity for participants to represent their understanding of the properties of geometric solids in a multimedia artifact created in Scratch. While designing in Scratch, participants determined which properties to address and how to address them. Through this decision-making process, participants engaged with specific math content beyond rote memorization. While existing studies document the benefits of LCM using other multimedia design tools, this study contributes new understanding for using Scratch as a multimedia design tool.

CHAPTER 3
RESEARCH METHODS

Introduction

This research study addresses the dearth of research evident when youth construct multimedia projects using Scratch, a contemporary multimedia-authoring tool, to demonstrate their understanding of math content in an academic setting. A body of research exists that identifies numerous benefits when youth engage in multimedia construction. In addition, evidence exists for using Scratch as a tool for expression in informal environments such as after school centers, community technology centers and Scratch's online community. This study seeks to capitalize on the affordances of Scratch as a design tool in a formal learning environment. Thus, the purpose of this study is to identify learning gains when young learners design and construct multimedia to demonstrate understanding of specific math content. Specifically, the target population for this study is young academically at-risk learners. With the purpose and population in mind, this study addresses the following research questions:

- How effective is learner-constructed multimedia at increasing learning gains in the properties of geometric solids for academically at-risk learners?
- What are the design principles for creating an innovative learning environment that integrates learner-constructed multimedia for academically at-risk learners?

This chapter provides an overview of this study's research design and addresses Step 2 of the design-based research (DBR) framework identified in chapter 1 of this manuscript. It also articulates the specific procedures conducted within the research design to complete the study. The chapter includes the following sections: theoretical framework, researcher bias, research design, research context, data sources and collection, data analysis procedures, trustworthiness and limitations of this study.

Theoretical Framework

As described in Chapter 2, constructivist learning theory, constructionist pedagogy and knowledge-as-design pedagogy provide the theoretical framework for this inquiry. Creating opportunities for learners to construct personally relevant multimedia artifacts that represent their understanding of content epitomizes a constructionist approach to learning. Constructionist pedagogy (Papert, 1980) is based on constructivism, the learning theory that posits that learners build knowledge structures through experiences. Constructionists extend this theory and argue that learning is particularly robust when learners have the opportunity to construct a shareable artifact (Harel & Papert, 1991; Kafai & Resnick, 1996).

Researcher Bias

The theoretical framework that provides the foundation for this study also indicates this researcher's bias on how individuals learn best. This researcher strongly believes that learning is most effective when a learner must engage in content with the intent of designing and constructing a shareable artifact that expresses what s/he understands about that content. This artifact can exist in multiple forms: a hand-drawn concept map, an online presentation, a word processing document or a multimedia display. Each artifact requires that the learner spend time and effort engaging in content by making meaning from the content, finding ways to organize the content into a meaningful representation and designing and constructing an artifact that represents the learner's understanding of the content. This belief about learning identifies this researcher as a constructionist, and it is essential to acknowledge this bias (Hatch, 2002).

Research Design

The research design most appropriate for addressing the research questions stated above is a qualitative case study. Merriam (1998) defined a qualitative case study as "an intensive, holistic description and analysis of a single instance, phenomenon, or social unit" (p. 21). For this study, this researcher conducted a qualitative case study of the learning event of academically at-risk youth constructing multimedia using Scratch to represent their understanding of the properties of geometrics solids in an academic setting. The term 'case study' is often used as a generic concept, so it is helpful for researchers to specify the design of a case study based on additional characteristics of the design. The case study design implemented in this study can be further defined based on its special features, its disciplinary orientation and its intent (see Table 3-1). These three aspects of a case study design provide information about the focus, the object of inquiry and the outcomes of the case study, respectively.

Table 3-1. Overview of the characteristics of this case study

Characteristics (Merriam, 1998)	Description of this case study
Special features: particularistic, descriptive or heuristic	Particularistic: this case study focuses on a specific pedagogical event
Disciplinary orientation: ethnographic, historical, psychological or sociological	Psychological: this case study targets the individual
Intent: descriptive, interpretive, evaluative	Descriptive: this case study provides a detailed overview

First, this case study is particularistic, an indication of the special features characterizing the study. Particularistic case studies "focus on a particular situation, event, program or phenomenon" (Merriam, 1998, p. 29), and this study's focus is on the specific pedagogical event of young academically at-risk learners designing and constructing multimedia to demonstrate their knowledge about specific math content. Particularistic case studies also provide information about successfully replicating the event in similar contexts and study a defined event that can contribute to a generalized understanding of the phenomenon-at-large (Olson in Hoaglin, Mosteller, Light, Stoto & McPeek, 1982).

Second, the disciplinary orientation of this case study is psychological. Psychological case studies target the individual and his or her behavior within an event (Merriam, 1998). This case study targets two young academically at-risk learners and documents their behaviors and learning as they design and construct multimedia to demonstrate their knowledge about specific math content.

Last, the intent of this case study is descriptive. It will provide a detailed overview of a pedagogical event. Descriptive case studies are valuable for “presenting basic information about areas of education where little research has been conducted” (Merriam, 1998, p. 38). There is evidence that learners benefit from constructing multimedia. In addition, using Scratch has been documented in informal learning environments. However, there is a dearth of research at the intersection of these two practices: using Scratch to construct multimedia in a formal learning environment. This descriptive case study provides important information to fill in this gap in research.

Collectively, these additional descriptors help define this case study. The research represented in this manuscript is a particularistic, psychological and descriptive case study. This description informs the reader that this case study describes individuals and their behaviors within a specific event.

Research Context

This section provides an overview of the research context in which this study occurred. The following sub-sections further clarify the research context.

Research Site

The K-12 school chosen for this research study is the local university's K-12 developmental research school. This school has demographics that match the demographics of the surrounding region. Thus, it includes a diverse population across numerous categories such as race and socioeconomic status. Other reasons for selecting this site include that a mission of the school is "to develop innovative solutions to educational concerns" (school website) and that the school maintains a collaborative relationship with the associated college of education. The school is also currently developing a math intervention model for students who are not performing well in math as identified by standardized test scores. Thus, using this site to evaluate an alternative pedagogical approach benefits the school as well as the larger educational community.

Practitioner Profile

An important feature of DBR is collaboration between a researcher and a practitioner. This researcher collaborated with Mrs. H., a practitioner based at the school site selected for this study. Mrs. H. previously earned a bachelor's degree in elementary education and a master's degree in special education from an accredited teacher education program at a large, southeastern public university. She is currently working part-time towards an education doctorate in curriculum, teaching and teacher education. Mrs. H. is also in her 6th year of teaching. Previously, she has taught 2nd, 3rd and 5th grades.

During the current academic year, she serves in an instructional support position that is divided between providing professional development to elementary teachers and working with Tier 3 reading and math students. Tier 3 students are identified as needing intensive, individualized interventions to remediate skill deficits based on data gathered from formal assessments such as state-level standardized tests or school-administered screening tests (Marston, 2005). Identifying students as Tier 3 refers to the Response-to-Intervention (RtI) framework. Schools adopting an RtI framework work to create learning environments where “instruction is layered over time in response to students increasing needs” (Vaughn, 2003, p. 2). Tier 3 intervention represents the most intensive layer.

Sample Selection

In conducting a qualitative case study, it is necessary to perform two levels of sampling to identify the unit of analysis (Merriam, 1998). First, the case is selected. Then, purposeful sampling is conducted within the case. For this research study, the selected case is the population of Tier 3 students for math in 5^{th} grade at the local university’s K-12 developmental research school. This population of academically at-risk learners needs additional targeted instruction to be successful in academic settings. Traditional teaching methods may not work with this population, yet approaches that create innovative learning opportunities may increase motivation and augment learning. Tier 3 students in 5^{th} grade were selected because Scratch, the design tool used by participants in this study, was created for young people ages 8 and up which matches the 5^{th} grade demographic.

Once the case was selected, purposeful sampling was conducted within the case. The initial case population for this research study is a school’s Tier 3 students in 5^{th}

grade, which consists of 8 students. There are 2 females (one mixed race and one Hispanic) and 6 males (2 black, 1 Hispanic and 3 white). The researcher in conjunction with the practitioner selected two individual cases in order to conduct maximum variation sampling, a type of purposeful sampling (Merriam, 1998). Maximum variation sampling attempts to capture levels of diversity within the studied phenomenon. For this study, the diversity was determined by observing the participants during the early part of this research study while participants learned how to use Scratch. One student, Dominic, frustrated quickly while learning how to use Scratch. Another student, Jennifer, quickly acquired new skills in Scratch and emerged as a leader in demonstrating how to complete tasks in Scratch to the other students. Because of the maximum variation with respect to learning about Scratch between these 2 students, the researcher and the practitioner selected Dominic and Jennifer as the participants for a case study. Thus, the unit of analysis for this study is a Tier 3 5^{th} grade student.

Research Environment

The Tier 3 5^{th} grade students in this school meet daily as a group with the Mrs. H. for about 25 minutes at the beginning of the school day. They are pulled from their regular classrooms and meet in Mrs. H.'s office. During this time, Mrs. H. provides additional instruction related to math content. This instruction is in addition to the math instruction provided in their regular classrooms. While these students are working on math skills with Mrs. H., the other 5^{th} graders are working on writing skills.

The researcher and practitioner (Mrs. H.) collaboratively designed a prototype of an innovative learning environment that integrates learner-constructed multimedia. Initially, the researcher and practitioner identified appropriate content that the practitioner's 5^{th} grade students would address when constructing multimedia using

Scratch. The content selected for this inquiry is the properties of geometric solids. This content was selected because it is emphasized in curriculum standards endorsed by several organizations (see Table 3-1). Addressing this content occurred in the practitioner's pacing guide at the time when the researcher was available to conduct this inquiry. The school site previously adopted Everday Mathematics (Bell, Bretzlauf, Dillard, Hartfield, Isaacs, McBride, Pitvorec, Saecker & Winningham, 2007) for its math curriculum, and the timing of this research project coincided with the teaching of Unit 11 in the text. Knowing the properties of geometric solids is one of the secure skills for this unit. In addition, the National Council of Teachers of Mathematics has identified this content as one of three curricular focal points for 5th grade. This content is also identified as a Big Idea in the State of Florida's Next Generation Sunshine State Standards. Specifically, there are two benchmarks that address this content: Analyze and compare the properties of two-dimensional figures and three-dimensional solids (polyhedra), including the number of edges, faces, vertices, and types of faces (MA.5.G.3.1) and describe, define, and determine surface area and volume of prisms by using appropriate units and selecting strategies and tools (MA.5.G.3.2).

Table 3-1. Content rationale

Organization	Content expectations
Everday Mathematics, University of Chicago School Mathematics Project	Unit 11 secure skill: Know the properties of geometric solids
National Council of Teachers of Mathematics	Grade 5 Curriculum Focal Point for *Geometry* and *Measurement* and *Algebra:* Describing three-dimensional shapes and analyzing their properties, including volume and surface area

Table 3-1. Continued

State of Florida Next Generation Sunshine State Standards	Subject Area: Mathematics Grade Level: 5 Body of Knowledge: Geometry Big Idea: BIG IDEA 3 - Describe three-dimensional shapes and analyze their properties, including volume and surface area. Benchmark Number: MA.5.G.3.1 Benchmark Description: Analyze and compare the properties of two-dimensional figures and three-dimensional solids (polyhedra), including the number of edges, faces, vertices, and types of faces. Benchmark Number: MA.5.G.3.2 Benchmark Description: Describe, define, and determine surface area and volume of prisms by using appropriate units and selecting strategies and tools.

Participants were first introduced to the properties of geometric solids in their 5th grade classrooms as part of the Everyday Mathematics curriculum. Mrs. H. provided additional instruction (intervention) and review on this specific content before 5th graders designed a Scratch multimedia artifact. Both types of instruction occurred before the onset of the current study.

During the study, participants were expected to design and construct multimedia that demonstrates their understanding of the properties of geometric solids. The design process occurred in two general phases: learning how to use Scratch (Phase 1) and designing a project using Scratch (Phase 2). Each phase could be further divided into sub-phases that better represent the specific activities of the participants (see Table 3-2). During Phase 1, participants were introduced to Scratch. Participants used Scratch (Version 1.4) installed on Apple iBook G4 laptops running the Mac OS X Version 10.4.11 operating system. They explored Scratch's interface and became familiar with some of its features. The Scratch developers created Scratch Cards, which are a collection of 12 cards that individually teach a specific skill in Scratch. For example, the Say Something Scratch Card (see Figure 3-1) identifies the steps required to have a sprite display a text bubble on the screen. During Phase 1, the practitioner shared the Animate It, Moving Animation and Say Something Scratch Cards with participants to learn the specific skill introduced by each card. The participants chose which Scratch Cards they would like to learn.

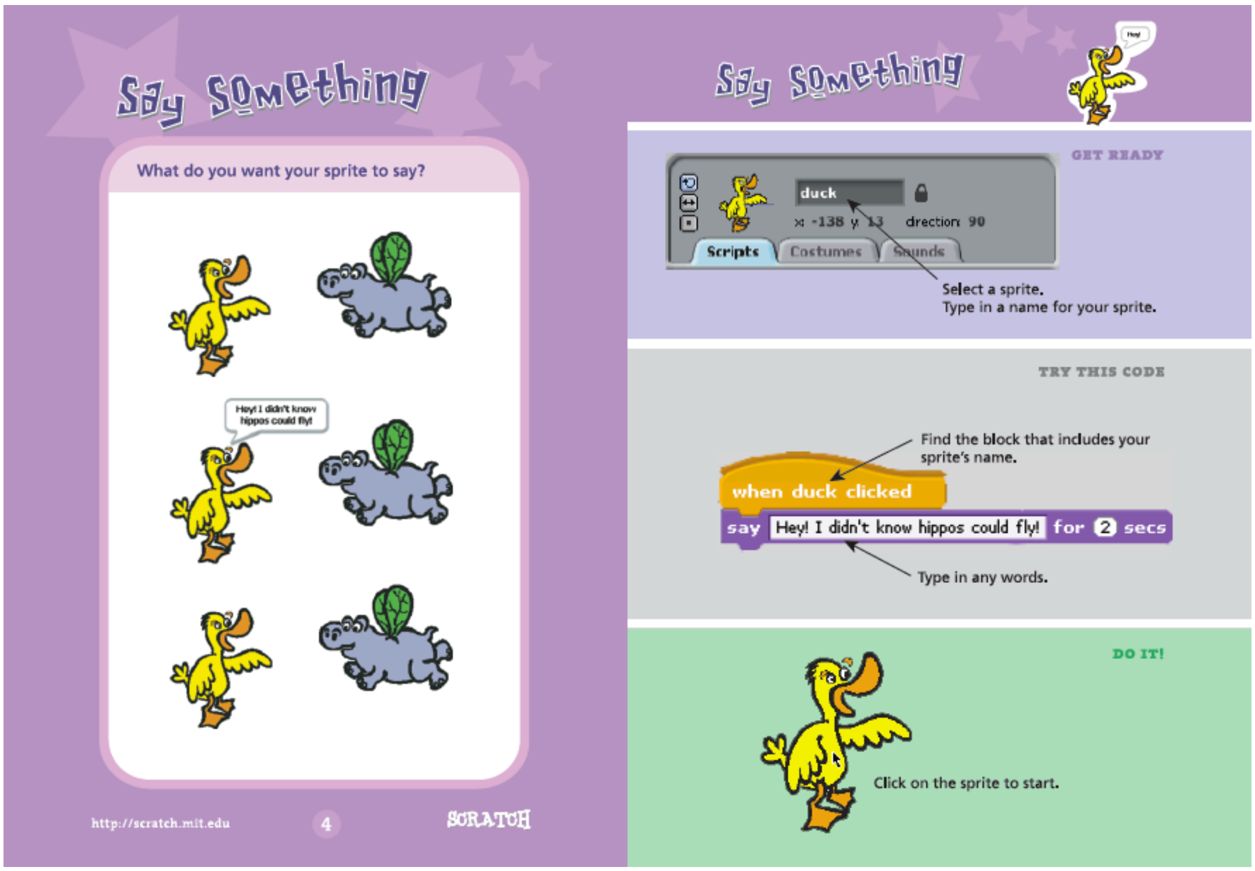


Figure 3-1. The front and back of the *Say Something* Scratch card

During Phase 2, participants planned, designed, produced and tested ways to represent their knowledge about the properties of geometric solids in Scratch. These steps are similar to the multimedia development process used by professional designers (Liu, Jones & Hemstreet, 1998). During this phase, participants were introduced to the project and began to brainstorm ways to express their knowledge of the properties of geometric solids. Participants added sprites and backgrounds from the existing libraries in Scratch or created their own. Throughout this phase, participants also tested and revised their project.

Table 3-2. Overview of daily activities

Day	Phase	Descriptions of class events
Day 1	Phase 1	Introduction to Scratch; overview of interface
Day 2	Phase 1	Creating sprites in Scratch
Day 3	Phase 1	Using the 'say' block in Scratch
Day 4	Phase 1	Using the arrow keys to move a sprite in Scratch
Day 5	Phase 1	Using sprite costumes in Scratch
Day 6	Phase 1	Switching a sprite's costume in Scratch
Day 7	Phase 1	Drawing geometric solids in Scratch
Day 8	Data collection	Complete pre-test on geometric solids
Day 9	Phase 2	Review properties of geometric solids
Day 10	Phase 2	Introduction to design project using Scratch
Days 11-21	Phase 2	Designing in Scratch
Days 22-25	Phase 2	Peer-reviewing and revising
Day 26	Data collection	Complete post-test on geometric solids

Data Sources and Collection

This section provides an overview of the sources of data employed to address the research questions posed in this study. There are multiple sources of data for this study (see Table 3-3 for a Source of Data Chart). Each source of data is further described in the following sub-sections.

Table 3-3. Source of Data Table

Data source	Research question 1	Research question 2
Interview between researcher and practitioner	X	X
Debriefing notes between researcher and practitioner	X	
Pre- and post-experience content tests	X	
Interviews between participants and researcher	X	X
Researcher reflections on participant-constructed Scratch artifacts	X	X

Researcher and Practitioner Interview

At the end of the project, the researcher interviewed the practitioner (Mrs. H.) to determine the design principles necessary for engaging in additional iterations of this DBR and for evaluating the effectiveness of this event as a pedagogical strategy. Thus, the transcript of this interview (see Appendix A) provides a data source for addressing both research questions posed in this study. The semi-structured interview guide used during this interview is shown in Appendix E.

Debriefing Notes

Daily notes recorded by the researcher to document debriefing sessions between the researcher and Mrs. H. that occurred immediately after each design session were used to document the design and implementation of this innovative learning environment. The debriefing notes included descriptions of the participants, the events and the interactions between these objects. These notes also include direct quotes made by participants or notes that capture the core of what is verbalized during the observations. In addition, field notes include comments made by the researcher while in the process of observing. These extensive field notes, in conjunction with debriefing notes between the practitioner and researcher, provide sources of data for informing the design of future iterations of this DBR and for developing a healthy response to research question #2.

Content-Based Pre- and Post-Tests

Participants completed a pre- and post-test of content measures to determine initial understanding and growth in conceptual understanding of standards-based content (see Appendix D). The practitioner identified the pre- and post-test curriculum-based content measure from the existing Everyday Mathematics curriculum resources that are routinely used as a traditional summative assessment at the school site. Changes in scores between the pre- and post-test provide data for identifying learning gains during this event and for responding to research question #1.

Researcher and Participant Interviews

Two participants selected for the case studies completed a post-experience interview with the researcher to determine how academically at-risk learners perceive how constructing multimedia contributes to their learning and motivation (Van Manen, 2001; Seidman, 2006). Appendix E includes the semi-structured Interview Guide used during the interviews. Each interview was recorded and transcribed (Poland, 2002). These transcripts provide valuable data for addressing research questions #1 and #2.

Researcher Reflections on Scratch Multimedia Artifacts

During Phase 2 of this study (the design phase), each participant used Scratch to design and construct a multimedia artifact that represented his/her understanding of the properties of geometric solids. After each design session, this researcher examined each Scratch artifact and noted the progress of each participant. In a spreadsheet, this researcher recorded the number of sprites, the number of backgrounds, the number of scripts, the number of command blocks used in scripts and the number of command block types used in scripts. Collectively, these data serve as quantifiable measures of each participant's progress (see Appendix G). In addition, this researcher recorded his reflections on participant's progress while analyzing each Scratch artifact (see Appendix C for an example). These reflections provide qualitative data for measuring each participant's progress.

Data Analysis Procedures

This section includes an overview of the data analysis procedures used to analyze the data collected during this study. This section is further divided into 4 sub-sections that each addresses a separate data analysis procedure. First, this researcher describes the data analysis procedure used to analyze the transcripts from interviews between the researcher and the practitioner and the researcher and the 2 case study participants. Second, the procedure used to conduct a cross-case analysis of the 2 separate cases is documented. Next, the process for comparing scores on the curriculum-based pre- and post-test is identified. Finally, this researcher shares the analysis process for examining the Scratch artifacts designed and constructed by the participants.

Textual Data Analysis

Tesch (1990) provided a systematic eight-step process for analyzing data in the form of text (See Table 3-4). The researcher applied this systematic process to analyze transcripts collected from interviews with the practitioner and with 2 case study participants (see Appendix F for an example of this process). The process described below was applied separately to text from both transcripts based on interviews between the researcher and the 2 case study participants. This data analysis generated a separate case study for both participants and is used to address one of the research questions: How effective is LCM at increasing learning gains in the properties of geometric solids for academically at-risk learners? The data analysis procedure was also applied to the text from the transcript of the interview between the researcher and practitioner. This researcher used this particular analysis to address the second research question: What are the design principles for creating an innovative learning environment that integrates LCM for academically at-risk learners?

Table 3-4. Data analysis steps for textual data

Step	Activity
1	Read through text to develop initial understanding; create brief notes
2	Reread text to develop meaning; create notes
3	Identify list of themes based on notes
4	Translate themes into codes; label text with codes
5	Group themes into categories
6	Convert categories into codes
7	Organize data based on categorical codes
8	Recode data, if needed

The first step is to carefully read through all of the transcripts with the purpose of developing a general understanding of the data. The researcher recorded early thinking and observations in the form of brief notes. This first step assists the researcher in developing an initial understanding of the data.

Second, each of the transcripts is reread. After each reading, the researcher took notes with the intent of capturing the overall meaning of the text and not the specific detail embedded within the text. This step ensures a careful reading of the transcripts and focuses the researcher on developing an understanding of the underlying meaning of each piece of textual data.

Next, the researcher identified an initial list of themes generated from the notes created during the previous step. These themes served as the initial framework for making meaning of the data.

The fourth step involves translating the themes into abbreviated codes. The researcher then returned to the transcripts and labeled each sentence phrase or sentence with an appropriate code. Phrases or sentences that could not be labeled with an appropriate code indicated that additional codes and themes should be generated. This step tests the initial framework of themes against the data and yields a revised framework of themes that addresses the data.

Fifth, the researcher narrowed the number of themes by grouping similar themes into categories. This step generates a manageable list of categories. Categories and their associated themes are identified in Appendix F.

Sixth, categories are converted into abbreviated codes. This step facilitates the process of coding the data. Next, the researcher organized the data based on the categorical codes. That is, individual phrases or sentences from the data were pulled from the transcripts and regrouped with similar data based on the categorical codes attached to the data. These regroupings provided evidence for making meaning from the transcriptions and field notes. Lastly, if needed, data is recoded.

The process described above was applied to each of the transcripts generated from the post-experience interviews with the 2 case study participants and with the practitioner. This process resulted in the production of two separate cases. With the availability of two cases, the researcher also conducted a cross-case study.

Cross-Case Analysis

This research study includes two case studies. Merriam (1998) identified two stages of analysis when multiple cases are present within a study. First, the within-case analysis occurs to generate “a comprehensive case in and of itself” (Merriam, 1998, p. 194). Next, cross-case analysis begins. This study identified two participants to serve as independent cases for the within-case analysis with the intent of generating two separate case studies. This researcher adopted Tesch’s (1990) textual data analysis for the within-case analysis as described above.

The next stage of analysis for a multiple case study is cross-case analysis. Cross-case analysis allows the researcher to "enhance generalizability" (Miles & Huberman, 1994, p. 173) and "to deepen understanding and explanation" (p. 173). This approach generates understanding beyond the uniqueness of an individual case and may lead to a more universal and less particular understanding of the phenomenon of interest. Miles & Huberman advocated for an "interactive synthesis" (p. 176) when conducting a cross-case analysis. An interactive synthesis combines data analysis procedures that separately focus on analyzing variables evident across cases (variable-oriented strategies) or on analyzing the individual qualities of each case (case-oriented strategies). Conducting an interactive synthesis first relies on the presentation of separate cases. Next, themes evident across cases are described (a variable-oriented strategy). These themes are then framed and supported within each case (a case-oriented strategy).

Pre- and Post-Test Analysis

Scores from the pre- and post-test were compared for each participant. The sample size for this study is too small to measure statistical significance between the two measures. However, an increase in scores indicated that a participant did gain some understanding of the properties during the experience.

Scratch Artifact Analysis

In this research study, each participant designed a multimedia artifact using Scratch that represented his/her understanding of the properties of geometric solids. These Scratch multimedia artifacts serve as a data source and can be analyzed. However, there exists only a single precedent for analyzing Scratch artifacts. Maloney et al. (2008) analyzed Scratch artifacts for evidence of programming concepts. They examined learned-constructed Scratch artifacts and identified command blocks included in each Scratch artifact. They argued that the use of a particular command block indicated a specific programming concept. Unfortunately, this approach is not appropriate for the current study because the research questions posed in this study are not concerned with programming concepts learned by participants. Rather, the Scratch artifacts needed to be analyzed to determine an impact on learning.

With this purpose in mind, this researcher examined each Scratch artifact daily. In a spreadsheet, he recorded the number of sprites, the number of backgrounds, the number of scripts, the number of command blocks used in scripts and the number of unique command block types used in scripts. In addition, he also listed the unique command blocks used in scripts for each participant's Scratch artifact (see Appendix G for an example). Next, he recorded his reflections on each participant's progress, noting evidence of content related to the properties of geometric solids and interpreting progress based on the data recorded in the spreadsheet.

The data contained within the spreadsheet could serve as a measure of the complexity of a participant's artifact. It is reasonable to assume that an increase in any of these values over time indicates that an artifact is evolving and becoming more complex. The reflections document this researcher's interpretations of the spreadsheet data. Collectively, the spreadsheet data and reflections provided additional evidence for completing the within-case and cross-case analyses.

Trustworthiness

Meeting sufficient levels of validity and reliability are concerns for all types of research, but these constructs are measured differently in qualitative and quantitative studies. Validity, reliability and generalizability all contribute to a qualitative study's trustworthiness. Trustworthiness ensures that research results can be trusted with a high level of confidence (Merriam, 1998).

Validity

A case study's validity ensures that the findings evident within the study match the reality of the context. Merriam (1998) identified six strategies for ensuring sufficient validity in qualitative case study designs: triangulation, member checks, long-term observation, peer examination, collaborative modes of research and researcher's biases. Triangulation involves "using multiple investigators, multiple sources of data, or multiple methods to confirm the emerging findings" (Merriam, 1998, p. 204). This case study design incorporated multiple sources of data (observational field notes, interview transcripts, content measures and artifacts of interactive multimedia) during the data analysis procedures to ensure that conclusions represented the data.

Member checks involve the interview participants in determining the plausibility of the interpretations developed by the researcher (Guba & Lincoln, 1989; Miles & Huberman, 1994; Moustakas, 1994). In this study, a member check was conducted with the practitioner (Mrs. H.) after her interview transcript was analyzed to ensure that conclusions arrived at by the researcher represented the data provided by her.

Engaging in long-term observation increases validity by providing sufficient time for the researcher to collect data. For this case study, the researcher observed the participants daily over a period of seven weeks.

Peer examination occurs when colleagues have the opportunity to provide comments as the researcher develops findings based on the data. For this study, once a case was analyzed, the researcher shared preliminary findings with a supervising faculty member to ensure that case's analysis was proceeding in an appropriate manner.

Collaborative modes of research provide opportunities for the study's participants to contribute to the research process. Since this study uses a DBR framework, collaboration between the researcher and the practitioner is an essential component of the case study. The researcher and practitioner had extended time to collaborate and to design the experience, and the practitioner served as a participant and as a source of data in the case study.

Bracketing the researcher's biases forces the researcher to clarify "assumptions, worldview, and theoretical orientation" (Merriam, 1998, p. 205) so that readers understand a researcher's biases. Bracketing acknowledges that biases are inherent in all human endeavors and ensure that they are made publicly available. The theoretical orientation was described above and clearly represents this researcher's biases.

Reliability

Reliability refers to the ability of the study to be replicated. Merriam (1998) shared three techniques for promoting reliability in qualitative case study designs: investigator's position, triangulation and audit trail. First, the researcher should clearly describe his or her role and decision making within the study. This chapter, overall, contributes to an understanding of the role of the researcher in this case study. Decisions made by the researcher are clearly articulated in previous sections. Second, triangulation contributes to validity as described above and also contributes to the reliability of a case study design. Third, providing a full and thorough account of how data is analyzed generates an audit trail (Rodgers & Cowles, 1993). This documentation ensures that others can understand the logic followed by the researcher in reaching conclusions based on the data. The documentation should be sufficiently thorough such that others could arrive at similar conclusions based on the analysis conducted. Appendices C, D, E and F provide an audit trail for the analyses conducted in this case study.

Generalizability

Generalizability is an indication of the extent to which conclusions drawn from this study can be applied to other contexts. Merriam (1998) articulated three strategies for ensuring generalizability in qualitative case study design: rich, thick descriptions, typicality and multisite designs. As articulated above, this is a descriptive case study. An outcome of a descriptive case study is a rich, thick description of an event. A rich, thick description provides an opportunity for readers to determine if findings can be applied in their contexts. Typicality highlights how representative the participants are for a particular population. This case study's participants are well described, and the participant selection identified the qualities required for participation in this study. Multisite designs can use different "sites, cases, [or] situations" (p. 212) within the study to represent diversity within the event to be studied. This case study uses purposeful sampling to identify two cases that represent maximum variation within the sample population.

Limitations of This Study

There are several limitations of this study. This study attempts to provide a rich description of the participants, context, events and the interactions between these objects. Yet, interviews, debriefing notes and researcher reflections may not fully account for an participant's behaviors. This represents a general limitation of case studies best articulated by MacDonald & Walker (1977) when they observed that "at all levels of the system what people *think* they're doing, what they *say* they are doing, what they *appear* to be doing, and what in fact they *are* doing, may be sources of considerable discrepancy" (p. 186, emphasis in original).

Another limitation of this study is the challenge of interviewing young learners. Hetherington and Parke (1986) claimed that "children are more difficult to interview than adults; children are less attentive, are slower to respond, and have more difficulty understanding questions than adults" (p. 24). Children may provide monosyllabic responses or answer 'I don't know' during interviews (Mauthner, 1997). These responses are difficult to interpret and may not provide sufficient evidence to support a particular finding.

It is also necessary to consider the uniqueness of the research context embedded within the school site used in this study. The small group structure for the 5th grade learners in this particular school may not exist in other school settings. Thus, it may be quite difficult to replicate this study in additional school sites. The unique characteristics of this site may also limit generalizations beyond this school.

A final limitation is the researcher's bias and its impact on the interpretation of the data collected during this study. This researcher's bias provided a perspective through which all data was interpreted.

CHAPTER 4
EVALUATION AND TESTING OF A SOLUTION IN PRACTICE

Introduction

This study seeks to identify learning gains when academically at-risk 5th graders design and construct multimedia using Scratch that represents their understanding of the properties of geometric solids. Based on this purpose, this study posed the following research questions:

- How effective is learner-constructed multimedia at increasing learning gains in the properties of geometric solids for academically at-risk learners?
- What are the design principles for creating an innovative learning environment that integrates learner-constructed multimedia for academically at-risk learners?

In this chapter, this researcher first summarizes the data collected from all participants then reports findings related to the first research question using data from case study participants' responses during the post-experience interviews, participants' performances on the pre- and post-test, debriefing notes from the practitioner and this researcher and an analysis of participants' Scratch artifacts. The next chapter addresses the design principles related to the second research question.

Summary of Participant Data

Eight 5th graders participated in this research study. Each created a Scratch multimedia artifact that expressed his/her understanding of the properties of geometric solids. This researcher daily analyzed each artifact and recorded specific data about each as described in Chapter 3. In addition, each participant completed a pre- and post-test addressing this specific content. Table 4-1 contains a summary of this data.

Table 4-1. Summary of participant data

Unit of analysis	Case study: Dominic	Case study: Jennifer	Other participants' means

Number of sprites	22	11	4.3
Number of backgrounds	5	4	2.2
Number of scripts	84	40	9.5
Number of blocks used in scripts	207	116	56.3
Number of block types used in scripts	11	12	11.5
Pre-test score	7	9	6.9
Post-test score	6	6	7.6

This data reveals that the 2 case study participants included considerably more sprites, backgrounds, scripts and command blocks than the other participants, though the number of command block types used in their Scratch artifacts remained consistent across the participant group. The 2 case study participants were the only participants to score lower on the post-test when compared to the pre-test. The non-case study participants scored higher on the post-test with the exception of one participant who scored the same on both.

The next section showcases 2 case studies with the intent of developing an understanding of the impact of LCM on learning.. These case studies are followed by a cross-case analysis.

Impact on Learning

One research question posed by this researcher seeks to understand the impact on learning when learners construct multimedia using Scratch. To address this research question, this researcher, in collaboration with the practitioner, selected two participants for in-depth case studies to determine the impact on their learning as described in Chapter 3. Each case study participant completed a curriculum-based pre- and post-test on the properties of geometric solids. In addition, each case study participant designed a multimedia artifact using Scratch. These artifacts were analyzed after each design session. This researcher also recorded, transcribed and analyzed an interview with each of the case study participants. Each of these data sources provides evidence for the case studies presented below.

Case Study #1: Dominic

Dominic is a friendly, polite African American 5th grade male from a professional family. Mrs. H. describes him as a student with low perseverance but high self-reflection. Mrs. H. notes that he frustrates easily when encountering challenges, but he is quite aware of his emotions and does not hesitate to share them. Before this research project began, Dominic often stayed beyond the scheduled time for the math intervention class to talk with Mrs. H. about personal issues. Dominic has been a part of the intervention class since the beginning of the school year. He was placed in the class because of low performance on standardized tests. Dominic's fraternal twin brother is also in the intervention class.

Based on an analysis of the interview between Dominic and this researcher, three themes emerged that document Dominic's thinking during this project and provide evidence for addressing the research question concerned with learning. The three themes identified include (1) Dominic's response to learning and using Scratch, (2) Dominic's response to this project, and (3) Dominic's response to his learning. These themes were further supported with evidence from both the practitioner's and researcher's observation notes.

Dominic's response to learning and using Scratch

Dominic's response to learning and using Scratch can be best summarized in his own words: "Scratch is really confusing and frustrating." He found Scratch difficult to learn because "it was hard to know what to do because there was so much stuff." By "stuff", Dominic is referring to the number of command blocks that are displayed on

Scratch's interface (see Figure 4-1 for a screenshot of the motion command blocks available in Scratch). The number of options available to him may have overwhelmed him and prevented him from progressing when learning about Scratch. Mrs. H also observed Dominic's confusion and frustration. On the third day of learning Scratch, Mrs. H. recorded the following in her daily notes: "Dominic hit a wall and couldn't persevere through a problem he ran into. He wanted me to just tell him how to get out of the situation. He didn't want to try to figure it out on his own at all. Very interesting. He left a bit upset today." Mrs. H. also noted Dominic's frustration on the 8^{th} day of learning Scratch ("Dominic got a little frustrated today") and on the 10^{th} day of learning Scratch: "Dominic was very vocal about wanting to go back to learning math this regular way instead of with Scratch because he feels like he's not ready for his test."

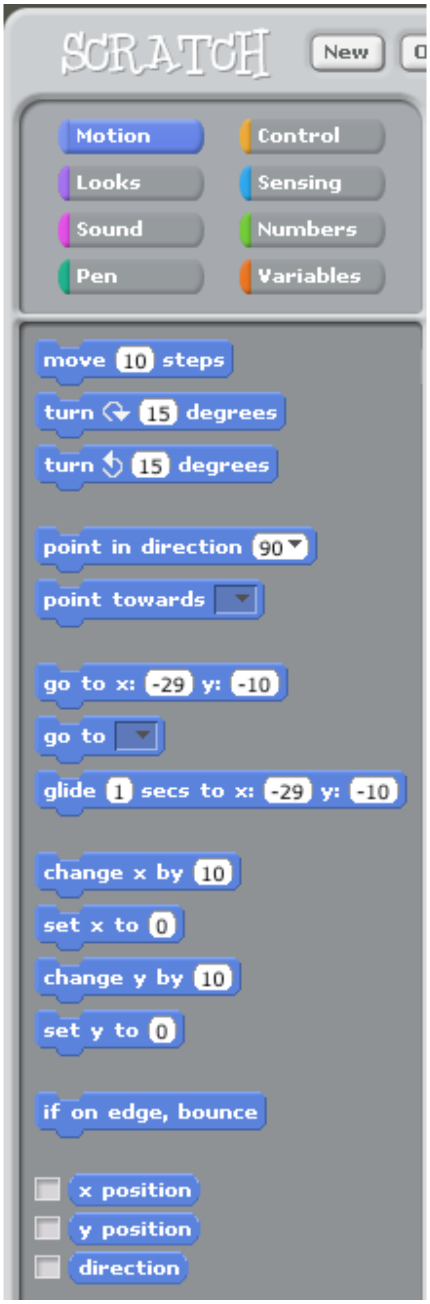


Figure 4-1. The Scratch's palette of motion command blocks

In spite of Dominic's self-reported confusion and frustration, he shared that he enjoyed using Scratch. In particular, he enjoyed "making all the new sprites and editing them" and "that there were so many sprites to use like a dragon and ghost and you can create your own sprites like raining milk". In fact, his Scratch artifact included a dragon sprite, a ghost sprite and three sprites of cylinders containing milk to portray raining milk. Dominic became quite skilled at drawing and editing sprites. His artifact included 22 sprites total (the mean for the non-case study participants is 4.3). He drew 10 original sprites and edited 12 existing sprites using Scratch's paint editor. On the 12th day of the project (the second day of designing), this researcher recorded in his field notes that Dominic "has spent quite a bit of time adding and editing sprites to his project but has spent very little time working on scripts which determine the actions and behaviors in the project." The following day this researcher noted that "Dominic has quite an imagination but he spends much of our meeting time adding characters to his artifact that are only loosely related to math content." If Dominic needed assistance on his artifact and if neither the practitioner nor the researcher were available to help him, he would spend time creating or editing existing sprites rather than exploring command blocks or testing out scripts for his artifact. On the third day of designing (the 13th day of this project), this researcher recorded that "[w]ithout assistance or prompting from the practitioner or researcher, he does not make significant progress."

Dominic also became proficient at recording sounds in Scratch. Dominic was the only participant to record his voice and integrate this voiceover into his artifact. He learned this skill on the 9th day of designing (Day 19 of the project). After learning this skill, he would record random talking or noises while waiting for assistance rather than making independent progress on his artifact or trying to resolve an issue by himself.

When asked how he thought someone should learn Scratch, he expressed "one simple thing at a time". By "thing", he is referring to the command blocks; he shared that someone should learn only a few command blocks from each of the different categories, preferably the most commonly used blocks. This may be an indication that he felt overwhelmed when first learning about Scratch. The participants were not introduced to command blocks separately. Rather, they identified a behavior or action that they wanted to include in their artifacts then received assistance in identifying the appropriate command blocks or stack of command blocks that would yield the desired behavior. This 'just in time' approach may not have worked for Dominic since he suggests an alternative approach for learning Scratch that focuses on exploring individual command blocks.

Overall, Dominic's response to learning and using Scratch is a mixed response. While he shared that he found Scratch confusing and frustrating, he enjoyed creating and editing sprites using Scratch's paint editor. In fact, this researcher repeatedly observed and noted Dominic's ability with these skills in his Scratch artifact, so he clearly learned how to use this aspect of Scratch. He was also the only participant to include a voiceover in his artifact.

Dominic's response to this project

During the post-experience interview, Dominic shared that he was not proud of his Scratch artifact and that he "was a little embarrassed…because everything was messed up the time I did it cause that was in the wrong place, that was in the wrong place, that was in the wrong place. Everything was in the wrong place." When asked if he would like to share his artifact with his 5th grade peers, he declined and said that he would "feel too embarrassed". He also acknowledged that if he were given another opportunity to design in Scratch that he would "want to make it better than the first one". He reflected that "I guess I should have done better, I said it like I didn't care, like in the sounds I said it like I didn't care." He felt like he did not provide much emotion in his voice recordings, so he expressed that he should have included more inflections in the voiceovers. Dominic's responses provide evidence that his artifact does not meet his own expectations. His concerns about his artifact may stem from inadequate progress made over the course of this study (see Figure 4-2 for a screenshot of Dominic's project).

Figure 4-2. A screenshot of Dominic's Scratch project

Dominic had a difficult time finishing his Scratch artifact. He relied heavily on the practitioner and researcher to make progress on his artifact. When neither was available, Dominic would use Scratch in ways in which he already felt confident and competent, such as drawing and editing sprites or recording his voice. He would not explore command blocks independently or seek help from his peers. On the 4th day of designing in Scratch (Day 14 of the project), this researcher observed that Dominic "does not seem to be making progress on his artifact though he certainly can add and modify sprites and add backgrounds. He uses the 'say' blocks to tell a part of his imaginative story, but he is not able to synchronize the dialogue into a coherent message or connect his story to math content."

On the 15th day of the project (the 5th day of designing in Scratch), Mrs. H. observed and noted that Dominic's artifact did not address geometric solids. The following day (Day 16 of the project and the 6th day of designing in Scratch), Mrs. H. worked with Dominic to capture his thinking on paper. Dominic had brainstormed a story idea for his artifact but had a difficult time transferring his ideas into a working project. Mrs. H. worked with Dominic to capture the story that would unfold throughout his multimedia artifact. Dominic shared his story with Mrs. H. while she recorded his script on paper. Below is the text of his script. Italicized words represent improvisations that Dominic made while recording the voiceover for his artifact. These words are not part of the original script recorded by Mrs. H. while Dominic narrated. The underlined words represent Dominic's attempt at integrating content vocabulary about the properties of geometric solids into his artifact.

> It all started at the theater. They were going to see a play about shapes. When they were watching the play, they were transported to the shape desert. When they got to the desert, the desert dragon showed himself. The cats asked the desert dragon to take them home because he has transporting powers. The dragon thought the cats lived in a creepy forest so that's where he transported them back to *and the land shark*. When the cats got to the forest, they ran into ghosts. The boss ghost captured the girl cat. The ghosts that worked for the boss ghosts captured the other cats in a ghostly cylinder. The second in command ghost transported everyone except for the girl cat to the geometric sea *and once again the land shark too*. While the cats were in the geometric sea, they saw a lot of shapes. The cats found a transporting sphere that transports them back to the theater. The dragon from the desert comes to help them because the sphere is

not powerful enough *but the land shark decides to live in the sea*. They all got transported back to the theater. When they got back to the theater, they found the girl cat with the boss ghost. The boss ghost then says, "You just passed the shape test!"

Dominic developed an elaborate story as the foundation for his multimedia artifact. However, this story only superficially addresses specific content about the properties of geometric solids. He integrated content-specific vocabulary into his artifact (cylinder, geometric, sphere) but does not define or describe the properties of those terms. His Scratch artifact does include hand-drawn representations of a sphere, cylinder, cone, pyramid and several rectangular prisms (See Figure 4-3). However, these representations are rough approximations of each geometric solid. They also serve only as props for the artifact; they are not specifically referenced or described during the artifact.

Figure 4-3. Dominic's hand-drawn representations of geometric solids

By Day 20 of the project (the 10th day of designing in Scratch), Dominic was still not making substantial progress particularly when compared to his peers. Mrs. H. noted: "Everybody was really rockin and rollin except Dominic. He really struggled working independently today." Similarly, this researched recorded:

> Dominic is dependent on directions and insight from a teacher. Dominic would tinker with blocks (especially the sound blocks) while waiting for either the researcher or practitioner to help him make progress on his artifact. Often, he needed input from the teacher to help clarify his thinking about the intent of his artifact. Dominic continues to struggle with his artifact. He has developed an elaborate story in his mind that is only loosely related to the idea of teaching someone else about geometric solids. He uses the vocabulary of geometric solids but only on a superficial level. He is unable to translate his story into Scratch without assistance from either the researcher or practitioner.

This was a consistent theme observed by Mrs. H. and this researcher. Dominic only made substantial progress if Mrs. H. or this researcher assisted him. He would not take initiative to explore Scratch independently. He also would not seek help from peers even if they could contribute.

By Day 22 of the project (the 12th day of designing in Scratch), Dominic appeared to notice that he was not making as much progress as his peers. This researcher recorded:

> Dominic expressed frustration that he is only able to make small changes to his project each day. He expressed that he doesn't understand why he is saving a new file each day (participants save a new version of their artifact each day) when he is not making much progress. He expressed some frustration that he is not getting as much help as he needs. He also wants to know when he can work on Scratch for fun and not a project about shapes.

Dominic's frustration may stem from realizing that his peers' artifacts are nearly complete, yet he still has more work on his artifact and that he only makes a small amount of progress each day.

While reviewing his multimedia artifact with this researcher, Dominic expressed, "I don't know if it was as good as everyone else's cause they're all moving and having conversation like [his brother's]." Dominic often compared himself to his brother. If his brother was praised for an aspect of his Scratch artifact, Dominic showed frustration that his artifact was not recognized. Early in the design phase, this researcher praised Dominic's brother for creating a clever conversation between two characters using text bubbles. This may have contributed to Dominic's remarks above because he specifically mentions the conversation in his brother's artifact. Mrs. H. had observed similar behavior in Dominic in the past. Any positive praise for Dominic's brother could lead to a negative attitude in Dominic.

Dominic also acknowledged that his multimedia artifact "is really different from everybody else's. Everybody else's seemed better because they're saying what shape is this then you type it in." Dominic's Scratch artifact is different from his peers. His artifact was the only Scratch artifact to include a narrated story (see script above). All of his peers' artifacts included text bubbles for one or more characters. Dominic's artifact did not include any text bubbles. Five of his peers (of 7 total) integrated a script that asks the user a question, allows the user to enter text in a textbox, and then provides feedback based on the entered text. Dominic chose not to use a similar script in his project. Clearly, Dominic's artifact is different, and he acknowledges it. Yet he also perceives that his peers' Scratch artifacts are better because his artifact is so different from theirs and does not include the ability to type in a response.

In summary, Dominic was not pleased with his final Scratch artifact. He perceived that his artifact did not work properly, and, therefore, did not meet his expectations for how he intended his project to work. He also perceived that his artifact was quite different from his peers and that it did not include several aspects that were common to his peers' artifacts. Thus, he determined that his artifact was not as good as his peers' artifacts.

Dominic's response to his learning

During the post-experience interview, Dominic shared that he did not think he learned any new math content during this project other than how to draw geometric solids. He believed that the math content he included in his artifact "are things I already know". Dominic's scores on the pre- and post-test support his thinking (see Table 4-2). Of the 13 points possible on the pre- and post-test, Dominic scored a 7 on the pre-test (mean for the group is 6.9), and he scored a 6 on the post-test (mean for the group is 7.6). Dominic was not able to calculate the area of a rectangular prism's face on the post-test though he was able to successfully complete the same calculation on the pre-test.

Table 4-2. Overview of Dominic's pre- and post-test results

Test items	*Pre*	*Post*
Able to identify geometric solids?	Yes	Yes
Able to calculate area of a prism's face?	Yes	No
Able to determine the height of a prism?	Yes	Yes
Able to calculate the volume of a prism?	No	No
Able to calculate the surface area of a prism?	No	No
Able to explain how to calculate the surface area of a prism?	No	No
Overall score	7/13	6/13

With respect to his learning, Dominic expressed that he liked to write and tell stories. This interest is clearly paralleled in his multimedia artifact. He developed an elaborate script for his artifact then narrated it. Recall that his Scratch artifact contrasts with his peers because it is so clearly story based. He also acknowledged that he did not like the question-answer action used by many of his peers in their Scratch artifacts ("I don't really like doing that"). Dominic's responses may be an indication of his learning style. He may prefer to learn through narrative rather than through question and answer discussions. When given choice and control to design his Scratch artifact, he chose a narrative approach rather than a question and answer approach selected by most of his peers.

Impact on Dominic's learning

Based on Dominic's responses during the post-experience interview, his performance on the pre- and post-test, field notes from the practitioner and researcher and an analysis of his Scratch artifact, it is evident that the pedagogical approach of having learners design a project in Scratch that integrates math content did not contribute to Dominic's learning about geometric solids. On several occasions, he became frustrated with the project and using Scratch. In fact, during one of Dominic's instances of frustration, he questioned Mrs. H. about when the group would return to the "regular way" of learning math. Although he reported enjoying Scratch, he was not successful using Scratch to adequately represent an understanding of the properties of geometric solids. His Scratch artifact includes only superficial references to geometric solids and does not adequately express an understanding of the properties of geometric solids. In addition, Dominic scored lower on the post-test when compared to the pre-test. Thus, Dominic's case provides evidence that learner-constructed multimedia may not be effective at increasing learning gains in the properties of geometric solids for learners similar to Dominic.

Though Dominic learned a few simple actions in Scratch and could repeat those actions as needed (e. g., creating a sprite, editing a sprite, recording his voice), he was not able to learn more advanced features of Scratch related to his artifact even when these actions were demonstrated several times to him by the practitioner or researcher. The number of options available in Scratch may have overwhelmed him, or he may not have had the necessary skills to successfully learn how to use a new multimedia-authoring tool, design a multimedia artifact using that tool and integrate math content into the design of the artifact. Dominic’s peers in this project were more successful learning and using Scratch to design a multimedia artifact that integrates the properties of geometric solids.

Overall, it is discouraging to discover that using Scratch to design and construct a multimedia artifact did not impact Dominic’s learning. However, it is important to acknowledge that learners differ in how specific pedagogical approaches will impact them, and it is reasonable to assume that there are additional learners that share Dominic’s learning preferences. Thus, it is imperative to understand and identify which types of learners may benefit from a particular pedagogical approach.

Case Study #2: Jennifer

Jennifer is a shy Hispanic 5th grade female. Her teachers describe her as quiet and are often unsure how much she understands material because she does not verbalize much. She has a history of poor school attendance. Jennifer did not begin the school year in the intervention group. She entered the group mid-year after she was recommended by a teacher based on her classroom performance and achievement data. Jennifer reports that she likes school (“I love to learn cause then I kind of get the subject more”) and that she is good at math in some areas, such as “adding and fractions and…exponents”.

Based on an analysis of the interview between Jennifer and this researcher, two themes emerged that document Jennifer's thinking during this project and provide evidence for addressing two of the research questions. The two themes identified include (1) Jennifer's response to learning and using Scratch, and (2) Jennifer's response to this project. Observation notes by the practitioner and this researcher provide additional data that support the themes evident in Jennifer's responses.

Jennifer's response to learning and using Scratch

Jennifer reported that she enjoyed using Scratch. She liked "making the shapes [creating sprites] and using the backgrounds", and she also liked working with the command blocks to create scripts because they allowed the sprites in her Scratch artifact to "move and they can do [it] by themselves". A screenshot of Jennifer's Scratch artifact is seen in Figure 4-4. Jennifer's artifact included 11 sprites (mean for the non-case study participants is 4.3). She used 116 command blocks across 40 separate scripts (means for the non-case study participants are 56.3 and 9.5, respectively).

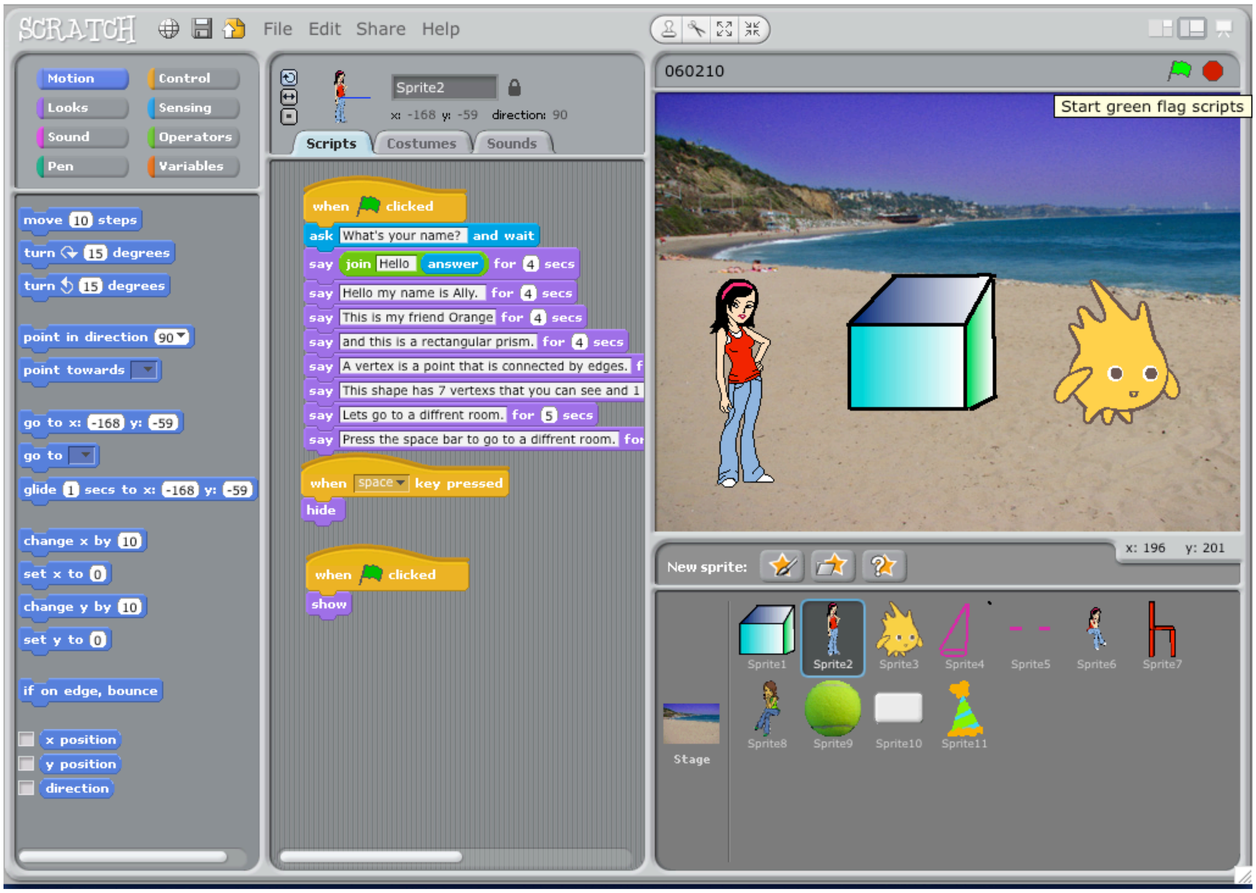


Figure 4-4. A screenshot of Jennifer's Scratch project

When compared with her peers, she clearly demonstrated that she learned how to create sprites and scripts. Both Mrs. H. and this researcher repeatedly observed that Jennifer made consistent progress on her artifact without help from an adult. On the first day of designing (the 11th day of the project), this researcher recorded the following in his observation notes:

> I'm pleased with Jennifer's progress today. She quickly developed her artifact idea. She attempted to create a rectangular prism though it appears to be a trapezoidal prism. She has started scripting and integrated an interactive aspect to her artifact by allowing the user some level of control when the user enters text (a name) and the artifact responds accordingly (hello 'name'). This may represent a lower level of interaction, but interaction is still evident. Jennifer is attempting to personalize the artifact for its users.

This observation documents Jennifer’s attempt to include a script in her Scratch artifact that asks the user’s name, allows the user to type in a name, then combines ‘hello’ with the user’s name in a text bubble on the screen. Jennifer was the only participant to include this action in her artifact, and when asked why she chose to include this script in her artifact, she replied, “that it would probably make them feel happy”.

When reflecting on learning Scratch during Phase 1 of the project, Jennifer shared, “at first it was kind of hard but then I got used to it”. She expressed that “learning how to use all the tools for what I could do” made Scratch difficult to learn in the beginning, but once she learned how to use aspects of Scratch, she felt confident and competent using Scratch. Early in the design phase of the project, Jennifer wanted to create an additional scene, but she did not want the sprites from the first scene to be visible, so she asked for help. This researcher demonstrated how to use the ‘hide’ and ‘show’ command blocks in Scratch so that the proper sprites would be visible during the appropriate scene. She quickly integrated these actions into her artifact. Two sessions later, Jennifer shared how to use the ‘hide’ and ‘show’ command blocks and switch backgrounds to transition between different scenes with a peer, who then shared with Jennifer how to incorporate a question and answer script. Mrs. H. observed this collaboration and noted: “saw some great collaboration between Jennifer and Sara today.”

Jennifer repeatedly demonstrated that she was a capable Scratch designer. An example of Jennifer’s competence using Scratch was recorded in this researcher’s observation notes:

> I observed that Jennifer added a script to her artifact that plays a sound effect when the ‘a’ key is pressed. Jennifer’s artifact contains a question and answer

> script that asks the user a question about the number of bases in a cone. If the user enters a correct answer, positive feedback in the form of text is displayed on the screen. When Jennifer interacts with her Scratch artifact, she presses the 'a' key after she enters the correct response [to play the sound effect]. I observed this behavior and asked her how the sound would play if she were in a different room when a user was interacting with her artifact [and answered the question correctly]. She immediately began addressing this issue without prompting or assistance from this researcher or Mrs. H.

Jennifer's ability to independently revise the scripts in her artifact to ensure that they worked properly is a clear indication of her confidence and competence using Scratch.

Another example of Jennifer's ability to independently revise scripts came during the 8th day of designing (the 18th day of the project). This researcher recorded this example in his notes:

> A student who is not part of this learning group came near the end of the meeting time to work with Mrs. H. While this student was waiting, Mrs. H. had Jennifer share her Scratch artifact with the student. Once the opening scene took place, the student did not know how to proceed until Jennifer told her to press the space key. Once Jennifer realized that a user would not know how to proceed without prompting, she added a 'say' block to the existing script to prompt the user to press the space key to transition to the next scene.

Neither Mrs. H. nor this researcher needed to explain how to change the existing script to ensure that user could proceed through the artifact. Jennifer observed how a user interacted with her artifact, discovered that a user could not proceed without additional prompting, and then made the necessary changes to the existing script to address the issue. This example provides additional support for Jennifer's competence in using Scratch.

Overall, Jennifer's response to learning and using Scratch is positive. She reported that she enjoyed using Scratch, and she repeatedly demonstrated that she was competent designing in Scratch. On several occasions, she independently revised the scripts in her artifact when confronted with an issue to ensure that her artifact worked properly. In addition, she also expressed that she would like to continue using Scratch for other projects during the post-experience interview.

Jennifer's response to this project

Jennifer response to this project is best summarized in her own words: "I got to do math but in a fun way". Her multimedia artifact clearly demonstrates her understanding of the properties of geometric solids. Both of the images in Figures 4-5 and 4-6 show Jennifer's understanding of this specific math content. Jennifer was not instructed to include this text in her artifact; she chose it independently. She also did not ask either an adult or a peer for help with the wording of this text. While Jennifer was working on this particular script, this researcher observed that she originally typed "this shape has 7 vertexs". He intended to ask her about this error (a rectangular prism has 8 vertexes) during the next session. However, she changed the text during the current session to include "and 1 that you can't see" because there is a vertex that is not visible as the rectangular prism is drawn. Neither Mrs. H. nor this researcher assisted her with this change, so she was able to self-correct independently. This text represents her understanding of a vertex and the number of vertexes for a rectangular prism. When asked how she learned this content, she replied, "I learned it in math in the classroom." Thus, she used Scratch to represent her understanding of content she learned during her math class. Another example occurs in the next scene of her artifact (see Figure 4-7). This scene embeds math content specific to the properties of a cone, and the text bubble displayed in this scene accurately identified the properties of a cone.

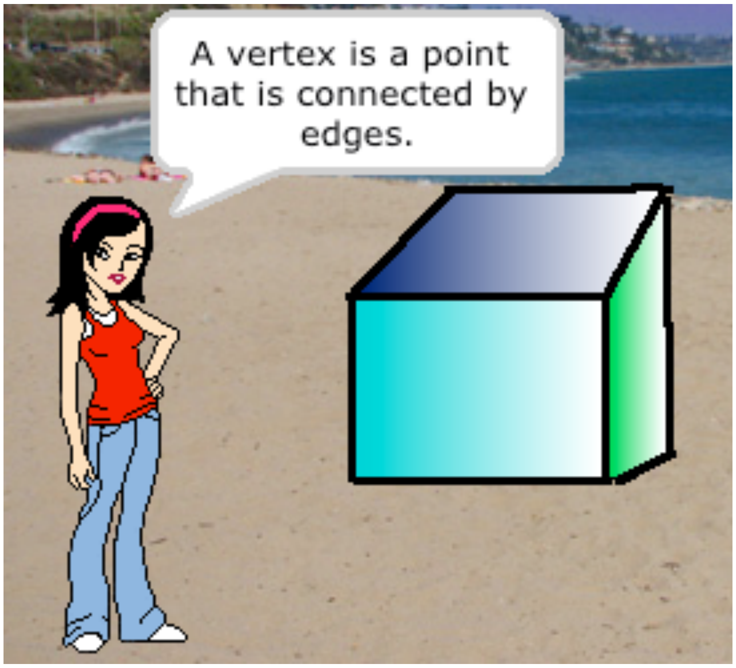


Figure 4-5. Text bubble about a vertex in Jennifer's Scratch project

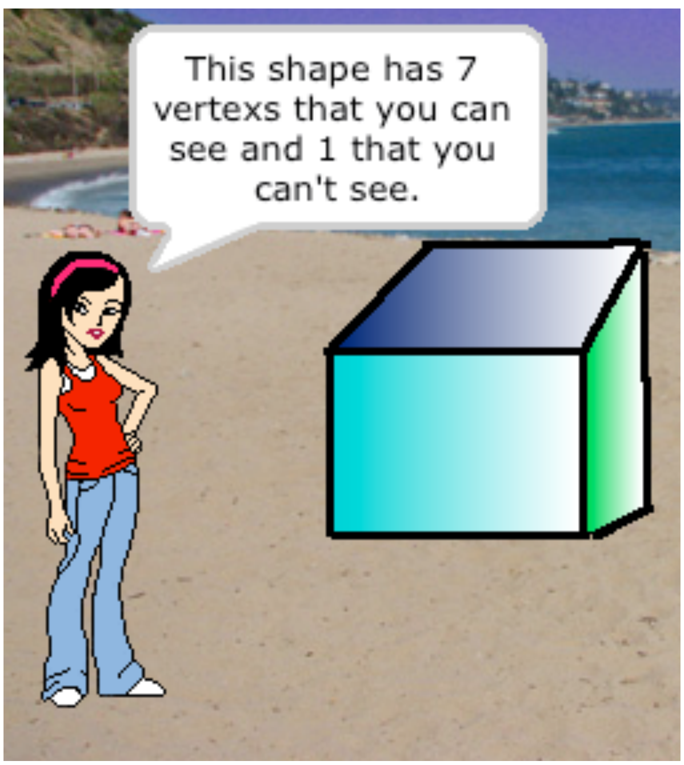


Figure 4-6. Text bubble about a prism's vertexes in Jennifer's Scratch project

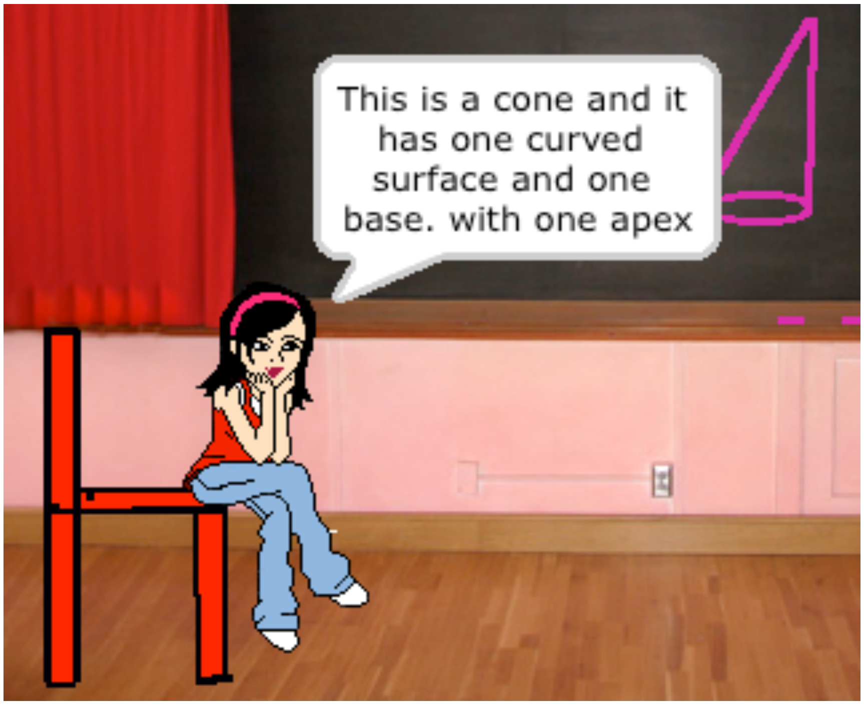


Figure 4-7. Text bubble about the properties of a cone in Jennifer's Scratch project

During the first two scenes of her Scratch artifact, Jennifer was deliberate in pairing a visual (e.g., a drawing of a cone) with a text bubble that describes the visual. This was an intentional aspect of the design of her artifact because she believed that learners "understand more by looking at the pictures". Jennifer's approach may represent how she prefers to learn, but it also demonstrates that she is thinking about the needs of the audience who may use her Scratch artifact. Jennifer carefully considered her audience, and she likened the act of designing a Scratch artifact for an audience to "making a surprise for somebody else". Her artifact included several questions for a user to answer. If a user answered properly, s/he received positive feedback and a sound effect would play. When asked why she included feedback, she responded, "so they [users] can be excited they got the right answer". Here again, she considers the audience and wants them to feel "excited" when they answer properly.

During the post-experience interview, Jennifer also considered changes that she would like to make in her artifact. She acknowledged, “I would make it a little bit longer and change the characters.” When asked about changing the characters in her project, she replied, “cause it was mostly all girls”. In fact, her project included 3 sprites representing young females. She may have realized that boys could also use her Scratch artifact, yet they were not represented in her artifact. Once again, she may be considering the audience for her artifact. With respect to making her artifact longer, she expressed that she would “keep on going with the game then after the game I’d probably go to another scene and then maybe follow another scene and another scene”. The game she references is the last scene in her artifact, which involves several shapes asking the user how many sides they have. Based on her response, it is reasonable to assume that Jennifer is capable of creating additional scenes in Scratch since she has the skills necessary to do so. Another improvement she wanted to make was to make her artifact more interactive. During the interview, she wondered aloud that “maybe if they could click on it” referring to having the user click on a shape, then the shape asks a question about its properties.

Jennifer expressed that she did not want to share her Scratch artifact with her 5th grade peers. She did not feel that 5th graders would be an appropriate audience because “they probably already know this. It’s probably more for little kids. They’d learn a little bit more.” This response provides additional evidence for how Jennifer carefully considered the audience for her artifact. She believed that the math content integrated into her Scratch artifact is more appropriate for younger learners rather than her peer group because they already understand this specific content.

Impact on Jennifer's learning

Based on Jennifer's response during the post-experience interview, field notes from the practitioner and researcher and an analysis of her Scratch artifact, it is evident that the pedagogical approach of having learners design a project in Scratch that integrates math content yielded mixed results with respect to Jennifer's learning about geometric solids. Jennifer's Scratch artifact integrated accurate content representing the properties of several geometric solids, so her project does represent her understanding of this specific content and could be used as an assessment of her learning. However, her performances on the pre- and post-test indicate that she did not acquire new learning (see Table 4-3). Of the 13 points possible on the pre- and post-test, Jennifer scored a 9 on the pre-test (mean for the group is 6.9), and she scored a 6 on the post-test (mean for the group is 7.6). Jennifer was not able to calculate the volume of a prism on the post-test though she was able to successfully complete the same calculation on the pre-test. She also failed to include proper unit labels for several of the calculations. Thus, Jennifer's case provides conflicting evidence on the effectiveness of learner-constructed multimedia on increasing learning gains in the properties of geometric solids for learners similar to Jennifer.

Table 4-3. Overview of Jennifer's pre- and post-test results

Test items	*Pre*	*Post*
Able to identify geometric solids?	Yes	Yes
Able to calculate area of a prism's face?	Yes	Yes
Able to determine the height of a prism?	Yes	Yes
Able to calculate the volume of a prism?	Yes	No
Able to calculate the surface area of a prism?	No	No
Able to explain how to calculate the surface area of a prism?	No	No
Overall score	9/13	6/13

Based on Jennifer's case, it is encouraging to discover that using Scratch to design and construct a multimedia artifact may impact Jennifer's learning. Jennifer reported that this project allowed her "to do math but in a fun way". Once again, it is important to acknowledge that learners differ in how specific pedagogical approaches will impact them, and it is reasonable to assume that there are additional learners that share Jennifer's learning preferences. Thus, it is imperative to understand and identify which types of learners may benefit from a particular pedagogical approach.

Cross-Case Analysis: Dominic and Jennifer

Each participant case was shared separately above. This section provides a cross-case analysis that identifies themes evident across both cases (a variable-oriented strategy) and attempts to develop an understanding of how the themes are represented by each case (a case-oriented strategy).

An analysis of the Scratch artifacts created by participants reveals that Dominic and Jennifer included substantially more sprites, more command blocks and more scripts in their projects than the non-case study participants (see Table 4-4). Dominic's artifact included numerous sprites. This is not surprising considering that Dominic's artifact consisted of multiple scenes. He also reported that he enjoyed drawing and editing sprites. In addition, he would draw and edit sprites if he did not know how to make progress on his artifact. Jennifer also included numerous sprites though her artifact contained fewer sprites when compared to Dominic's artifact but contained more sprites when compared to the other participants' artifacts. Jennifer's artifact also consisted of multiple scenes, and she also reported that she enjoyed adding sprites to her project.

Table 4-4. Overview of analysis of Scratch projects

Unit of analysis	Dominic	Jennifer	Other participants' means
Number of sprites	22	11	4.3
Number of backgrounds	5	4	2.2
Number of scripts	84	40	9.5
Number of blocks used in scripts	207	116	56.3
Number of block types used in scripts	11	12	11.5

Both Dominic and Jennifer included many more scripts and commands blocks than the other participants. However, the high number of scripts and command blocks in Dominic's artifact can be largely attributed to assistance from either Mrs. H. or this researcher. He did not independently add the scripts and blocks. Mrs. H. or this researcher demonstrated how to create scripts that matched the intended behaviors for his artifact. In fact, five entries in this researcher's observation notes and two entries in Mrs. H.'s notes include references to Dominic's choice to create sprites (a skill he enjoyed and demonstrated competence) rather than independently designing, testing and revising his Scratch artifact. In contrast, only a small portion of the scripts and commands blocks in Jennifer's artifact can be attributed to assistance from an adult. Most of the scripts and command blocks added to Jennifer's artifact are a direct result of Jennifer's independent actions or through collaboration with a peer. This contrast was noted in this researcher's reflections on the 10th day of designing in Scratch (Day 20 of the project):

> There is a fascinating dynamic playing out in this learning environment that juxtaposes two different types of learners. Throughout this project, Jennifer has demonstrated that she is an active participant in the learning process while Dominic demonstrates the characteristics of a passive learner. Jennifer is able to work independently. When confronted with an issue while designing her artifact, she will 'tinker' with blocks and attempt to resolve the issue independently. Dominic is dependent on directions and insight from a teacher. Dominic would tinker with blocks (especially the sound blocks) while waiting for either the

researcher or practitioner to help him make progress on his artifact. Often, he needed input from the teacher to help clarify his thinking about the intent of his artifact.

This reflection summarizes a key difference between the two case study participants.

Dominic and Jennifer were the only participants to have lower scores on the post-test when compared to the pre-test (See Table 4-5). One participant's scores remained the same between tests. The remaining participants increased their scores. Dominic was not able to calculate the area of a rectangular prism's face on the post-test though he was able to successfully complete the same calculation on the pre-test. Jennifer was not able to calculate the volume of a rectangular prism on the post-test though she did successfully calculate the volume on the pre-test. These results are perplexing. It is difficult to understand how a learner can successfully demonstrate a skill on one occasion but can fail to replicate the skill at a later occasion. This suggests that it may be necessary to provide multiple assessment opportunities for learners to adequately document whether or not learners have effectively acquired specific skills.

Table 4-5. Overview of pre- and post-test results for selected cases

	Dominic		Jennifer	
Test items	*Pre*	*Post*	*Pre*	*Post*
Able to identify geometric solids?	Yes	Yes	Yes	Yes
Able to calculate area of a prism's face?	Yes	No	Yes	Yes
Able to determine the height of a prism?	Yes	Yes	Yes	Yes
Able to calculate the volume of a prism?	No	No	Yes	No
Able to calculate the surface area of a prism?	No	No	No	No
Able to explain how to calculate the surface area of a prism?	No	No	No	No
Overall score	7/13	6/13	9/13	6/13

Dominic's and Jennifer's pre- and post-test data provide inconclusive evidence for determining an impact on learning specific math content when learners design multimedia representing the math content in Scratch. However, when this data is combined with participant responses during interviews and with data from an analysis of participant Scratch projects, there is reasonable support for considering the impact of this approach if the learning styles of individuals are supported. Dominic's learning style was not supporting during this project. The design of this project did not provide the required support for Dominic to be successful rather than frustrated. A linear process that included specific, short-term goals may have benefited Dominic. A similar process may have also benefited Jennifer. However, she accomplished considerably more in her project than Dominic even though they both worked in the same educational environment. Jennifer appeared to thrive when she was granted choice and control in the design of her artifact. She shared with the researcher that she "got to do math but in a fun way." She independently created several scenes for her artifact based on her vision for how her artifact should be used. For Dominic, choice and control seemed to serve as barriers for his learning that he needed to overcome. Dominic could not independently create the scenes he wanted to include based on his vision. Jennifer could independently implement the plan for the design of her artifact with occasional adult support while Dominic needed almost constant adult support to ensure that he progressed.

Summary of Case Study Findings

In summary, both case study participants participated in the same innovative learning environment that created an opportunity for academically at-risk learners to design a multimedia artifact using Scratch that represents their understanding of the properties of geometric solids, yet both participants seemed headed in different directions. Mrs. H. observed how Jennifer emerged as "one of the leaders" who "really felt good about herself" while Dominic "got lost in the project" because of "not maybe fully understanding the math behind it, not fully understanding his thoughts or how to tackle projects or persevere."

Collectively, both case studies provide a mixed response for addressing the following research question: How effective is learner-constructed multimedia at increasing learning gains in the properties of geometric solids for academically at-risk learners?

Dominic's case provides evidence that indicates that LCM using Scratch may not be effective at increasing learning gains in the properties of geometric solids for certain types of learners. Generally, designing a Scratch artifact was frustrating for Dominic, and there is no supporting evidence to indicate that Dominic developed an increased understanding of the properties of geometric solids.

Jennifer's case provides mixed evidence that this pedagogical approach increased her understanding of the properties of geometric solids. A decrease in scores from pre-test to post-test does not provide support for increasing learning gains. However, Jennifer's Scratch artifact included accurate content representing some of the properties of geometric solids. This provides evidence that she understands and can express aspects of the properties of geometric solids. It also suggests that she engaged in this specific content during the design and construction of her Scratch multimedia artifact.

In conclusion, these case studies reveal that the educational community should consider the relationship between the learning preferences of the individual and the nature of the pedagogical approach to ensure that learning is maximized. Not all learners will thrive when a particular pedagogical strategy is employed. Dominic's and Jennifer's experiences within this study support this claim. Both experienced a similar learning environment with the common pedagogical approach of LCM, yet their experiences yielded distinctly separate outcomes for each learner.

CHAPTER 5
DOCUMENTATION AND REFLECTION TO PRODUCE DESIGN PRINCIPLES

Introduction

This chapter addresses the final research question: What are the design principles for creating an innovative learning environment that integrates learner-constructed multimedia (LCM) for academically at-risk learners? An appropriate response to this question should identify the design principles for integrating LCM for academically at-risk learners. To address this question, this researcher analyzed data collected from the two case study participants presented in the previous chapter and interviewed the practitioner, Mrs. H., to discuss the features that benefited learners in the innovative learning environment that integrated LCM (see Appendix A for a transcript of this interview). This researcher analyzed the transcript using Tesch's (1990) eight-step process described in Chapter 3 to extract the design principles. These design principles serve as outcomes or findings for this research study and inform the next iteration of the DBR process and the educational community.

Design Principles

Several design principles emerged from analyses of the two cases presented in the previous chapter in conjunction with an analysis of the interview with Mrs. H., the practitioner. Recall that Mrs. H. reflected that Jennifer emerged as one of the leaders while Dominic appeared to get lost in the project. It is reasonable to assume that other learners share common characteristics with Jennifer and Dominic, so their experiences within this study can inform the educational community about a broader population of learners. The following design principles emerged over the course of this study:

- Use multiple approaches to learn Scratch
- Scaffold the design experience

- Explicitly and repeatedly state learning goals
- Assess artifacts regularly

Each of these design principles is discussed below.

Use Multiple Approaches to Learn Scratch

Learning how to use a multimedia tool is a prerequisite for designing with the tool. Specifically, it is necessary to have some level of competence with Scratch before designing an artifact using Scratch. There is no single approach to learning Scratch that can meet the needs of all learners. Yet, this study demonstrated that several approaches to learning Scratch used together ensured that participants developed competence using Scratch. These approaches include direction instruction, differentiated instruction and peer collaboration. Both Dominic's and Jennifer's experiences provide examples of how these three approaches assisted them in learning how to use Scratch.

Both Jennifer and Dominic had time to learn how to use Scratch before using it to design an artifact. Their initial learning in Scratch was structured to ensure that basic competencies were learned, such as how to add or create a sprite or how to add command blocks to a script. These skills are necessary to create a wide variety of artifacts in Scratch, and these skills were explicitly taught to the entire group of participants. Additional differentiated instruction was provided 'just-in-time' once participants identified an action or behavior they wanted to include in their Scratch artifacts but did not know how to do so. This differentiated approach allows learners to customize their multimedia artifacts. Participants also collaborated with each other to learn new aspects of Scratch. If one participant learned a new skill in Scratch, then this new expertise could be shared with peers. Therefore, the approach to learning Scratch in this research study included direct instruction, differentiated instruction and peer collaboration.

Jennifer's case provides an example of the three types of instruction in action. Jennifer demonstrated competence adding existing sprites from the Scratch library to her multimedia artifact and designing her own unique sprites relevant to her artifact. These skills were part of the direct instruction that all participants received before participants were allowed to design in Scratch. Jennifer expressed an interest in having multiple scenes in her artifact through which a user would navigate, so she needed to learn how to use the 'show' and 'hide' command blocks so that the proper sprites would be visible or hidden depending in the appropriate scenes. Jennifer learned how to integrate these command blocks with instruction from this researcher, an instance of differentiated instruction specific to Jennifer. Sarah, one of Jennifer's peers, observed Jennifer's artifact and wanted to include a similar action in her project. Jennifer observed that Sarah's artifact included a question and answer script and decided that she would like a similar action in her project. So Jennifer and Sarah collaborated to learn the actions from each other.

Dominic's case provides an additional example of the three types of instruction in action. Dominic demonstrated competence modifying existing sprites from the Scratch library and designing his own unique sprites. Recall that these specific skills were intentionally taught before the design phase of the study began. In addition, Dominic was the only participant to learn and integrate voice recordings. When Dominic expressed an interest in narrating the story he conceived for his multimedia artifact, both this researcher and Mrs. H. assisted him in learning how to record his voice and integrate the recordings into his Scratch artifact. This skill was not taught to the other participants because the other participants did not express an interest in integrating voice recordings into their projects, so Dominic received differentiated instruction specific to this skill. Dominic observed that Jennifer's Scratch artifact included multiple scenes and expressed an interest in having multiple scenes in his artifact as well. Jennifer collaborated with Dominic to teach him how to use the 'hide' and 'show' command blocks just as she did with Sarah.

In summary, both Jennifer's and Dominic's experiences demonstrate how three approaches to learning Scratch used collectively assisted them in learning Scratch. Using multiple approaches may ensure more effective learning over adopting a single approach. Providing just direct instruction may not allow learners opportunities to customize their artifacts. Limiting learning to differentiated instruction may be an unwieldy burden on the teacher as s/he attempts to individualize learning for all students. When solely relying on peer collaboration, learners may not develop sufficient competence because there may not be enough expertise within the peer group. When all three approaches are integrated, direct instruction allows learners to develop basic competency while differentiated instruction and peer collaboration increase competency and allow for customization.

Scaffold the Design Experience

Both Jennifer and Dominic designed a Scratch artifact, yet their individual cases support the design principle that it is imperative to scaffold the design experience to meet the needs of the individual learner. Dominic may have benefited from additional scaffolding that was not provided during the design stage of this research study. Too much choice and control and too few checkpoints to meet throughout the design process may have contributed to Dominic's frustration during this study. Mrs. H. reflected that Dominic struggled "because there wasn't enough structure for him." She also reflected that Dominic needed "sequential" scaffolding that included specific steps "that he needed to check off". During an interview, this researcher asked Dominic about the best way to learn how to use Scratch. Dominic shared that he thought it should be "one simple thing at a time". In his response, Dominic may be expressing how he likes to learn, not only how to learn Scratch but also how he prefers to learn in general. Dominic may need to learn something new in small steps. Additional scaffolding could reduce Dominic's frustration.

However, while Jennifer may have also benefited from additional scaffolding, she appeared to thrive with the amount of choice and control offered during the design process. Recall that Mrs. H. noted that Jennifer emerged as a leader among the participants. She could independently troubleshoot and revise her Scratch artifact when she encountered an issue. She could also share her expertise about Scratch with her peers. In fact, several actions evident in her Scratch artifact eventually found their way into several of her peers' artifacts.

Dominic's and Jennifer's nearly polar performances during this research study suggest that scaffolding is a necessary component to construct multimedia, but the scaffolding and support must be appropriate for the individual learner. Dominic may require substantially more scaffolding than Jennifer. It is likely that learners may benefit along a continuum of scaffolding with some learners requiring more scaffolding and others requiring less scaffolding.

Explicitly and Repeatedly State Learning Goals

Before participants began designing their Scratch artifacts, Mrs. H. and this researcher shared the learning goal for the design process. The learning goal was explicitly stated and recorded on the wall where it remained throughout the duration of this study. Though the learning goal was explicitly stated at the beginning of the project, it was not consistently readdressed during the extent of this study. This may provide some account for why there is not a significant impact on learning observed. If learners are not repeatedly made aware of the learning target when designing multimedia, then they may forget their purpose for learning and their multimedia artifact may not fully represent or address the learning goal.

Dominic's Scratch artifact only included superficial references to the properties of geometric solids. This indicates that at some point during the design process he was aware that his artifact should include some information about the properties of geometric solids. However, had the learning goal been repeatedly restated, Dominic's Scratch artifact may have addressed a deeper level of content. During the post-experience interview between Dominic and this researcher, this researcher asked Dominic if he could recall the goal of the design process. Dominic stated that he did, but he could not articulate the original goal.

Jennifer's Scratch artifact addressed more content on the properties of geometric solids than Dominic's artifact. It is reasonable to assume that Jennifer was also aware that her artifact should include information about the properties of geometric solids and that she was able to retain this learning goal longer than Dominic. Jennifer may also have benefited from multiple reminders about the learning goal. They may have helped her focus on important aspects of the content or have encouraged her to include additional content.

Though the learning goal for the design process documented in this research study was not repeatedly restated while participants were designing their Scratch artifacts, it was explicitly stated at the beginning of the study. Yet, explicitly stating a learning goal is necessary but not sufficient for ensuring that all students meet a learning goal. The learning goal for designing a multimedia artifact should consistently be addressed to ensure that learners are working towards the appropriate target.

Assess Artifacts Regularly

One of the analyses conducted by this researcher was an analysis of each participant's Scratch artifact. This analysis was conducted after each design session. This researcher collected data from each artifact (see Appendix G) and recorded observations of each participant's progress (see Appendix C). This daily analysis ensured that this research had some degree of awareness of each participant's progress during the design process. If inaccurate content appeared in a Scratch artifact or if a Scratch artifact was not working properly, Mrs. H. or this researcher could address the issue with the participant. However, this is only possible if someone is aware of any issues, and it is only possible to be aware of issues if someone has assessed the artifacts.

Regularly assessing artifact could be considered a daunting task if a teacher is responsible for a large number of students. However, having students collect and record their own data in a community spreadsheet could mitigate this concern. Thus, a teacher could review the spreadsheet to determine progress then examine individual Scratch artifacts as needed. Students could also record and reflect on their daily progress in learning journals, which the teacher could review to ascertain individual progress.

Summary of Design Principles

This research study revealed four design principles that provide guidelines and insight for teachers who choose to integrate LCM into their existing practice. The design principles include:

- Use multiple approaches to learn Scratch
- Scaffold the design experience
- Explicitly and repeatedly state learning goals
- Assess artifacts regularly

These design principles also serve to inform the next iteration of DBR examining the impact of LCM on learning content. These four principles should be explicitly integrated into a future design of an innovative learning environment that allows learners to construct multimedia to represent their understanding of specific content.

CHAPTER 6
CONCLUSION

Summary of Findings

Based on the analyses of interviews between case study participants and this researcher and the practitioner and this researcher, an analysis of participant-constructed Scratch artifacts, an analysis of this researcher's reflective observation notes and data from a curriculum-based pre- and post-test, this study reveals that learning gains may or may not occur when learners design a multimedia artifact using Scratch. Data collected and analyzed in this study yield inconclusive evidence for an impact on learning. Yet, this does not imply that there is no impact on learning. One reasonable explanation for why no impact was measured may be a result of the content-based measure used for the pre- and post-test during this study. Recall that both case study participants, Jennifer and Dominic, scored lower on the post-test than the pre-test. This measure may not have adequately captured participants' content knowledge before or after the experience.

Situating This Study within Existing Literature

Recall from Chapter 2 that there is a reasonable amount of evidence within the existing literature that identifies positive outcomes when learners design multimedia artifacts. However, there exists little documentation that captures how learners use Scratch to design multimedia in a classroom setting though the use of Scratch in after school programs, community technology centers and Scratch's online community is documented. This study documents how young learners use Scratch in a classroom context to design a multimedia artifact that represents their understanding of required math content. This study contributes to the current void of literature that documents how learners use Scratch in formal K-12 educational environments to learn required curriculum content.

Implications for Practice

There are several implications for current practices when teachers and schools consider integrating LCM using Scratch as a pedagogical approach. These implications include:

- LCM allows multiple learning paths for students.
- LCM encourages self-directed learning.
- LCM promotes collaboration.
- LCM creates an alternative method of assessment.
- LCM changes the role of the teacher from giver of knowledge to coach.

Each of these implications is discussed below.

LCM Allows Multiple Learning Paths for Students

One of the implications evident from this study is that integrating LCM in schools creates an opportunity for learners to engage in math content in an alternative manner to rote learning. Mrs. H. reflected that “instead of just them being the consumers of the knowledge and then just spitting it back out on a test and regurgitating it, they actually had to think outside of themselves and think how would somebody be engaged in learning about this shape”. The environment featured in this study created an opportunity for learners to become producers rather than consumers. Participants designed a Scratch artifact that expressed their understanding of the properties of geometric solids. Therefore, participants needed to think about which specific content they wanted to include in their Scratch artifacts and to make decisions about how that content would be expressed in their artifacts. This approach created multiple paths for participants to design their artifacts. There was no single common path that all participants used.

It is likely that participants chose to express their understanding of the properties of geometric solids in a manner that reflected how they prefer to learn. For example, during the interview between Dominic and this researcher, Dominic shared that he enjoyed writing and telling stories. His Scratch artifact was clearly story based. It included a recorded narration of a story he created, and it was the only Scratch artifact that included a voice recording. Though Dominic's Scratch artifact superficially referenced the properties of geometric solids, his narrative approach to designing his artifact may represent how he prefers to learn. If all participants were expected to follow a common path while designing their Scratch artifact, Dominic may not have been able to design a narrative artifact.

Another aspect of allowing multiple learning paths relates to approaches for learning Scratch, the multimedia-authoring tool used in this research study. There are multiple ways to learn how to use a new tool such as Scratch. One approach, as Mrs. H. shared, involves "watch me, now you do it, watch me, now you do it". This approach consists of a cycle of modeling by the teacher followed by guided practice for the student. When the participants were first learning Scratch, this direct instruction was the approach adopted by the practitioner and researcher. However, after sharing some of the most common actions in Scratch, other approaches to learning Scratch were employed. Participants were encouraged to explore Scratch independently to determine which command blocks were required for their scripts, and the practitioner and researcher provided 'just-in-time' instruction depending on the individual needs of the participants. In addition, participants collaborated with each other to share expertise.

Regardless of the approach for learning Scratch, no single approach or learning path works for all learners. Some learners need the additional structure of the cycle of modeling and guided practice and do not thrive when given the opportunity to tinker. Dominic represents this type of learner. He would only make progress on his Scratch artifact when an adult was available to guide him. Others feel constrained by the cycle of modeling and guided practice and learn more when allowed to independently figure out how Scratch works. One of the non-case study participants emerged as a leader while learning Scratch. He independently tested and revised scripts and tried out various command blocks until the scripts worked the way he intended them to work, then he would share his new learning with his peer group. Of all the participants, this individual included 16 unique command blocks in his Scratch artifact, more than any other participant (mean for the group is 11.5 with a range of 5-16). This demonstrates that this individual was willing to tinker in Scratch and to figure out how certain command blocks worked.

When a teacher creates opportunities for learners to follow multiple learning paths, s/he encourages choice. Schiefele (1991) reported that choice encourages learners to expend more effort on learning and understanding content. Turner and Paris (1995) argued that choice can be a strong motivator. Open-ended activities create numerous opportunities for choice and "provide students with opportunities to mold tasks to interests and values, thus supporting their efforts to make meaning while engaging them affectively" (Turner & Paris, 1995, p. 665).

Creating multiple learning paths ensures that learners have the opportunity to learn in a manner that reflects the ways they prefer to learn. This implication is also related to another implication relevant to this environment: self-directed learning.

LCM Encourages Self-Directed Learning

Participants in this project were afforded a fair amount of choice and control in the design of their Scratch artifacts. The overall goal of designing a Scratch artifact that includes the properties of geometric solids was a common expectation for all participants. However, how they chose to address that goal varied significantly across the participants. One participant chose a narrative approach. The participant recorded his voice, telling a story he had written over the course of several scenes. A second participant included a series of scenes that each shared information about the properties of a specific geometric solid then asked the user to respond to a question about that information and to answer it correctly before transitioning to the next scene. Several participants used a quiz-like format that included a series of questions about geometric solids without including background information. All three of these approaches met the expectation of addressing the properties of geometric solids to some extent though some participants integrated more content than others.

Self-directed learning was also evident through the level of engagement displayed by participants. Mrs. H. noted that participants arrived at each session and "immediately started working. They don't ever do that…. Ever. And if you go watch them in their rooms, they're the least attentive and most checked out in their regular classrooms. So for them to come in and just, bam, get down to work was huge." While there is not sufficient evidence to determine the exact cause of this engagement and considering that there may be influences from other factors, it is still reasonable to assume that engagement may increase when learners are responsible for their learning.

Jennifer's experience during this project provides support for this assumption while Dominic's experience refutes it. Mrs. H. recognized Jennifer "as one of the leaders" during this project while "Dominic got lost in the project". This may indicate that self-directed learning only benefits learners when they have necessary skills to be self-directed. Self-directed learning may be a learned skill; one that needs to be developed over time. Jennifer repeatedly demonstrated that she could be a self-directed learner, so during her past experiences, she developed the necessary skills to be a successful self-directed learner. Dominic, however, may not have had the necessary skills to be a self-directed learner. So when he was placed in an environment that encouraged self-directed learning, he became frustrated and confused rather than thriving. He required near constant guidance from either Mrs. H. or the researcher to make progress on his multimedia artifact.

Self-directed learning encourages control of learning with the learner. Ryan and Grolnick (1986) reported that students in classrooms where the control of learning is shared between the student and the teacher demonstrate increased interest in schoolwork and perceived competence than students in teacher-controlled classrooms. Turner & Paris (1995) reported that "[s]hared control provides students with both the tools and the opportunities to take responsibility for their learning" (p. 667). Encouraging self-directed learning may require that learners have additional skills in place before becoming a successful self-directed learner. One skill that may be beneficial for self-directed learning is collaboration with peers.

LCM Promotes Collaboration

Mrs. H. noted that a significant implication of this environment was the opportunity for collaboration: "collaboration with each other when they were having to create, but then also when they were having to revise…. Somebody would say how do you do that? Somebody else would say just do hide and then broadcast or whatever. That's collaborate."

Throughout the design process, participants were encouraged to learn from each other's experiences. If a participant wanted to include a particular action (e. g., hiding and showing sprites so they appear in the proper scenes) but was unsure how to build the script for that action, the practitioner or researcher partnered that participant with another participant who had previously integrated that action and script into his/her project. This type of collaboration resulted in multiple instances of 'cross-contamination' when a particular action and script integrated into one participant's Scratch artifact would become part of another participant's Scratch artifact after the two participants collaborated.

Near the end of the project, participants also collaborated in a peer review process. Participants reviewed each other's Scratch artifacts to ensure that they worked properly. Participants also reviewed the artifacts for spelling, punctuation and convention errors. This type of collaboration resulted in more polished Scratch artifacts but also allowed participants to demonstrate and share their expertise in Scratch.

There is a reasonable amount of research evidence in the existing education literature to support including opportunities for peer collaboration in schools. Schunk (1989) observed that young learners observing each other's progress increased their own confidence. Slavin (1987) reported that working with peers promoted engagement on tasks. Turner and Paris (1995) argued that “social guidance and cooperation in classrooms are also fundamental to motivation” (p. 668).

While the collaboration described above yielded positive results, collaboration can also result in a negative consequence. Late in the project, one participant discovered an existing sprite in the Scratch library of a jetpack that included several pre-made scripts that allow a user to move the jetpack sprite around the screen using the keyboard’s arrow keys. He added the jetpack sprite to his project even though it had no relationship to the design and content of his multimedia artifact. He simply found it entertaining. The following day, 3 participants, including the one with the jetpack sprite, collaborated to peer review each other’s Scratch artifacts. Not surprisingly, the other 2 participants added the same jetpack sprite to their multimedia artifacts after this collaboration even though it was an irrelevant addition to their artifacts.

LCM Creates an Alternative Method of Assessment

During this project, participants completed a curriculum-based pre- and post-test that was taken directly from the test bank of the math curriculum used in this school. This type of assessment was the most common type of summative assessment used in the 5th grade. Yet, the Scratch artifacts created by participants could also serve as a summative assessment of participants’ learning. Each Scratch artifact included content related to the properties of geometric solids, and participants expressed their understanding of this content to varying degrees in these artifacts. Therefore, these Scratch artifacts could represent a form of summative assessment that documents students’ understanding of required content.

Based on Scratch artifacts, the participants in this project demonstrated various levels of understanding. For example, Dominic, one of the case study participants, only included superficial references to geometric solids in his Scratch artifact. He created sprites of several geometric solids and included them in his artifact but did not reference them or elaborate on them. They existed as props in several scenes. As a summative assessment of his learning, a teacher might conclude that Dominic does not have a meaningful understanding of the properties of geometric solids because he was not able to articulate any properties of geometric solids in his Scratch artifact though he did use several related vocabulary terms. In contrast, Jennifer, the other case study participant, explicitly stated the properties of two geometric solids in her Scratch artifact. She was able to articulate these properties based on her understanding of this specific content. In the design of her Scratch artifact, she is applying this understanding by articulating the properties. As a summative assessment of Jennifer's learning, a teacher might conclude that she does have a meaningful understanding of some of the properties of two geometric solids because she articulated aspects of the properties of a cone and rectangular prism.

Recall that neither Dominic nor Jennifer showed gains on the post-test when compared to the results of the pre-test. If the post-test used in this study was used as a traditional summative assessment of Dominic's and Jennifer's learning, then neither individual demonstrated learning gains for the content addressed by the post-test. Yet, such a limited approach does not necessarily capture the full range of a learner's understanding for a particular content area. Jennifer's Scratch artifact clearly contained content related to the properties of geometric solids that were not assessed by the post-test. In reality, no single assessment, including a multimedia artifact, can fully document a learner's understanding of specific content. As a form of assessment, designing a multimedia artifact could serve as one of several assessment tools that teachers employ to capture and document what learners really know and understand. In fact, McFarlane, Williams and Bonnett (2000) supported the student use of multimedia authoring software as a form of alternative assessment though there is a dearth of research that indicates how to assess a multimedia artifact for evidence of learning.

LCM Changes the Role of the Teacher from Giver of Knowledge to Coach

Mrs. H. clearly observed how her role in this project changed from a "giver of knowledge" to a "coach" (Carver, Lehrer, Connell & Erickson, 1992). When students become more self-directed and have ample choice and control over a project, the role of the teacher must change to accommodate the way students work. Mrs. H. noted that during the design phase of this project, it was not possible for "everybody [to be] lock step, we're all going to do this at the same time". Rather, it was "way more individualized". Mrs. H. reflected:

> Instead of me saying everybody on their paper draw a cone. OK. Now let's all label the cone. Instead of that…most of them included something about a cone or a different shape and they got to choose how they were going to talk about the faces or the bases. And they still did that skill; they just did it because however they chose to do it. It wasn't me having everybody do the same thing at the same time.

When students become self-directed, the teacher's role changes because, as Mrs. H. observed, the "learner is driving the train, and [the] teacher is behind the scenes."

It may be assumed that when a teacher moves away from the role of giver of knowledge that learning may break down since there is no transfer of content from the teacher to the learners. Yet, it is important to acknowledge that teachers still play critical roles in ensuring that learners learn required content in their roles as coaches.

In the role of teacher as coach, teachers must have an informed understanding of individual learner's needs to be able to provide appropriate support as learners progress through a project, such as when learners design a multimedia artifact that represents an understanding of specific content.

Summary of Implications

Based on case study analyses and an analysis of the interview between Mrs. H. and this researcher, several implications exist when teachers integrate LCM as a pedagogical approach for academically at-risk learners. Collectively, these implications are important aspects to consider when implementing this pedagogical approach. The implications identified in this study include:

- LCM allows multiple learning paths for students.
- LCM encourages self-directed learning.
- LCM promotes collaboration.
- LCM creates an alternative method of assessment.
- LCM changes the role of the teacher from giver of knowledge to coach.

When designing a multimedia artifact using Scratch, learners can select from multiple learning paths if they are given a common goal but provided with choice and control for how to reach that goal. Choice and control also encourage self-directed learning as learners work to realize their designs. As self-directed learners, learners become active participants in the learning process, and teachers provide support as needed as they take on a coaching role. Collaboration among peers is also encouraged as learners work on their designs. Completed multimedia artifacts can serve as an alternative form of a summative assessment depending on how the design goal is structured.

Suggestions for Further Research

The current study serves as the first iteration of the DBR process. The design principles identified by this study serve as a design framework for the next iteration.

Each principle will be integrated into the next iteration of this study. In addition, further research is needed in several areas.

Rather than assuming that a particular pedagogical approach works equally well for all students, the research community must identify the types of learners that benefit the most from a particular approach. We must acknowledge that learners benefit along a continuum for a particular pedagogical approach or strategy. A strategy may work particularly well for certain types of students though it may have no impact on other types of students. Identifying specific approaches for specific learners will ensure that an individual's learning needs are met. Though this study did not identify learning preferences of the participants, future iterations of this study should attempt to ascertain these preferences in order to understand which types of learners benefit the most from a LCM approach.

The research community also needs to further document the outcomes for learners when they use Scratch to design multimedia artifacts that represent their understanding of specific content. This study represents a single contribution to understanding this particular phenomenon, but substantially more studies are needed to develop a clearer understanding. We also need to determine effective procedures for assessing learning evident in Scratch multimedia artifacts. Little research currently exists to assess learning when learners design multimedia artifacts. With additional research in this area, traditional pre- and post-tests may no longer be necessary to solely capture a learner's understanding of content. Additional forms of assessment, such as assessing a learner's multimedia artifact, could complement data generated from pre- and post-tests.

APPENDIX A
INTERVIEW TRANSCRIPT BETWEEN PRACTITIONER AND RESEARCHER

This appendix includes the transcript of the post-project debriefing interview recorded between the practitioner and researcher.

Researcher	**Practitioner (Mrs. H.)**
How did your students react to using Scratch? If you want to give specific examples, feel free. If you want to generalize, feel free. Try to give any evidence that you can or your observations or thinking. Feel free to explain that.	I think they reacted in a lot of different ways. And I think they reacted in different ways based on where we were in the project too. So I think at first, they were all super excited about learning really differently, learning beyond just the whiteboard and the markers and pencil and paper, going more digital. I think they're really excited about that. And then I think when it turned into, well it's time for them to really include some math stuff, it's not just about learning, playing with the computer. It's time to include some math stuff. I think some people were like wait a second, but then I think they pushed through that. So then I think the reaction may be at first was like well I don't, wait, now it has to get actually down to some work. But then I think they pushed through it because it was so engaging. So I think that really didn't matter. And then I think as they started really getting into it, I'd say for a good period, everybody was really actively engaged, really responding very positively. And then I think once it started getting towards the end and it was time to finish, that's when I think I started to see some people, the reactions starting to split a little bit more. I think some people disengaged because they didn't, they hit kind of a level of OK, I don't really know how to keep going. I think some people kept persevering and just kept kind of altering their project and adding another room and then just adding layers to it, which was great. And then I think some people like Dominic, it just, it just got to be like this mountain, and he didn't have any clue how to get up the mountain. He knew. He kind of knew that he was on a mountain because of the little panic attacks, but he had no real strategy to get up the mountain. And so I think his reaction is one that was more negative, but I think that's one out of the whole group, so I don't think that was how everybody was.

So you talked earlier about a range of reactions to using Scratch. Initially, everyone is interested, curious. And then when the project is introduced, the goal to design about math, who did you think reacted? Did they all react negatively or were there specific students?	I would say Caleb maybe kind of reacted, like wait a second. I think, I don't remember specifically, I wish I could remember specific times or specific instances or quotes, but I don't. I'm just going based on what I kind of feel, and I think that Dietrich maybe had that reaction too. But I don't, I think everybody else was fine. Everybody else just kind of, oh, OK, then we'll do that.
And then you also talked about how once we got going to overcome that initial reaction to bringing in the math, then everybody was doing fine. And you mentioned near the end, we had some reaction as well, maybe some negative reaction to kind of finishing up. Who do you think, as we started going through the project, who do you think really reacted positively to the project, and who do you think reacted negatively to the project?	I think almost everybody reacted positively, so Sabrina, Connor, Jennifer, Fernando. I would give Troy kind of a in the middle, but I think in general, I mean he was actively engaged and he did what he needed to do. I just think towards the end that's when he started to kind of fall off. Caleb, same thing. Pretty actively engaged, but then towards the end started to fall off. But Sabrina, Jennifer, Nathaniel and Fernando, I think were pretty solid all the way through.
Did you mention Dominic?	No. Dominic was not solid all the way through. I think he was solid at the beginning, kind of, in Dominic's way. But at the end he just kind of fell apart. Helpless.
Do you think that there, any idea what the cause of that might be, that helpless feeling that Dominic has?	I think anxiety is a big part of it for him.
Anxiety about?	He has a higher level of anxiety in life. I don't think it's just anxiety about technology or anxiety about math or school. I think it's just anxiety. I think that's just Dominic. He would have anxiety about getting up in the morning and brushing his teeth, and that's just Dominic. So I think, but if was something particular to the project, I think it was because there wasn't enough structure for him. Maybe he didn't have things that he needed to check off and do this first and sequential. Do this. Do this. Or I don't know, I just think he got, he started chasing his tail and got lost in the whole thing, which caused even more anxiety.
Do you think it was easy or difficult for your students to learn	I think it was pretty easy for them to learn how to use Scratch. I think they're naturally inquisitive, and

how to use Scratch?	I think once they started to see the features and started to notice, oh I can make things glide, make things move with arrows, they started to, I think, come up with even more of a story line or a concept based on their schema of games and stuff. So I think they took to it very naturally.
Are there ways that are better to learn Scratch than others, do you think based on this population?	I don't know. That's a good question. I think based on this population I would probably lean towards watch me, now you do it, watch me, now you do it, and I think we did that, but not as structured maybe as they would normally get instructed because of them. And I don't think that was bad.
You don't think it was bad that they didn't get as much structure?	No, I don't think that's bad.
But you think more structure might have helped them?	For certain kids like Dominic.
Anybody else?	No. I mean I think individually that's really when we were coaching them that's really what was happening, but it was just not everybody lock step, we're all going to do this at the same time. It was just way more individualized.
How do you think having students create something in Scratch helps them learn?	Because I think it helps them think about the concepts on a completely different level than they would have to think about just identifying them with a piece of paper and a pencil or if I were just doing it on the board and they had to verbally say it, I think it helps them think about it in such a deeper way.
What do you mean by a deeper way?	Well, I mean, I don't really know how I feel about Bloom's but it's beyond just identify or analyze or those types of things. They have to actually think about how someone else may think about a shape and how can I get this person to say cone, and now I actually have to draw a cone, and now I actually have to now create something around this cone to make someone else engage in this, to not give them the answer. You had to really think on so many different levels beyond pointing to a cone and saying "yep I know that that's a cone" or "yep cones have this". I don't know if that really made sense.
You said something about different ways of thinking. Maybe expand a little bit more some of the different ways of thinking you thought they had to wrestle with while designing in Scratch.	I think they had to use critical thinking skills that maybe they typically wouldn't have had to use if they were learning about shapes or geometric solids just in a regular way.

Critical thinking skills is kind of general. Can you be more specific about thinking skills, critical thinking skills?	When I say critical thinking skills, I think about communication, analyzing in a different way. Really having to analyze things, not just figure out an answer, but really having to analyze things. I guess when I say critical thinking I also think about perseverance as well. That's not really a thinking skill, but I think it's a behavior that comes when you are thinking critically. I'm trying to think of another specific skill that would be under critical thinking. I mean I could pull out any tons of different verbs, but I don't really know, comparing. It's critical thinking! It's hard to explain.
So then related to that question, this focus on critical thinking, so how was learning about math different for your students when they used Scratch as opposed to how they traditionally have learned that content?	Well because I think they got to engage in it in the ways that they chose to engage in it, so I think choice is a huge piece behind it.
Give me an example of that choice.	So an example would be instead of me saying "everybody on their paper draw a cone. OK. Now let's all label the cone." Instead of that, they got to, most of them included something about a cone or a different shape and they got to choose how they were going to talk about the faces or the bases. And they still did that skill, they just did it because however they chose to do it. It wasn't me having everybody do the same thing at the same time. They got to match their personality to it. I forgot the question.
So it was about how they're learning about math differently, you know, using Scratch versus, you know, your normal instruction or even classroom instruction.	I also think having to think about how to explain it to someone else is also another level of the critical thinking and how they had to learn it differently. Because instead of just them being the consumers of the knowledge and then just spitting it back out on a test and regurgitating it, they actually had to think outside of themselves and think how would somebody be engaged in learning about this shape. Well, I'm going to do it by having cats spinning around. Or I'm going to do it by having two sisters standing there doing a game show. I think that is completely different than if they just had to sit there, take it in and spit it back out on a test.
So it sounds like the engagement on the part, student engagement is different whey they're using	I think. I don't have that measured. That's what I saw. Just based on the anecdotal data.

Scratch versus in other learning contexts.	
How do you think your students reacted to creating something for 2nd graders to use?	Well, that was interesting watching them. I didn't think they would have to do it to 2nd graders. I really thought they were going to want to 5th graders.
You were surprised they chose to show it to 2nd graders rather than their peers?	I really was. I don't really know, I guess I know what that's about, it was just kind of a fear of being judged by their peers. But I expected them to want to show that to their peers. But I don't really know how much planning it for 2nd graders really that they took into account. I think, I think they thought about that towards the end when they were revising. I think as they were creating, I don't know how much of the audience, them being 2nd graders, really played into how they made their projects.
And that wasn't necessary part of the goal. It just said to someone else. We didn't specify 2nd graders. They chose that later. So that may have also been part of them not focusing on 2nd grade. How was student motivation to work on this project affected by having to design for someone else.	I don't know if the designing for someone else affected the motivation, but I think just the fact that they were getting to create and do this type of math and learning through this program affected the motivation. They came in and they were immediately started working. They don't ever do that before. Ever. And if you go watch them in their rooms, they're the least attentive and most checked out in their regular classrooms. So for them to come in and just, bam, get down to work was huge. I think that wasn't because they were creating for someone else. I think it was because they were engaged in the project itself.
The project or in Scratch, do you think?	Scratch. I think it was Scratch. I think the computer too.
So student motivation was impacted by using Scratch?	Yes.
Do you think student learning was impacted by using Scratch based on your observations?	I think so. That would be something I would want to probably further explore and maybe push a little bit more. I don't really know how to do that. But I think that if we were to ask these kids about geometric solids 5 years down the road, they will know it more than if we were to ask them when they have there traditional type of instruction. So I don't really know if it's going to show right now, but I think it would show later on. I feel like it went somewhere different in their brain because of what they were doing.
Tell me more about that, about it went somewhere else in their brain.	Well, I feel like it kind of embedded itself further down in there into a memory, a place in their memory that's different. I don't know what type of

	memory that's called. I don't think that's working memory, but long term retrieval, I don't know. I feel like it was way more of a significant event of learning in their life, which then in turn will help them really know it versus just learning it with pencil and paper in their regular way.
Regular way meaning?	Without Scratch, without creating some project around a secure skill. Just kind of sitting and getting.
Direct instruction?	Yeah.
What did you observe about the sharing today that you thought was a positive?	I loved watching the sharing. That was probably one of my favorite parts of the whole thing. So what did I observe? I just felt like they really brought themselves down to the 2nd graders and they were asking them questions and scaffolding their learning, giving them high fives and talking them through their projects and some of them started showing them extra parts of Scratch and showing it off a little bit. For me, watching them feel happy and proud of their work is something that I think is, that's everything. That should happen with everything, and it doesn't.
Are there any negative aspects of the sharing that you observed?	No.
Overall, it was overwhelmingly positive?	Yeah, I can't think of something that would be negative out of it.
You felt like the 5th graders, do you think the 5th graders also believe that it was a positive experience?	I think so. I think if I were their classroom teacher and had more of a, I think, stronger connection relationship to them, I would be able to answer that better, but since I only see them for 20 minutes, it's hard for me to really get a read, but I think that they were happy. Dominic gave me a hug as we walked out. You could just tell by the smiles, but I don't have any specific quotes to go along with that.
If we were to do this all over again, what would you change about the implementation of the project? What should be different about what happened this time?	Well. I don't know if anything really needs to be different meaning that it could be better. I think things maybe to explore if this were to get done again would maybe be giving some structure to the kids that started just chasing their tail. I don't know if that would look more of like a rubric or just a graphic organizer to help them think. Maybe a graphic organizer for all of them up front to help them scenes or something. But then again I wouldn't want to structure it to be like "you must include a rectangular prism, a cone, you must include certain things". But on the other hand, I do

	want them to include that stuff, so I don't know. I would have to think about that. I think for certain kids though, I think I would include something like that but I don't think everybody would need that because I think they would get it just by some individualized coaching they'd pick up what the goal is.
So knowing your kids' abilities, knowing your students' abilities then determines level of support, whether it's graphic organizers, rubrics, etc. to meet the goals of the project?	Yeah. I think for parents though, they would want to know, just because this is how it is, about grades and how you would get an A on that and how do you get a B, so that would be an interesting thing to explore like how do you quantify these projects with a letter grade. How would you grade it? I don't know. How do they get feedback and know that, yeah, this, you know, you don't want to tell them that is crappy. You get an F because that's stupid. Is there a way to give them more direct feedback and say, I don't know, it that's verbal or that's written down or what.
What do you think were the design elements that were a part of this project? What do you think about the design features? What were the design structures that sort of guided this project?	What's a design structure?
A design element, a design structure are sort of, what are the key elements that make this project work? I'm probably not explaining this as well as I'm thinking about it. It's, you know, what were the features in the past 6 weeks or so that we've been together? What were some of the key aspects of what was going on? For example, one element is kids as designers or learners as designers. To me, that's a design element of this where we're putting kids, 5th graders, in the role of a designer of media, a media designer. They created media using Scratch about content. So are there any other design features that you noticed or design elements that you	So I immediately think of, and I don't know if this is this is really, but something about intervention students, students who struggle. Allowing students who struggle a different way of learning, something like that.

noticed as part of this project that you thought, oh, that's a key, you know, piece of this kind of work.	
I think that actually makes sense because	Not that that's a design
Well, it is part	A theme
A theme, that's a way to think about it. A theme of the project is that we're creating opportunity for intervention students to have alternative ways of learning content. So that would be a theme. Would you agree with that?	Yeah
Are there any other themes, elements, features, you can call it whatever you want to call it, that you observed as part of this project?	Self-directed learning
Tell me more about that	So they got to choose how they were going to display their knowledge. They weren't having to fit into a box.
So choice?	Yes. Collaboration, in lots of different ways. Collaboration with us as their coaches, collaboration with each other when they were having to create, but then also when they were having to revise and they were having to kind of, somebody would say "how do you do that". Somebody else would say "just do hide and then broadcast" or whatever. That's collaborate. And then collaborate with the 2nd graders to collaborating to show a final product. I would like to think of a math theme, but I don't really know. I mean. Alternative assessment in mathematics theme, kind of.
Even though we did use a use sort of a traditional pre post, but their individual projects could be evaluated, could be assessed.	And I also think teacher as coach is a theme. It's not teacher as giver of knowledge. Learner is driving the train, and teacher is behind the scenes.
Is there anything else?	Am I missing one?
No. This isn't a right or wrong.	Sorry.
That's OK. Is there anything else I should know about the experience? Is there anything else you want to share that I didn't ask you about that you want to tell me about this experience?	I just think it was really powerful for me to see that Tier 3 students can do something like this, and I wish that that knowledge could be shared to everybody because I feel like that something that just pisses me off in this position with these kids is that they're getting, I feel like they're instructional

	casualties. They're not dumb kids that can't do it or can't learn. I feel like this shows it too. This is a hard program, and they did it. And so it there would be a way to just use this as a platform to show that these kids can do this type of stuff.
Did you ever feel like that maybe they wouldn't be able to do this in the beginning? Did you have a concern that maybe this might be stretching them?	No, there wasn't.
Anything else you want to add?	Nope, I think I'm good.
How do you think Jennifer handled this project?	Great. I think she was one of the leaders, a very quiet leader, but that doesn't mean, that's not bad. I think she really shined, and I think she really felt good about herself doing it too. And I think she had a very varied, intricate story line, lots of, I don't know, changes and characters. Good. Made a lot of sense. Really, I think took into account the person who was going to be watching her stuff. Very girly. Two girl characters.
You've talked a lot about Dominic. How do you think Dominic handled the project?	I think Dominic got lost in the project, and I think that was a mix of a lot of things. A mix of him not maybe fully understanding the math behind it, not fully understanding his thoughts or how to tackle projects or persevere, just figure things out, and I think it's just a representation of what goes on in Dominic's life.

APPENDIX B
DEBRIEFING NOTES

5/12/10
Practitioner (P): today was a big shift; felt group was charged up today; moving forward on the project; projects are coming together; stories are developing
Researcher (R): projects are meatier: details such as hiding/showing; changing backgrounds and creating new scenes; answering repeat; sprites moving then talking; need to teach how to reset positions if sprites are moving during the project

5/13/10 (Co. absent today)

P: proud of S: showed independence, recreated similar behavior that was worked out collaboratively with P the day before; F is more aware of his environment that gave credit for…thought he was in his own world, but he is listening to his peers
R: observed more independence; at times, I was just watching students work; students didn't need help; D needs to be refocused; seems to spend more time drawing; very careful drawings provide fine details; N seemed to spend more time drawing

5/14/10
P: saw collaboration between S and G, evidence of reciprocity; Ca. seemed off task today; N wanted help but didn't get it because of time; Co. wanted to demonstrate his project to both of us; F is often off-task, dazed in his classroom, is focused on the task, "capable of not going into the dazed-out zone"
R: D more focused with integrating content; spent a lot of time drawing sprites and focused on a story; still needs help developing his story to integrate

5/17/10
P: worked with D to storyboard and script out his project; his project is based on a story he created
R: worked with G to integrate a lesson about calculating surface area of a rectangular prism.

5/18/10
No project time; 5th grade students presented their 20th century project

5/19/10
P: N did really well on his 20th century project yesterday and received a lot of positive feedback, so D may have felt a little jealous of his brother's success; has observed this behavior before; when leaving classroom today, D was frustrated with his project and thinks that his project is not very good, said "mine's not better than N's" but this attitude may stem from yesterday

5/20/10 (Only G, F and D attended today; S, N, Co., Ca. & T were absent)

R: able to spend most of the time working with D; he had a much better attitude today; willing to work but relied on researcher for prompting on next steps; still has an elaborate story in mind that is only loosely related to geometric solids; asked G if cone may be in the wrong position; F added a jetpack sprite from the Scratch sprite library that includes several scripts; his intent is to have the user control the jetpack while responding to the questions.

P: another student looked at G's project yesterday but wasn't sure how to proceed, so G added a say to direct the user; D asked when we could use Scratch to design about something other than shapes.

5/21/10
Ca. and S needed to finish testing so they did not participate today. D did not progress unless the researcher or practitioner is working with him. He will practice recording.

G was able to fix design errors in her project once D worked through it or the researcher asked her about the sound clip even though P has tried to get her to identify the errors independently. Thinking outside one's self is difficult for young learners.

D demonstrated that he can manipulate the direction of a sprite and change the size of a sprite using the grow and shrink tools.

There is a fascinating dynamic playing out in this learning environment that juxtaposes two different types of learners. Throughout this project, G has demonstrated that she is an active particpant in the learning process while D demonstrates that characteristics of a passive learner. G is able to work independently. When confronted with an issue while designing her project, she will 'tinker' with blocks and attempt to resolve the issue independently. D is dependent on directions and insight from a teacher. D would tinker with blocks (especially the sound blocks) while waiting for either the researcher or practitioner to help him make progress on his project. Often, he needed input from the teacher to help clarify his thinking about the intent of his project. D interacted with G's project and G observed that D did not know how to proceed in several instances throughout the project. She was able to observe how an individual user will encounter her project and noticed that she need to provide additional prompting in order for the user to successfully interact with her project. As soon as D finished interacting with her project, G immediately began adding additional blocks to existing scripts to provide appropriate prompts for the user. She did not need assistance from either the researcher or the practitioner. Another example of G's willingness to be responsible for her learning stems from an interaction between G and the researcher. The researcher observed that G added a script to her project that plays a sound effect when the 'a' key is pressed. G's project contained a question and answer script that asks the user a question about the number of bases in a cone. If the user enters a correct answer, positive feedback in the form of text is displayed on the screen. When G interacts with her project, she would press the 'a' key when she entered the correct response. The researcher observed this behavior and asked her how the sound would play if she was in a different room when a user was interacting with her project. She immediately began addressing this issue without prompting or assistance from the researcher or practitioner. D continues to struggle with his project. He has developed an elaborate story in his mind that is only loosely related to the idea of teaching someone else about geometric solids. He uses the vocabulary of geometric solids but only on a superficial level. He is unable to translate his story into Scratch without assistance from either the researcher or practitioner.

N worked on a scene consisting of a dialogue between 2 characters about riding dragons. This scene does not related to math content.
T added a cylinder to his project.
C finalized a dialogue between a prism and a cylinder, but the conversation is not related to math content. His project has numerous spelling and punctuation errors.

5/24/10 (G was absent today)
R: N needed assistance today with the flying dragon scene. This scene is not related to math content.
T needed assistance coordinating dialogue between 2 sprites. The timing was off.
D recorded the desert part of his script. He needed assistance setting up his 3rd scene (the woods). He expressed frustration that he is only able to make small changes to his project each day. He expressed that he doesn't understand why he is saving a new project each day (participants save a new version of their project each day) when he is not making much progress. He expressed some frustration that he is getting as much help as he needs. He also wants to know when he can work on a project for fun and not a project about shapes.
C needed assistance with fixing an error he couldn't identify. The project kept asking the question repeatedly even if the correct response was entered by the user. The error was due to a misspelling (cyinder-cylinder).
F is finished with his project from his perspective.
C did not ask for assistance nor accepted it when offered. He expressed that he was wrapping up his project.

5/25/10
Those that were finished with their projects shared their projects with each other and received feedback.

5/27/10
Proofing each other's projects

5/28/10
Proofing each other's projects

6/1/10
Checked for punctuation, spelling and conventions.
Co., Ca., F & S reviewed each others' project.
R worked with D. P worked with G. To finish projects

D literally hit a wall: he placed his head on the door and rested it. He's feeling frustrated because he's comparing his project to others. He doesn't feel confident that he will be able to share his project with others.

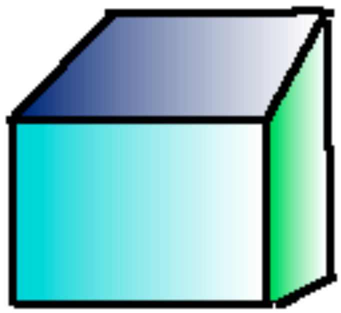
G needs more time.

6/2/10
Ca., S, T & N are absent today.
P worked with F and Co to proof their projects, particularly spelling and punctuation.
R worked with G and D to complete projects.
D is capable and confident importing sprites, shrinking or growing sprites, editing sprite costumes, changing a sprite's directions. He has numerous sprites in his project (more than any other participant). He needs consistent help with the programming aspects of his project. He does not try to work independently. He will wait until either the researcher and practitioner is able to help him.

6/3/10 (G was absent today)
Ca., S, Co., T and N proofed their projects.
D attempted to complete his project. He consistently changes where the sprites are displayed for each scene rather than focusing on the programming. He still needs to record the voiceover for his sea scene and the final theatre scene. He did record these 2 final voiceovers. The R helped him synchronize his completed project.
Nathaniel removed an irrelevant scene from his project then wanted to add another geometric solid to his project. He also needed to slow down the dialogue to ensure that 2nd graders could read the text displayed on the screen.
N: "Where's the thing hide?" R: "It's under looks."
Connor worked on coordinating a dialogue between a cylinder and a prism.
Ca., S and T are finished.

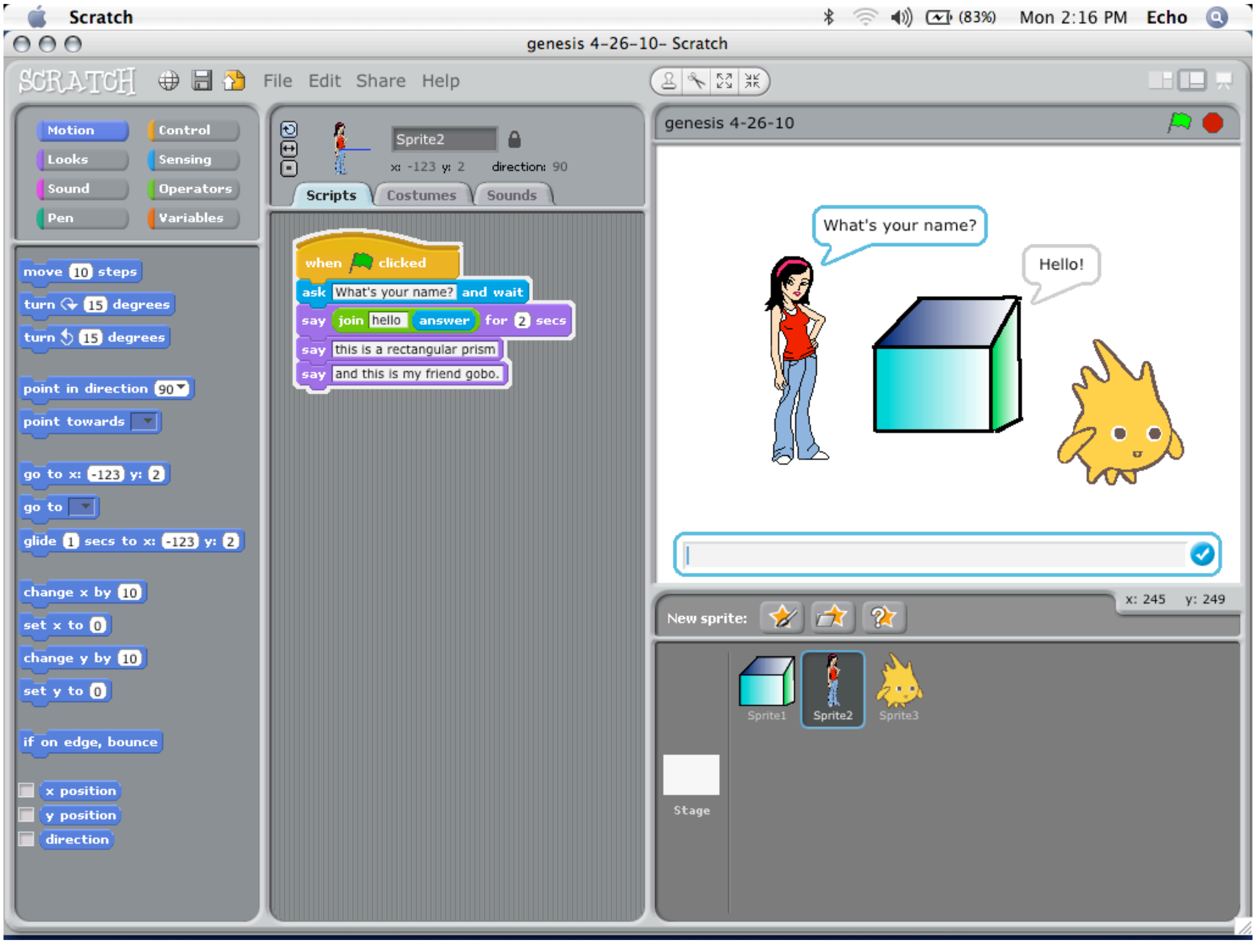
APPENDIX C
SCRATCH ARTIFACT ANALYSIS

5/3/10
G created a costume for the existing cat sprite and added 2 sprites to her project. She created a costume of a rectangular prism for the default cat sprite. This sprite now has 3 costumes but two of these costumes are default costumes. The rectangular prism costume is currently displayed. The rectangular prism drawn by G appears to be a trapezoidal prism rather than a regular rectangular prism.



She added a sprite of a young female who is standing and a fantasy character labeled as a 'gobo'. Both sprites are from the existing sprite library. She has not altered the stage; she is currently using the default white background. She has created 2 scripts. One script is for the rectangular prism. When the project is started (green flag), the prism states "Hello!". The second script is for the young female. When the project starts, the female asks "What's your name?" and waits for a response to be typed into a text box. After the user types in text and presses enter or uses the mouse to click on check mark located in the text box, the female states "hello <text>" followed by two statements: "this is a rectangular prism" and "and this is my friend gobo.". However, the first of these 2 statements is only flashed on the screen because G used the 'say' block rather than the 'say for x secs' block. Scratch processes scripts in a linear fashion. When there are 2 or more 'say' blocks in sequence, Scratch displays the text from the first 'say' block then immediately displays the text from the next 'say' block, which makes the text from the first 'say' block unreadable. G will need to replace the 'say' blocks with 'say for x secs' blocks to ensure that the text is displayed properly and is readable by the user. In both scripts, she used 9 blocks total, and she used 6 different block types.

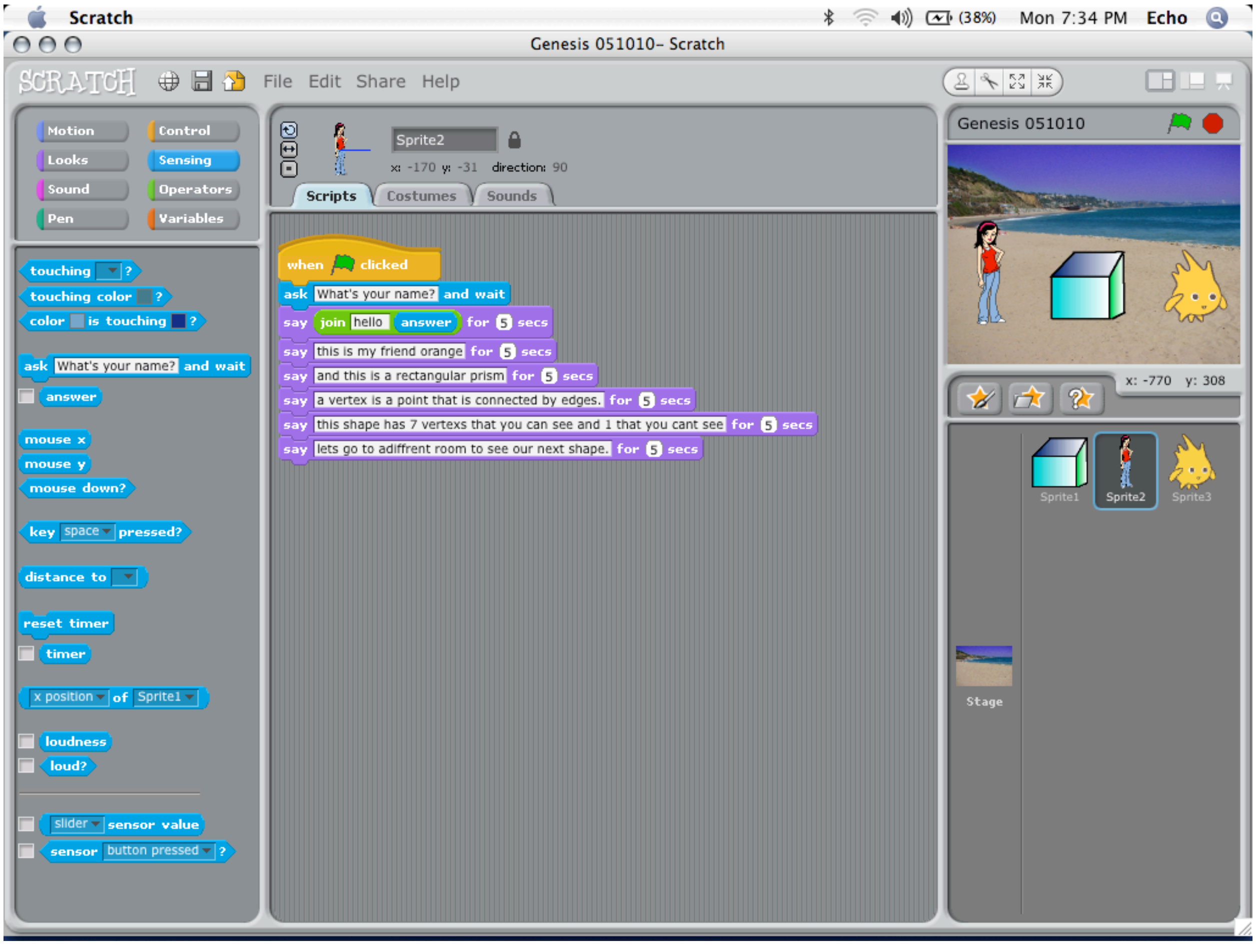
I'm pleased with G's progress today. She quickly developed her project idea. She attempted to create a rectangular prism though it appears to be a trapezoidal prism. She has started scripting and integrated an interactive aspect to her project by allowing the user some level of control when the user enters text and the projects responds accordingly. This may represent a lower level of interaction, but interaction is still evident. G is attempting to personalize the project for its users.



5/10/10

G is still using the same sprites. She did add a new background of a beach scene to her project. G continued to develop her scripts. She removed the 'say' block from the prism, so it no longer states "Hello!". Because she used a 'say' block rather than a 'say for x secs' block, the text remained on the screen indefinitely. She did leave the 'when flag clicked' block in the scripts area, so she may plan to have the prism complete a different action. G updated the script on the female by changing the 'say' blocks to 'say for x secs' blocks so that the text displays appropriately. She now has the young girl stating: "this is my friend orange", "and this is a rectangular prism", "a vertex is a point that is connected by edges.", "this shape has 7 vertexs that you can see and 1 that you cant see", "lets go to adifferent room to see our next shape.". Each of these statements is displayed on the screen for 5 seconds. While G was working on this script, the researcher observed that she originally typed "this shape has 7 vertexs". He intended to ask her about this error during the next meeting. However, she changed the text during the meeting, so she was able to self-correct. Neither the researcher nor the practitioner addressed this concern with her. She may have received a clue from the meeting space's whiteboard, which did include a drawing of a rectangular prism with its 8 vertices identified. G also created a script for the gobo. She used the 'when space key pressed' block to trigger the gobo to state "Hello!". In both scripts, she used 12 blocks total, and she used 7 different block types. In addition, she has one block on the prism sprite that is not part of a script.

I helped G with her text display issue because she was using 'say' blocks rather than 'say for x secs' blocks. She quickly updated her script and added to it. I'm impressed with how she self-corrected her vertex error during our meeting time. This took no prompting from either the researcher or the practitioner.

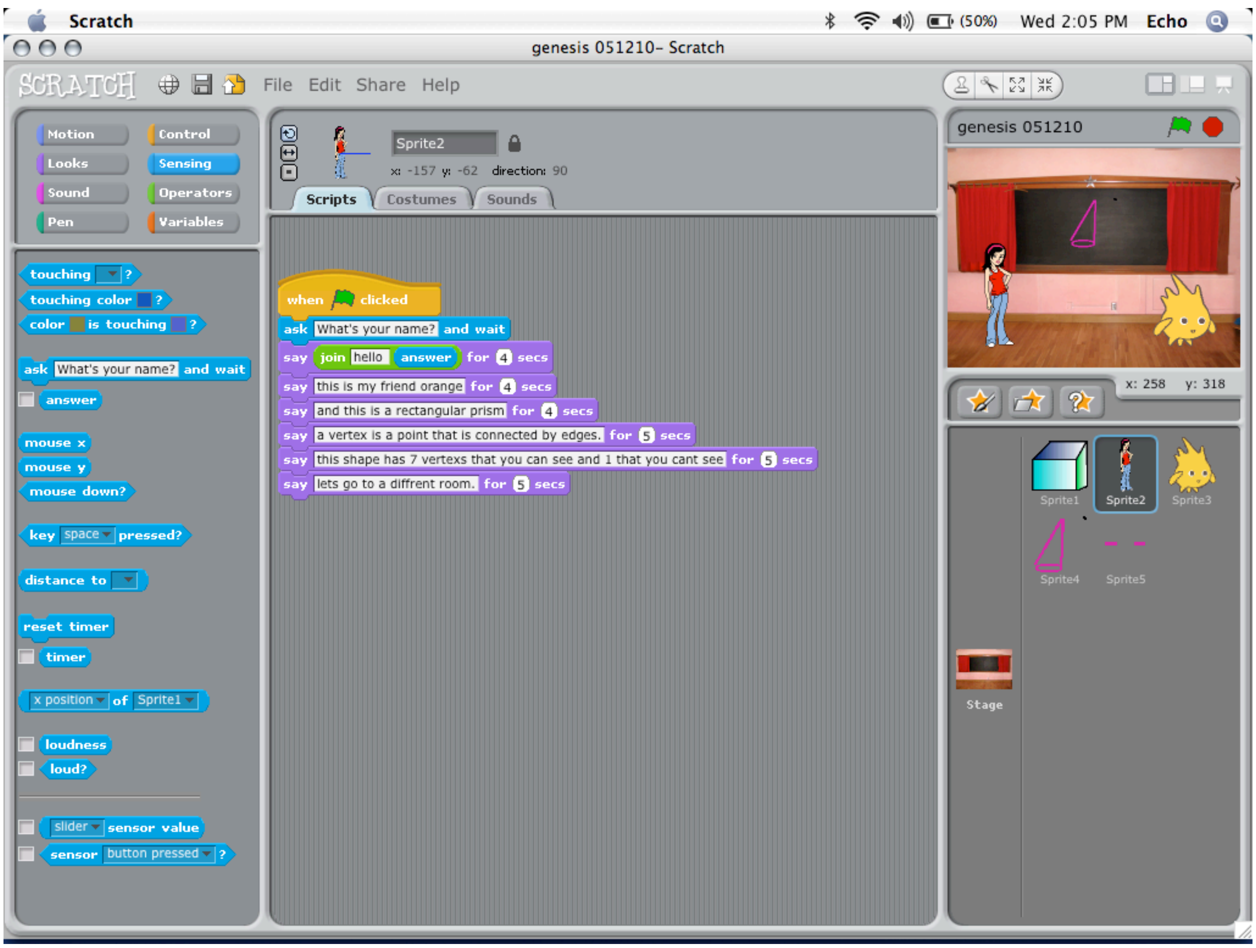


5/11/10
G was absent today. She was participating in FAIR testing.

5/12/10
G is using the same sprites and has added additional sprites. She created 2 sprites: one that is an outline of a cone and another that is a pair of short horizontal lines. She also added a chalkboard scene as an additional background and removed the default white background from her project. She created 2 small scripts for the stage. One scripts sets the beach scene as the opening background. The other script changes the background to the chalkboard when the space key is pressed. She also included a 'when up arrow key pressed' block in the scripts area, but there are no additional blocks attached to it. To the rectangular prism, she added two small scripts to indicate that the

prism should be visible in the beginning but should not be visible once the space key is pressed. G did not alter the scripts on the young female or gobo. To the cone sprite, she added the visible/not visible scripts similar to the scripts for the prism. However, she reversed the behavior. The cone is not visible in the beginning but does become visible when the space key is pressed. G also created a small script for the pair of lines that makes them disappear at the beginning of the project. G has no created 9 scripts for her project. Across all scripts, she has used 26 blocks, and she used 9 different types of blocks. In addition, she has one block on the stage that is not part of a script.

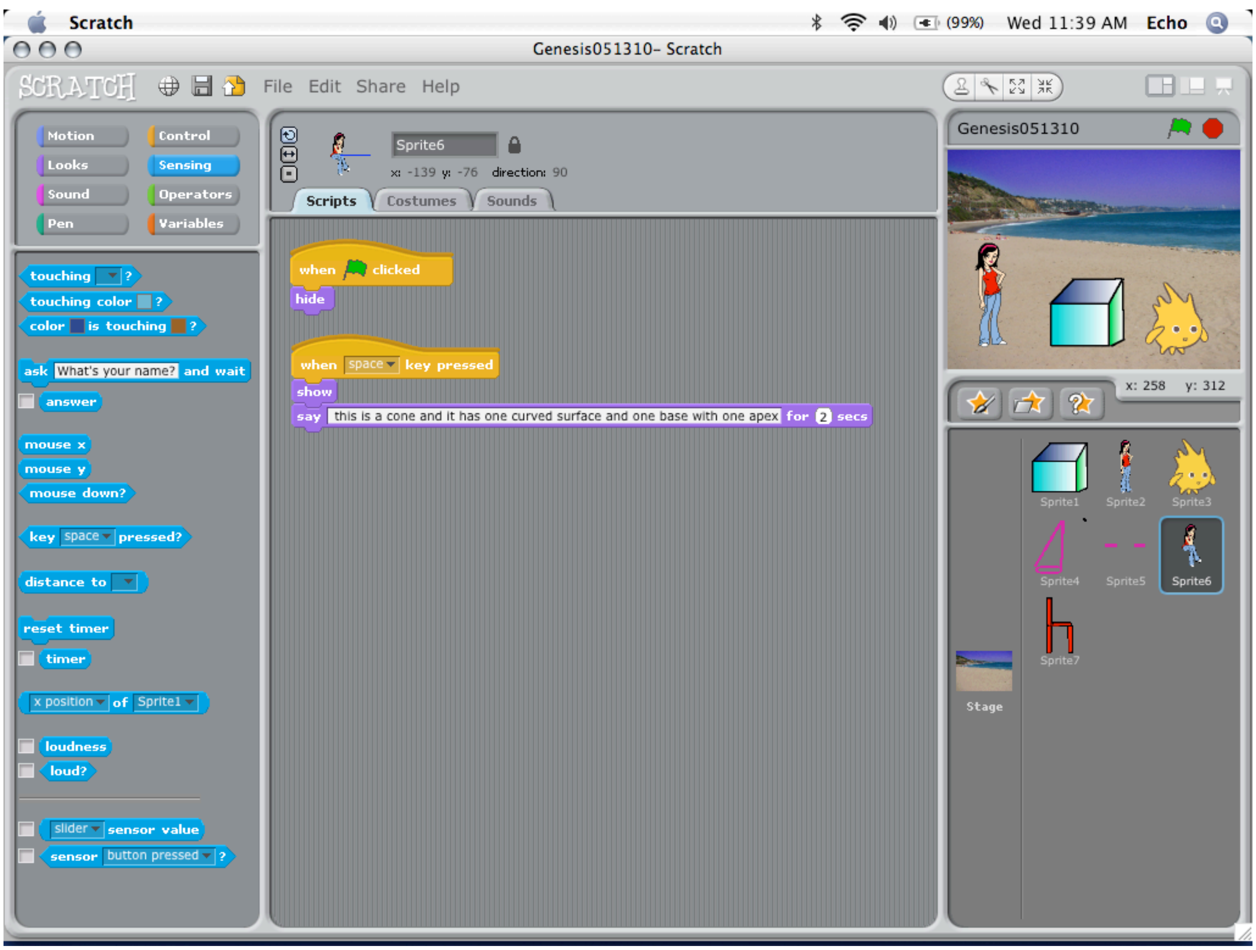
G is clearly making progress. She is working to create an additional scene focused on a cone. The researcher demonstrated how to show and hide sprites using the appropriate blocks, and she quickly integrated this action into her project. It's not clear yet how a user will know that the space bar needs to be pressed in order to advance to the next scene.



5/13/10
G is using the same sprites and created 2 additional sprites. One sprite is from the Scratch library; it is a sitting version of the same young female she used previously. She used the paint editor to create a sprite that resembles a chair and has placed the chair so that the previous sprite appears to be sitting on it. Her backgrounds have

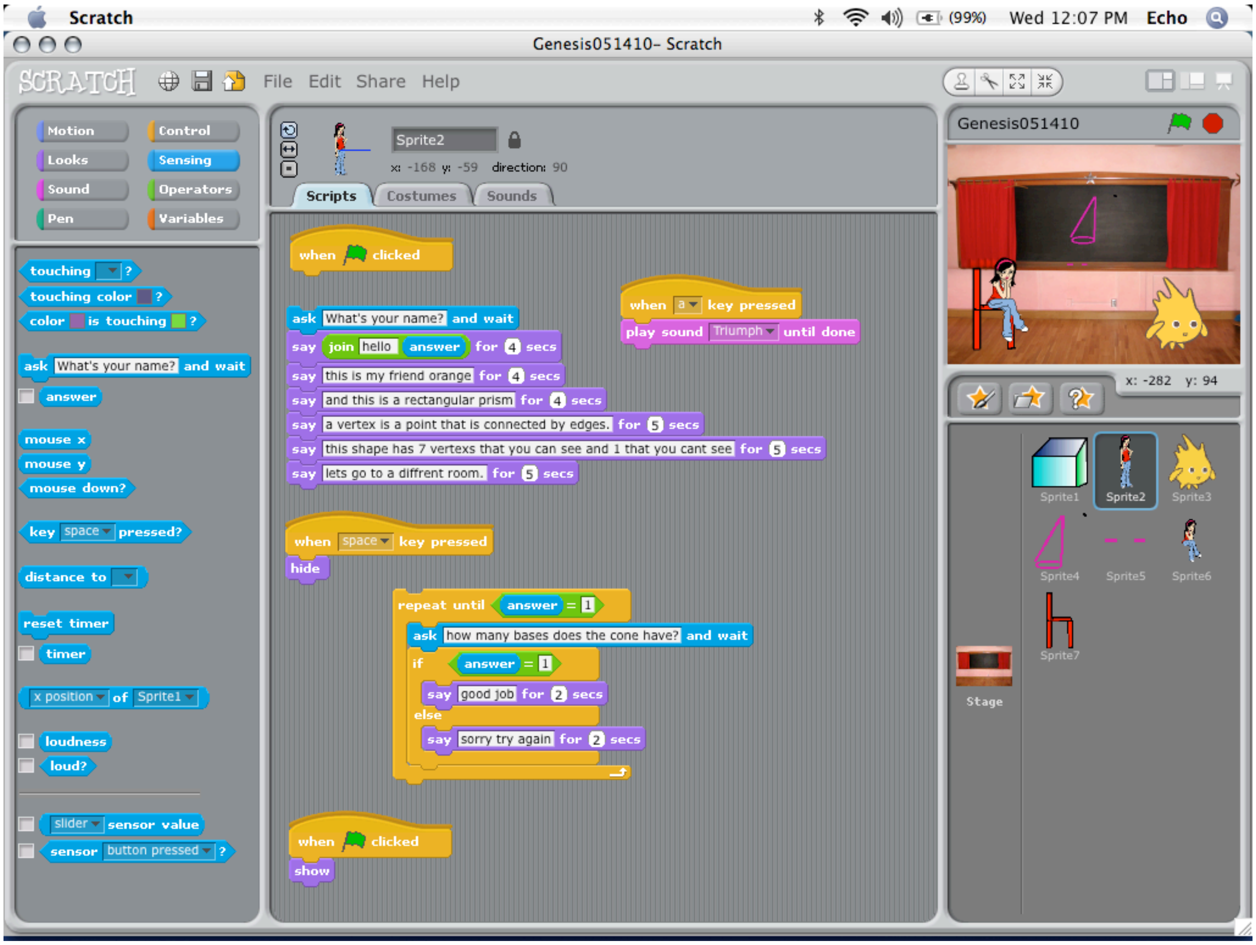
remained the same. She now has a total of 16 scripts. She did not alter the scripts on the stage, prism, gobo and cone. She added 2 small scripts to the standing female to ensure that she is visible at the beginning but is not visible when the scene changes (when the space key is pressed). It is now apparent that the pair of short horizontal lines represent pieces of chalk for the chalkboard scene. G created 2 small scripts to hide the chalk at the beginning and make the chalk visible when the scene changes. G created 2 scripts for the sitting female sprite. She has hidden this sprite at the beginning but made it visible when the scene changes. The sprite then states "this is a cone and it has one curved surface and one base with one apex". G also added 2 scripts to the chair sprite to ensure that it is not visible in the beginning but is visible when the scene changes. Across all 16 scripts, she has 41 blocks, and she has used 9 different types of blocks. In addition, she has one block on the stage that is not part of a script. Though the number of scripts and blocks has increased, the number of different types of blocks has remained the same.

G hasn't addressed how the user will know to press the space key to transition to the next scene. In addition, some of the text displays too quickly, so it may be difficult to read for struggling readers. G worked independently today. She needed no help.



5/14/10
G did not create additional sprites or backgrounds today. She spent most of the meeting time working on a script that asks a question of the user then provides positive or negative feedback depending on the response. The question is asked by the sitting female in the chalkboard scene and is preceded by a description of the properties of a cone. The user must enter a response until the correct one is provided. She originally created this script on the standing female sprite. The researcher showed her how to move the script to the appropriate sprite. G disconnected the original opening script on the standing female from its corresponding trigger so the opening scene no longer functions appropriately. She also added a music sound effect that is triggered when the user presses the 'a' key. Across all 16 scripts, she has 42 blocks, and she has used 10 different types of blocks. In addition, she has 22 blocks on sprites and the stage that are not part of any scripts. The majority (18) of those blocks are found in 2 stacks located on the standing sprite. One stack was separated from its trigger. The other stack was originally created on the wrong sprite but was later copied to the appropriate sprite.

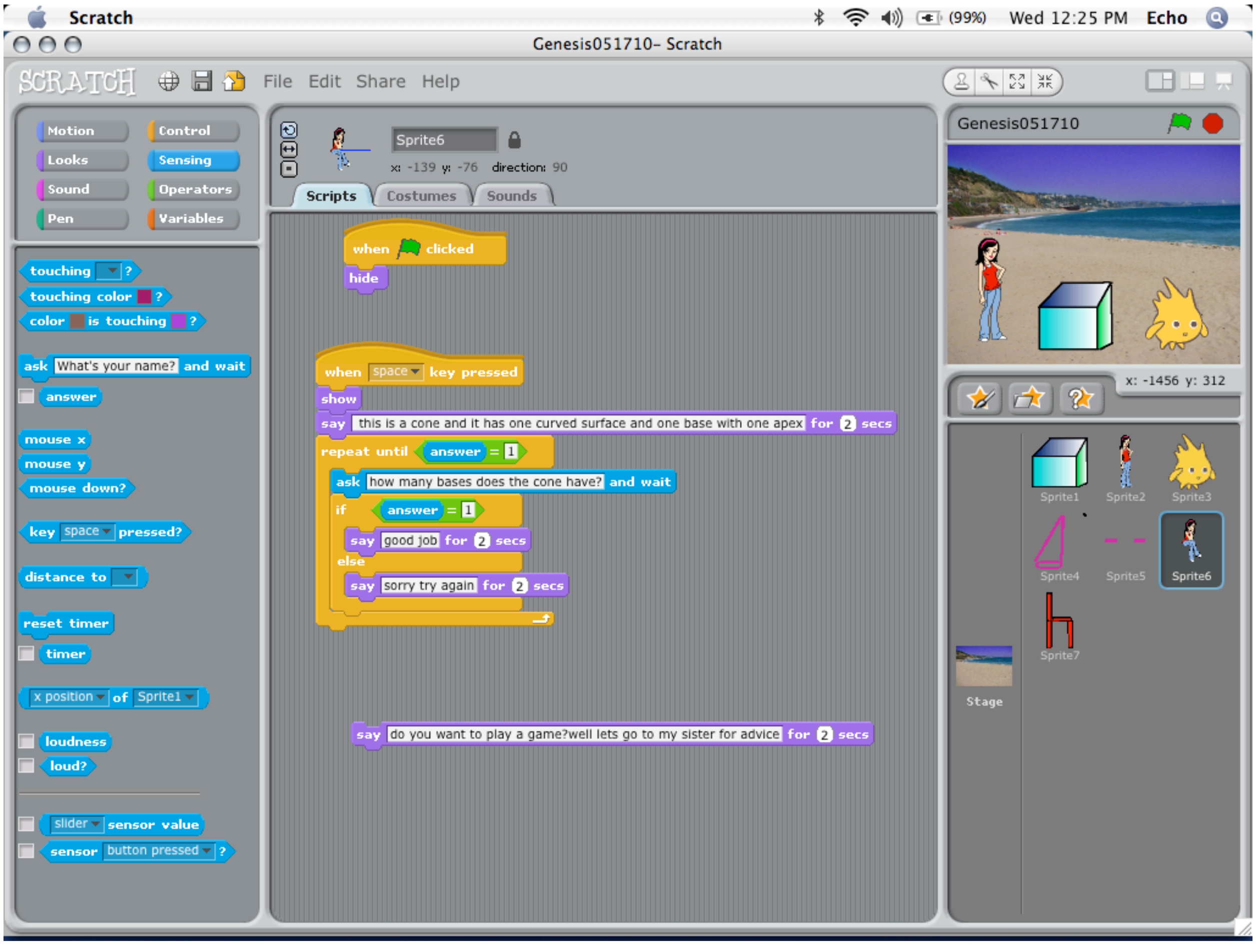
G still hasn't addressed how the user will know to press the space key to transition to the next scene or corrected the speed of the text as described yesterday. The user will also not know how to trigger the music. G integrated a question/answer script that was demonstrated by the researcher for another student's project (F). G collaborated with S to share expertise. G shared how to hide and show sprites and switch backgrounds to transition between different scenes. S shared how to ask a question for the user to enter a response and receive appropriate feedback. Both G and S's projects demonstrate this collaboration since each project contains an aspect of the other's project.



5/17/10

G did not create additional sprites today but did create an additional background, a living room scene. G reconnected the trigger to a stack of blocks that created the opening scene on the standing female. She also removed some unnecessary blocks from that sprite. She added a script to the gobo sprite that states “well i've got to go now bye guys” when the space key is pressed. However, this script conflicts with a similar script on the sprite. G now has 18 scripts that contain 54 blocks that represent 10 different types of blocks. In addition, she has 5 blocks on sprites and the stage that are not part of any scripts.

G still hasn't addressed how the user will know to press the space key to transition to the next scene or know how to cue the music or corrected the speed of the text as described previously.

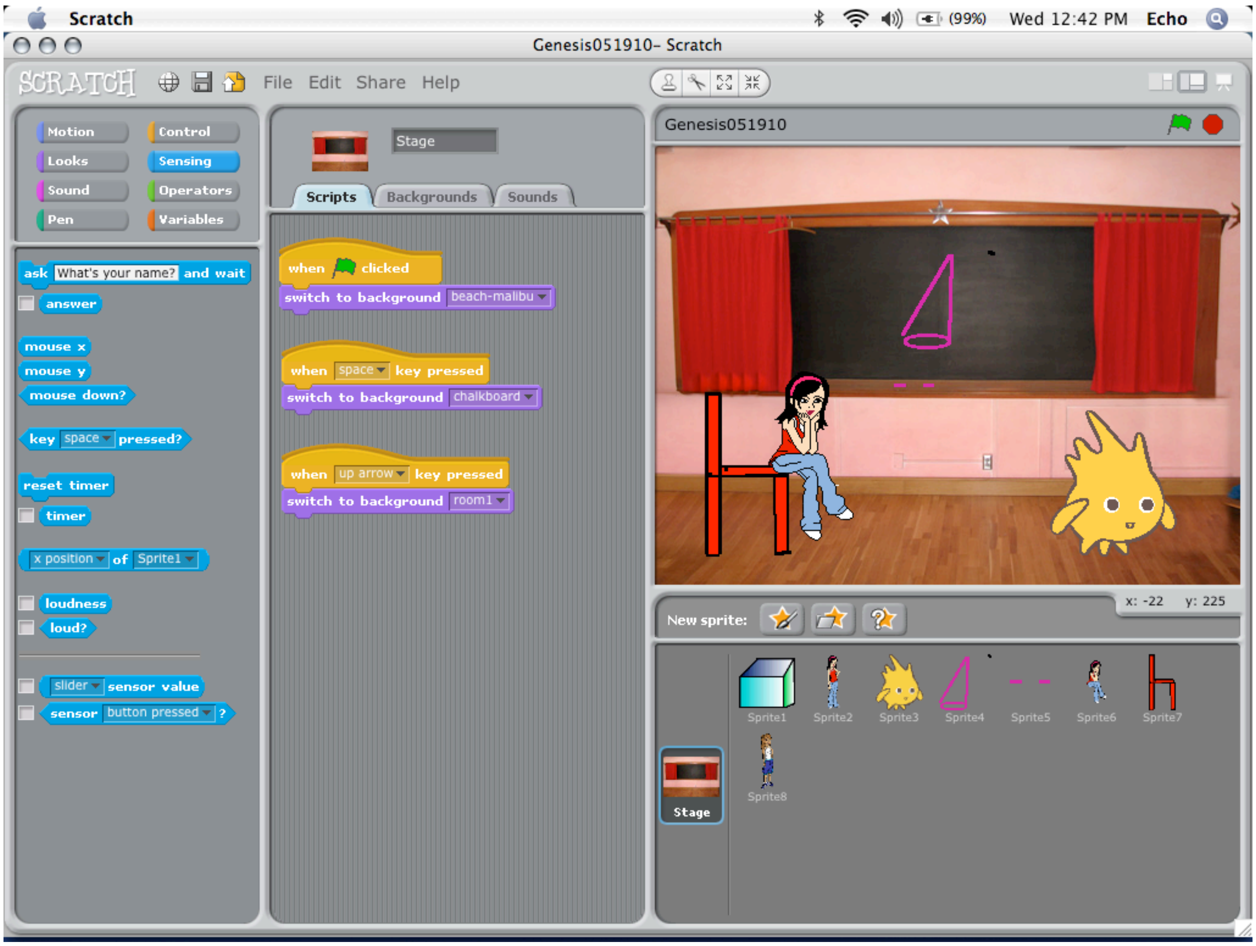


5/18/10
No meeting because of 5th grade 20th century project presentations.

5/19/10
G added a new sprite of a different standing female available in the Scratch sprite library. G provided a 'say' block to prompt the user to press the space key to transition to the next scene (a different room). A student who is not part of this learning group came near the end of the meeting time to work with the practitioner. While this student was waiting, the practitioner had G share her project with the student. Once the opening scene took place, the student did not know how to proceed until G told her to press the space key. Once G realized that a user cannot proceed without prompting, she added the prompt as described above. The cone is not visible when the text appears that describes the properties of the cone. G previously created a third background which indicates a new scene. She also has added several scripts to various sprites to coordinate when sprites will be visible or not visible depending on the scene. For example, the new sprite she added today is hidden at the beginning of the project but will appear when the user presses the up arrow key. She added a 'say for x secs' block that states "press the up arrow to go play a game". The researcher challenged her to include something about surface area in her project. It appears that she intends to have the user play a game in the new scene. She now has 24 scripts in

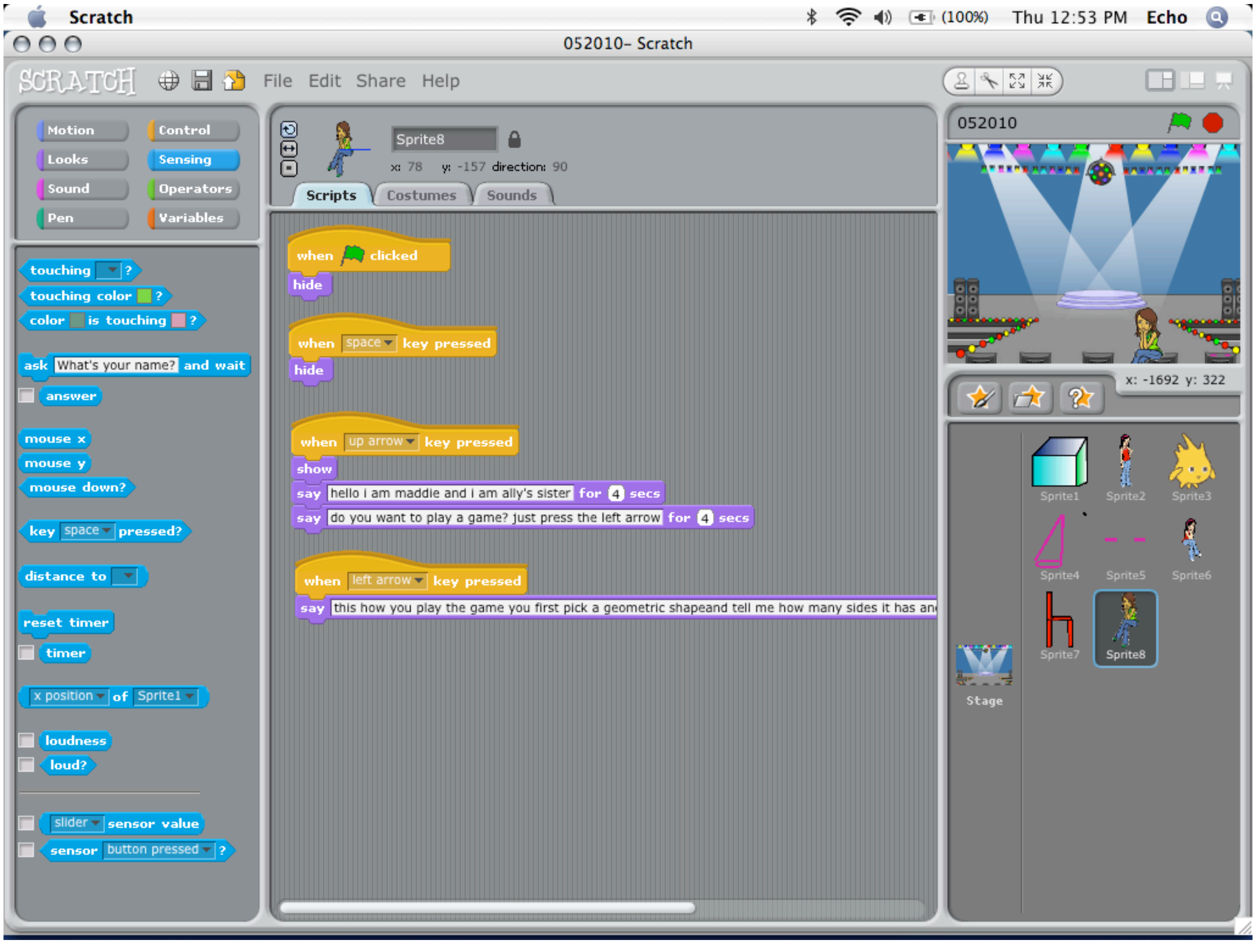
her project that use 67 blocks. In addition, she has 3 blocks on sprites that are not part of any scripts.

G has created a new scene that will incorporate something about surface area, though it is not functioning completely yet. She has included scripts to coordinate the hiding and showing of her sprites and to display the appropriate background for each scene included in her project.



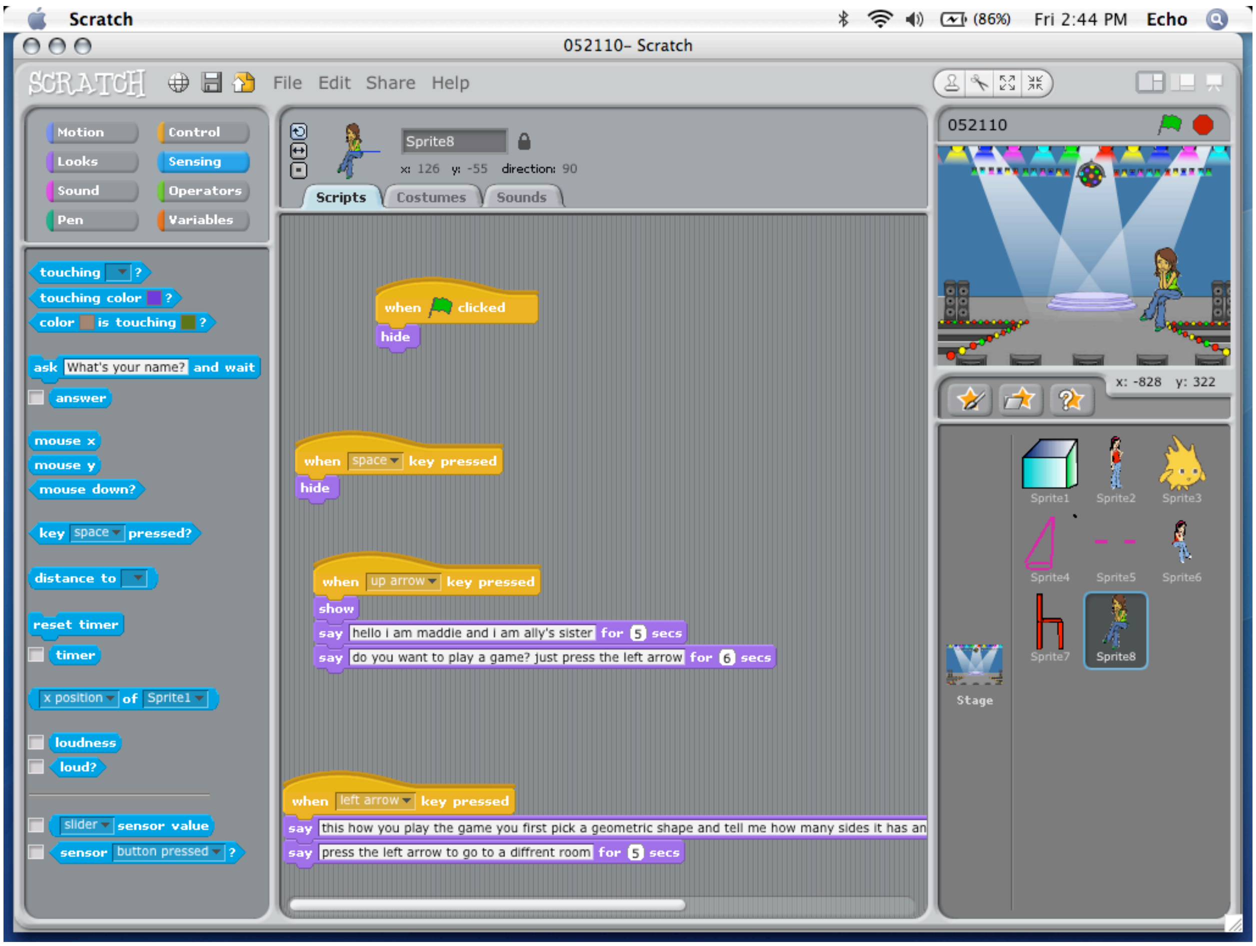
5/20/10
Researcher encouraged G to move the cone to a different location on the stage so that it would be visible when the female sitting sprite describes the properties of a cone. Previously, the text appeared in front of the cone, so only a small portion of the top of the cone was visible. G added a say block that states the name (ally) of the young standing female sprite at the beginning of the project. G added another background to her project. The background is a stage with spotlights. G now has 4 scenes in her project: the beach, the chalkboard, a living room and a stage. The project provides a prompt to transition between the first 2 scenes, does not provide a prompt to transition to the 3rd scene though the say block with a prompt is located in the scripts area (however, it is not attached to a script), does provide a prompt to transition to the last scene. G now has 28 scripts that use 80 blocks from 10 different block types. In

addition, there are 2 blocks that are integrated into any script (one of these is the say block mentioned earlier on the sitting female sprite; the other appears to be a misplaced ‘when space key pressed’ block on the prism sprite).



5/21/10

G is close to finishing up her project. She had D interact with her project today. G was able to fix design errors in her project once D worked through it or the researcher asked her about the sound clip even though P has tried to get her to identify the errors independently. Thinking outside one’s self is difficult for young learners. D interacted with G’s project and G observed that D did not know how to proceed in several instances throughout the project. She was able to observe how an individual user will encounter her project and noticed that she need to provide additional prompting in order for the user to successfully interact with her project. As soon as D finished interacting with her project, G immediately began adding additional blocks to existing scripts to provide appropriate prompts for the user. She did not need assistance from either the researcher or the practitioner. Another example of G’s willingness to be responsible for her learning stems from an interaction between G and the researcher. The researcher observed that G added a script to her project that plays a sound effect when the ‘a’ key is pressed. G’s project contained a question and answer script that asks the user a question about the number of bases in a cone. If the user enters a correct answer, positive feedback in the form of text is displayed on the screen. When G interacts with her project, she would press the ‘a’ key when she entered the correct response. The researcher observed this behavior and asked her how the sound would play if she was in a different room when a user was interacting with her project. She immediately began addressing this issue without prompting or assistance from the researcher or practitioner.



APPENDIX D
CURRICULUM-BASED PRE- AND POST-TEST

Unit 11 Checking Progress

Complete each sentence with one of the following names of geometric solids:

pyramid   cone   rectangular prism   ~~cylinder~~

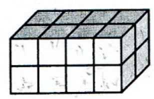
1. I have exactly two bases and no vertices. I am a Cylinder.

2. All of my faces are triangular. I am a pyramid.

3. I have one base and one curved surface. I am a Cone.

4. I have a pair of bases and exactly eight vertices. I am a Rectangular prism.

The prism at the right is made of centimeter cubes.



5. What is the area of the base of the prism? 8

6. What is the height of the prism? 2

7. What is the volume of the prism? 10

8. What is the surface area of the prism? 32

9. Explain how you found your answer for Problem 8.
I added all the sides up.

10. If you kept the base the same, but tripled the volume of this prism, what would be the height? ____

11. Write a number sentence to show how you solved Problem 10. ____

APPENDIX E
INTERVIEW GUIDES

Semi-Structured Interview Guide for Case Study Participants

I want to talk to you about your experience designing about math in Scratch. I want you to be honest. If you do not feel comfortable answering a question, you do not need to answer the question.

1. Did you enjoy using Scratch? Explain.
2. Was it easy or difficult to learn how to use Scratch? Explain.
3. What is the best way to learn how to use Scratch?
4. Do you think that creating something in Scratch helps you learn? How?
5. Did designing in Scratch help you learn math?
6. Did your score on the math post-test improve from the pre-test? Why or why not?
7. Did you enjoy creating something for 2nd graders to use? Explain.
8. Does designing something for someone else to use encourage you to work harder? Explain.
9. Is there anything you want me to know about this experience that I didn't ask you?

Thank you so much for talking with me. You've been very helpful.

Semi-Structured Interview Guide for Practitioner

I want to talk to you about your experience.

1. How did your students react to using Scratch? Explain.
2. Was it easy or difficult for your students to learn how to use Scratch? Explain.
3. What is the best way to teach students how to use Scratch?
4. How do you think that having students create something in Scratch helps them learn? How?
5. How was learning about math different for your students because they used Scratch? Explain.
6. How do you think your students reacted to creating something for 2nd graders to use? Explain.
7. How was student motivation to work hard affected because they were creating something for 2nd graders to use? Explain.
8. Is there anything you want me to know about this experience that I didn't ask you?

Thank you so much for talking with me. You've been very helpful.

APPENDIX F
TRANSCRIPT AND ANALYSIS OF DOMINIC'S INTERVIEW

This appendix includes the transcript and 8-step analysis of the post-experience interview recorded with Dominic, one of the case study participants.

Researcher questions	**Participant responses**	**Record brief notes while reading transcript (Step 1)**
Did you enjoy using Scratch?	Well, yes.	Enjoyed Scratch
What about using Scratch did you like?	Well, the part was making all the new sprites and editing them, like that cat right there <yes> I made her a tongue and eyelashes, made her look like a girl not a boy cat because I think every cat in here is a boy.	Enjoyed creating and editing sprites
So you liked taking the existing sprites and changing them, right?	Yeah	
OK. What else did you like about using Scratch?	Well, that there were so many sprites to use like a dragon and ghost and you can create your own sprites like raining milk.	Enjoyed existing library of sprites within Scratch
OK. So you like that you could design your own sprites <yeah> and you also like that there were lots of other sprites that were part of Scratch that you could use?	Yes.	
Yes. OK. Good. Do you think it was easy or difficult to learn how to use Scratch?	I say it was difficult.	Scratch is difficult
It was difficult to learn how to use Scratch?	Yes.	
What made it difficult to learn how to use?	Well, pretty much it was hard to know what to do because there was so much stuff. Like when you were saying *** at *** and turn around cause look at all these stuff glide 1 sens x -29 and y -10 and change x by 10 and all this other stuff.	Scratch is difficult because of too many command blocks
Sure. So all those	Yeah	

blocks, maybe there are just too many blocks showing so it gets confusing?		
OK. So because there are a lot of blocks there, what do you think would be the best way to learn how to use Scratch? Or what would be the best way for you to learn how to use Scratch?	I don't really know.	
You don't really know? What would have been the best way to help you learn Scratch?	Maybe get some professional help	
Get some professional help?	Yeah	
What do you mean by that?	Maybe a person who's done Scratch for awhile or a person who maybe created it.	Get help from an experienced Scratch user (did not perceive researcher or practitioner as an experienced user)
Oh, maybe the person who created it. Do you think they would be able to help you?	Yeah	
What about in a classroom? How could we learn Scratch in the classroom because we probably wouldn't be able to bring in	You mean the 5th grade classroom?	
Sure, in the 5th grade classroom. What would be the best way to learn Scratch? If you were going to work with your because you know something about Scratch now. How would you teach your classmates about Scratch?	Maybe one simple thing at a time.	Teach in small steps
OK. Maybe one simple	I guess but if I didn't know it, how	

thing at a time. Do you think that would help you too?	could I teach it?	
Well, right, but I'm saying if someone was teaching you, would it help you to do one simple thing at a time?	Yeah.	Dominic may like it when taught in small steps
And what do you mean by one simple thing?	Like the first thing after another like creating the sprites. Then, well, first, the motion, then the looks, sound, pen, control, sensing, operation, variables.	Learn to create sprites first (he enjoyed), then work through categories of command blocks
So are you saying we should go through each block to teach you one block at a time?	Well, not all of these. That would take forever.	Don't teach all command blocks
That would take a long time?	Yeah, just like motion and that and that and that and that and then looks	Teach a few command blocks in each category
OK, so maybe do a few blocks from each of those categories?	Uh-huh (yes)	
Maybe the ones you'd use the most?	Yeah	Teach most commonly used command blocks
OK. That's reasonable. Do you think designing in Scratch helps you learn? Do you think you learn something while designing in Scratch while working on this project?	Learning math?	
Sure let's talk about learning math. Do you think you can learn math while working on this project?	Umm…I really don't. Some of that stuff I already know like a pyramid. I don't know that much about pyramids but cylinder and cone I already know about those two.	Already knows about content
OK. So you already knew about some of the math you used?	Yes	
So you didn't really learn about math in this project?	No	Didn't learn math
Is there anything you	Well, how to draw some of them	Learned how to draw

felt like you did learn from this project?		some geometric solids
So how to draw those shapes?	Yeah	
Yeah, you drew a number of shapes. I see a cone, rectangular prism, cylinders even a pyramid there. You've learned how to draw them. Anything else you think you learned in this project?	Well, I did learn that…not really. I was just saying that I was a little embarrassed when I was saying my project because everything was messed up the time I did it cause that was in the wrong place, that was in the wrong place, that was in the wrong place. Everything was in the wrong place.	Embarrassed by project
You mean when you were showing it to the 2nd graders?	Yes, everything was in the wrong place.	Embarrassed when showing to 2nd graders
Everything was in the wrong place?	Maybe not everything. Not in the right position. They're all supposed to be. He needs to be bigger. They're all supposed to be facing.	Project isn't working correctly; didn't finish
Oh, so some of the sizes are not right	See look. See	
So he's facing the wrong direction?	Yeah, that's one.	
OK. OK.	Well, do you want to see?	
We'll go through it in a minute, OK? Anything else you learned? Anything else you can think of that you learned while doing this project?	Uhm…probably…uhm…maybe…maybe learning how to do it.	
Learning how to do Scratch?	Yes.	Learned how to use Scratch
Yeah, you learned how to do Scratch a little bit because you said you, one thing you liked was drawing the sprites and editing the sprites, so you definitely learned how to do that, right?	Yeah.	Learned how to draw and edit sprites in Scratch
Did you learn how to record your voice?	Yeah	Learned how to record his voice in Scratch
I think you're, in fact, the only person that recorded their voice,	Well, yeah. I think.	Only student to record voice in Scratch project

right?		
I think you were. You learned that and I don't think anybody else learned about that. When you were designing this, were you thinking about designing for 2nd graders?	I didn't even know we were going to show it to 2nd graders.	Didn't know he would share his project with 2nd graders
You didn't realize we were going to show it to 2nd graders?	No	
OK. That's fair. Do you remember the original goal of the project?	Yeah	Claims to remember the project goal
What was the goal of the project?	Make it creative?	Thought goal was to make a creative project
To make it creative.	I don't know if that was one of them. I don't know if that was one of them.	Not sure if goal is to make a creative project
OK. So think back to why did you design what you designed. What was this trying to show?	I was trying to make it creative and make them move and make them have a conversation but instead I was the only one talking. I thought the 2nd graders would get bored.	Wanted to have sprites move and have a conversation but instead recorded his voice
Well, so what happened yesterday with the 2nd graders? Did they get bored?	Well, they were looking at it. I don't know if they got bored because I'm not them but, I don't know if it was as good as everyone else's cause they're all moving and having conversation like Nathaniel's. He was like it impressed me like fine let's go on the dragons. Duh-duh-duh. Dud-duh-duh. Fine let's go. Yee-haw. And that's what happened. And mine's not amazing as that. Mine's just blah, blah, blah, blah, blah, blah, blah. Blah, blah, blah, blah, blah, BLAH, blah. And then blah, blah, BLAH, blah. Yeah.	Compared his project to his brother's; he is impressed by his brother's project; he thinks his project is not as good
Well so everybody has a different approach to doing it and did you know that Nathaniel got rid of that dragon	Why?	Doesn't understand why his brother removed a scene about dragons that he really likes

scene?		
You have to ask him.	You mean the dragons go like this?	
Yeah he got rid of it.	Why?	
You'll have to ask him. I don't know why.	So what did he make?	
Well, he had the conversation going at the beginning.	Oh.	
I want to look at your project with you so let's go through your project.	OK.	
So first scene of your project, your telling a story. PLAY FIRST SCENE.	That's wrong. See how everything is messed up.	Project does not look the way it is supposed to look
What's messed up here	Well, he's supposed to be facing left. He's supposed to be right there.	
There's some cats in the wrong place and they're facing the wrong directions	WATCHING WOODS SCENE: Oh, come on. Ugh	Frustrated that sprites are in the wrong places
He's supposed to be behind?	That's supposed to be grabbing its tail.	Sprite is in the wrong place
Did that get changed? Was it like that yesterday?	Yes.	Didn't finish the project (yesterday was the last day to work on projects)
How does the land shark	See. Everything is messed up.	Frustrated
That looks right to me	You know those aren't supposed to be like that	
Well, we talked about that yesterday. What about the land shark. How does the land shark related to geometric solids?	Wait. What do you mean? Well, he went there because it's the sea and I guess he doesn't like it. Are land sharks real?	Trying to rationalize why there is a land shark in a project about geometric solids
I don't think so. I like the end by the way. I like how you used your fluctuation in your voice there. So, how do all these cats, ghosts, land shark, dragon, how does those relate to teaching someone	Well, the shapes are there and I said to pay well the last part when they were done that I just wanted to make sure they were paying attention I said what were the shapes in the background.	Shapes are part of project

about geometric solids.		
So the shapes are in the background. Do you ever talk about the shapes?	Uh, do I ever, well, when it's done I say "what shape is that?" and they're trying to guess it.	Asks "what shape is that" verbally but it is not part of his project
So explain that to me again	Cause when I'm done I want to make sure if they're paying attention.	
So when you were done, when you watched this, so you asked, did you ask the 2nd graders "what shape is this?"	Uh-huh (yes)	
So that wasn't part of your project, that was just something you just asked them?	Yeah	
OK. That's fair. We asked you some questions before the project started and then last week near the end of the project, you answered those same questions. You might not have remembered it. OK, let's take a look. I'll show you what I'm talking about. So this is what you did when we started the project. Remember looking at this? And this is what you did last week? So we want to compare answers. So, cylinder, cylinder, pyramid, pyramid, cone, cone, rectangular prism, rectangular prism. In the beginning and at the end, you could identify which geometric solid it is. No problem. So then here we have what is the area of the base	Is that right or wrong?	Concerned about getting correct answer

of the prism. You said 8.		
What do you think it is?	I guess right	
So how do you find area?	I forgot.	
But over here you have the area of the base is 16. So it looks like	It's 8	
It's 8. So you can count the cubes. 1, 2, 3, 4, 5, 6, 7, 8. But here you put 16. So one of my questions is what happened here. You forgot?	I thought it was 8 16	
8 plus 8 is 16? OK, then look at here. What's the height of the prism. You have 2 and then you have 2. Is it 2?	Yes	
Yeah, because you can count, so that was no problem. What is the volume of the problem	I said 16.	
And then over here I can't tell if it's 16 or if that's 10.	I think it's 10.	
I'm not sure how you went from here to here but when we	I think this is right.	
This one's right.	Yeah	
Yeah, you're right because you take	OK, which one's the one I did first?	
This one's first, this one's second	Oh, OK	
Then you did. You're right because you take the area of the base times the height	I think I improved more on this one (pre-test).	Thinks he did better on pre-test
You think you improved more. You think you did better on this one (pre-test).	Yeah, that one (post-test) I did horrible.	
Well, I don't think you did horrible. I think that	Yes	

maybe you just kind of forgot. And then here but I want to show you something. Look here. 8 and 9. You just put question marks, which looks to me like you didn't try, but here, you tried, you put answers and you said I just looked at the surface. So at least you tried, you tried something right?		
So do you think you improved on the second one compared to the first?	I think I did better on the first one.	
I would say maybe just a little bit better. It's pretty similar, don't you think?	Yes	
Is there anything else you want to tell me about using Scratch or doing this kind of project?	Scratch is really confusing and frustrating.	Scratch is confusing and frustrating
Scratch is confusing and frustrating.	I was wondering why when I got to the 2nd graders it was doing all this stuff to me	
Like what do you mean?	When we we're doing this project without the 2nd graders, nothing was happening, it was just normal, but then once I got the 2nd graders, all these lunatic stuff started to happened like the computer shut off, these Chinese words appeared and everything got mixed up.	Had issues with computer when he shared his project with 2nd graders
Yeah, that was strange yesterday, wasn't it? How we had to shut down you computer, that was, because that hadn't happened to you this whole time?	No	
Then it suddenly did.	Yes	

So you said it was frustrating.		
Would you ever want to use Scratch again?	Uhm…yeah, I do. And I want to make it better than the first one I want to make it more better. My voice could be talking and they could be moving and stuff.	Wants to make a better project in Scratch, wants to integrate movement
OK	I don't know if I can do it again because I'll be in 6th grade.	
Well, you can use Scratch. The nice thing about Scratch it's free	Free? I can do it on my computer?	
You can download it on your computer.	How?	
You just have to download it from the Scratch website. Have your parents help you. Say "I want to find Scratch", and you can do it for free. So you'd be interested in using Scratch again.	Yeah.	
You kept telling me during the project that "when are we going to do a project that's not about shapes".	Yeah	During the project, he wanted to do a different project not about shapes
Did you not like the shapes?	Well, the shapes, I, well, no, I kind of liked it.	
OK. But you kept wanting to move on to a different project?	Yeah	Wanted to do a new project
How come?	Well, the shapes. I thought it was kind of weird when they were saying, they looked like adults but they were saying they were going to see a movie about shapes.	Reflecting on his story idea
What was the idea for your you know you had this story. How did you come up with all those different ideas?	I don't know. It just pops up in my head	
Just pops up in your head? OK. Do you like math?	A little	Likes math a little

Do you think you're good at math?	No, no	Perceives he's not good at math
Do you think that you could learn math using Scratch?	Maybe?	Not sure if you can learn math using Scratch
Maybe how?	The things I'm writing down are things I already know, so how could it teach me?	What he included in his project is what he already knows about the content
Great question. I don't know the answer. So what you were doing was demonstrating what you know about math in this project?	Yeah	Knows that he was demonstrating what he knows about math
Anything else you want to share with me about the project? Here's your change to tell me anything you want to tell me about the project?	The things I didn't like was just, I guess I should have done better, I said it like I didn't care, like in the sounds I said it like I didn't care.	Reflecting on his project: he should have tried harder on his recordings
Oh, so you would want to redo your sounds?	Not all over cause, I was speaking like I didn't care	
Right, didn't put a lot of emotion into it	Except for the last part	
The last part, yeah, you definitely put a lot emotion in the last line however you said that "the shape test", which is pretty funny. Anything else I should know about working on the project, anything else you want to tell me about this	Uhm…uhm…uhm…maybe…uhm…I just know what's going to happen if I don't tell you this and then later when then maybe Monday comes I'll have something I want to tell you then it will be too late, so I'm trying to think of something.	
I appreciate that	Uhm…well…maybe it's about how mine is really different from everybody else's. Everybody else's seemed better because they're saying "what shape is this" then you type it in.	Reflecting on project: his is different from other students (other students ask questions of user, his tells a story)
So to you that seemed better	Well…not…no. I don't really like doing that	Doesn't like the question approach
You don't like doing what?	The part when you say "what's this shape"	

Yeah, so	Well, maybe it would be fun	
Do you like to tell stories	Yes	Likes to tell stories
Do you write stories a lot?	Yes	Writes stories
So what you did seems something that you're good at then.	Really?	
To me. Cause you had this very elaborate story and nobody else really had a story like you had a story, so I thought it was interesting that you just said that other kids asked what shape is this but you said well I don't really like that. So, it seems like to me in your project you did what you like to do	Well, I did	Reflecting on how he likes to learn, how his project reflects that
Isn't that OK you did it the way you like to do it?	Well, yeah, it's OK.	
The way you like to do it?	Well, yeah, it's OK	
While I'm thinking about it, would you want to share this with your 5th grade classmates?	I'd feel too embarrassed	Does not want to share with peers
You'd feel embarrassed to share that with them? How come?	Everyone in the 5th grade is mean.	
Everybody in the 5th grade is mean?	Not everyone. Everyone's mean and rough and tough, and I don't want to do it. I'll be scared.	
OK and we're not going to do it, so I don't want you to think I'm going to do it, I just wanted to know what you think	I would do but I'll be too scared	
Yeah, I appreciate that. And do you think other 5th graders should learn how to use Scratch	They could	
They could learn how to	Yeah	

use Scratch?		
Do you think they'd like to learn Scratch?	Some kids but some kids would think it would be a waste of their time	
Why do you think some kids would think it would be a waste of their time?	Cause they're not grateful	
Cause they're not grateful? Anything else you want to share with me?	Probably not.	

General notes recorded while rereading transcript (Step 2)

- Enjoyed creating and editing sprites
- Like the library of sprites in Scratch
- Scratch is difficult, frustrating and confusing; too many blocks
- Thinks it would be helpful to learn one block at a time and to learn just a few blocks from each of the categories. He may like to learn this way
- Didn't learn math from this experience; already knew the math; did learn how to draw geometric solids
- Learned how to draw and edit sprites and record voice in Scratch
- Not proud of project; embarrassed; many sprites are in the wrong location or facing the wrong direction; compared his project to his brother's project and to peers; didn't finish his project; could have tried harder; doesn't want to share with 5th graders
- Reflective on his project; wondering about his story idea
- Superficial representation of math content
- Would like to use Scratch in the future; improve his project
- Likes stories
- Reflects on how he likes to learn

Generated themes based on general notes (Step 3)

Dominic's reaction to using Scratch

- Enjoyed creating and editing sprites
- Like the library of sprites in Scratch
- Scratch is difficult, frustrating and confusing; too many blocks
- Would like to use Scratch in the future; improve his project

Dominic reflecting on learning Scratch

- Thinks it would be helpful to learn one block at a time and to learn just a few blocks from each of the categories. He may like to learn this way
- Learned how to draw and edit sprites and record voice in Scratch

Dominic reflecting on learning math during this project

- Didn't learn math from this experience; already knew the math; did learn how to draw geometric solids

Dominic reflecting on how he learns

- Likes stories
- Reflects on how he likes to learn

Dominic’s reaction to his project

- Not proud of project; embarrassed; many sprites are in the wrong location or facing the wrong direction; compared his project to his brother’s project and to peers; didn’t finish
- Reflective on his project; wondering about his story idea

Codes from Themes and Coding Data (Step 4)

(Code: Theme)
Scratch reaction: Dominic’s reaction to using Scratch
Learning Scratch reflection: Dominic reflecting on learning Scratch
Learning math reflection: Dominic reflecting on learning math during this project
Learning reflection: Dominic reflecting on how he learns
Project reaction: Dominic’s reaction to his project

Researcher	**Participant**	**Coding Data**
Did you enjoy using Scratch?	Well, yes.	Scratch reaction
What about using Scratch did you like?	Well, the part was making all the new sprites and editing them, like that cat right there <yes> I made her a tongue and eyelashes, made her look like a girl not a boy cat because I think every cat in here is a boy.	Scratch reaction
So you liked taking the existing sprites and changing them, right?	Yeah	Scratch reaction
OK. What else did you like about using Scratch?	Well, that there were so many sprites to use like a dragon and ghost and you can create your own sprites like raining milk.	Scratch reaction
OK. So you like that you could design your own sprites <yeah> and you also like that there were lots of other sprites that were part of Scratch that you could use?	Yes.	Scratch reaction
Yes. OK. Good. Do you think it was easy or difficult to learn how to use Scratch?	I say it was difficult.	Learning Scratch reflection

It was difficult to learn how to use Scratch?	Yes.	Learning Scratch reflection
What made it difficult to learn how to use?	Well, pretty much it was hard to know what to do because there was so much stuff. Like when you were saying *** at *** and turn around cause look at all these stuff glide 1 sens x -29 and y -10 and change x by 10 and all this other stuff.	Learning Scratch reflection
Sure. So all those blocks, maybe there are just too many blocks showing so it gets confusing?	Yeah	Learning Scratch reflection
OK. So because there are a lot of blocks there, what do you think would be the best way to learn how to use Scratch? Or what would be the best way for you to learn how to use Scratch?	I don't really know.	Learning Scratch reflection
You don't really know? What would have been the best way to help you learn Scratch?	Maybe get some professional help	Learning Scratch reflection
Get some professional help?	Yeah	Learning Scratch reflection
What do you mean by that?	Maybe a person who's done Scratch for awhile or a person who maybe created it.	Learning Scratch reflection
Oh, maybe the person who created it. Do you think they would be able to help you?	Yeah	Learning Scratch reflection
What about in a classroom? How could we learn Scratch in the classroom because we probably wouldn't be able to bring in	You mean the 5th grade classroom?	Clarification: Irrelevant to research questions
Sure, in the 5th grade classroom. What would be the best way to learn Scratch? If you were going to work with your	Maybe one simple thing at a time.	Learning Scratch reflection

because you know something about Scratch now. How would you teach your classmates about Scratch?		
OK. Maybe one simple thing at a time. Do you think that would help you too?	I guess but if I didn't know it, how could I teach it?	Learning Scratch reflection
Well, right, but I'm saying if someone was teaching you, would it help you to do one simple thing at a time?	Yeah.	Learning reflection
And what do you mean by one simple thing?	Like the first thing after another like creating the sprites. Then, well, first, the motion, then the looks, sound, pen, control, sensing, operation, variables.	Learning Scratch reflection
So are you saying we should go through each block to teach you one block at a time?	Well, not all of these. That would take forever.	Learning Scratch reflection
That would take a long time?	Yeah, just like motion and that and that and that and that and then looks	Learning Scratch reflection
OK, so maybe do a few blocks from each of those categories?	Uh-huh (yes)	Learning Scratch reflection
Maybe the ones you'd use the most?	Yeah	Learning Scratch reflection
OK. That's reasonable. Do you think designing in Scratch helps you learn? Do you think you learn something while designing in Scratch while working on this project?	Learning math?	Clarification: Irrelevant to research questions
Sure let's talk about learning math. Do you think you can learn math while working on this project?	Umm…I really don't. Some of that stuff I already know like a pyramid. I don't know that much about pyramids but cylinder and cone I already know about those two.	Learning math reflection
OK. So you already knew about some of the	Yes	Learning math reflection

math you used?		
So you didn't really learn about math in this project?	No	Learning math reflection
Is there anything you felt like you did learn from this project?	Well, how to draw some of them	Learning math reflection
So how to draw those shapes?	Yeah	Learning math reflection
Yeah, you drew a number of shapes. I see a cone, rectangular prism, cylinders even a pyramid there. You've learned how to draw them. Anything else you think you learned in this project?	Well, I did learn that…not really. I was just saying that I was a little embarrassed when I was saying my project because everything was messed up the time I did it cause that was in the wrong place, that was in the wrong place, that was in the wrong place. Everything was in the wrong place.	Project reaction
You mean when you were showing it to the 2nd graders?	Yes, everything was in the wrong place.	Project reaction
Everything was in the wrong place?	Maybe not everything. Not in the right position. They're all supposed to be. He needs to be bigger. They're all supposed to be facing.	Project reaction
Oh, so some of the sizes are not right	See look. See	Project reaction
So he's facing the wrong direction?	Yeah, that's one.	Project reaction
OK. OK.	Well, do you want to see?	Clarification: Irrelevant to research questions
We'll go through it in a minute, OK? Anything else you learned? Anything else you can think of that you learned while doing this project?	Uhm…probably…uhm…maybe…maybe learning how to do it.	Learning Scratch reflection
Learning how to do Scratch?	Yes.	Learning Scratch reflection
Yeah, you learned how to do Scratch a little bit because you said you, one thing you liked was drawing the sprites and editing the sprites, so you definitely learned	Yeah.	Learning Scratch reflection

how to do that, right?		
Did you learn how to record your voice?	Yeah	Learning Scratch reflection
I think you're, in fact, the only person that recorded their voice, right?	Well, yeah. I think.	Learning Scratch reflection
I think you were. You learned that and I don't think anybody else learned about that. When you were designing this, were you thinking about designing for 2nd graders?	I didn't even know we were going to show it to 2nd graders.	Project reaction
You didn't realize we were going to show it to 2nd graders?	No	Project reaction
OK. That's fair. Do you remember the original goal of the project?	Yeah	Project reaction
What was the goal of the project?	Make it creative?	Project reaction
To make it creative.	I don't know if that was one of them. I don't know if that was one of them.	Project reaction
OK. So think back to why did you design what you designed. What was this trying to show?	I was trying to make it creative and make them move and make them have a conversation but instead I was the only one talking. I thought the 2nd graders would get bored.	Project reaction
Well, so what happened yesterday with the 2nd graders? Did they get bored?	Well, they were looking at it. I don't know if they got bored because I'm not them but, I don't know if it was as good as everyone else's cause they're all moving and having conversation like Nathaniel's. He was like it impressed me like fine let's go on the dragons. Duh-duh-duh. Dud-duh-duh. Fine let's go. Yee-haw. And that's what happened. And mine's not amazing as that. Mine's just blah, blah, blah, blah, blah, blah, blah, blah, blah, blah. Blah, blah, blah, blah, blah, BLAH, blah. And then blah, blah, BLAH, blah. Yeah.	Project reaction
Well so everybody has	Why?	Irrelevant to research

a different approach to doing it and did you know that Nathaniel got rid of that dragon scene?		questions
You have to ask him.	You mean the dragons go like this?	Irrelevant to research questions
Yeah he got rid of it.	Why?	Irrelevant to research questions
You'll have to ask him. I don't know why.	So what did he make?	Irrelevant to research questions
Well, he had the conversation going at the beginning.	Oh.	Irrelevant to research questions
I want to look at your project with you so let's go through your project.	OK.	Irrelevant to research questions
So first scene of your project, your telling a story. PLAY FIRST SCENE.	That's wrong. See how everything is messed up.	Project reaction
What's messed up here	Well, he's supposed to be facing left. He's supposed to be right there.	Project reaction
There's some cats in the wrong place and they're facing the wrong directions	WATCHING WOODS SCENE: Oh, come on. Ugh	Project reaction
He's supposed to be behind?	That's supposed to be grabbing its tail.	Project reaction
Did that get changed? Was it like that yesterday?	Yes.	Project reaction
How does the land shark	See. Everything is messed up.	Project reaction
That looks right to me	You know those aren't supposed to be like that	Project reaction
Well, we talked about that yesterday. What about the land shark. How does the land shark related to geometric solids?	Wait. What do you mean? Well, he went there because it's the sea and I guess he doesn't like it. Are land sharks real?	Learning math reflection
I don't think so. I like the end by the way. I like how you used your fluctuation in your voice	Well, the shapes are there and I said to pay well the last part when they were done that I just wanted to make sure they were paying attention I	Learning math reflection

there. So, how do all these cats, ghosts, land shark, dragon, how does those relate to teaching someone about geometric solids.	said what were the shapes in the background.	
So the shapes are in the background. Do you ever talk about the shapes?	Uh, do I ever, well, when it's done I say "what shape is that?" and they're trying to guess it.	Learning math reflection
So explain that to me again	Cause when I'm done I want to make sure if they're paying attention.	Learning math reflection
So when you were done, when you watched this, so you asked, did you ask the 2nd graders "what shape is this?"	Uh-huh (yes)	Learning math reflection
So that wasn't part of your project, that was just something you just asked them?	Yeah	Learning math reflection
OK. That's fair. We asked you some questions before the project started and then last week near the end of the project, you answered those same questions. You might not have remembered it. OK, let's take a look. I'll show you what I'm talking about. So this is what you did when we started the project. Remember looking at this? And this is what you did last week? So we want to compare answers. So, cylinder, cylinder, pyramid, pyramid, cone, cone, rectangular prism, rectangular prism. In the beginning and at the	Is that right or wrong?	Learning math reflection

end, you could identify which geometric solid it is. No problem. So then here we have what is the area of the base of the prism. You said 8.		
What do you think it is?	I guess right	Learning math reflection
So how do you find area?	I forgot.	Learning math reflection
But over here you have the area of the base is 16. So it looks like	It's 8	Learning math reflection
It's 8. So you can count the cubes. 1, 2, 3, 4, 5, 6, 7, 8. But here you put 16. So one of my questions is what happened here. You forgot?	I thought it was 8 16	Learning math reflection
8 plus 8 is 16? OK, then look at here. What's the height of the prism. You have 2 and then you have 2. Is it 2?	Yes	Learning math reflection
Yeah, because you can count, so that was no problem. What is the volume of the problem	I said 16.	Learning math reflection
And then over here I can't tell if it's 16 or if that's 10.	I think it's 10.	Learning math reflection
I'm not sure how you went from here to here but when we	I think this is right.	Learning math reflection
This one's right.	Yeah	Learning math reflection
Yeah, you're right because you take	OK, which one's the one I did first?	Learning math reflection
This one's first, this one's second	Oh, OK	Learning math reflection
Then you did. You're right because you take the area of the base	I think I improved more on this one (pre-test).	Learning math reflection

times the height		
You think you improved more. You think you did better on this one (pre-test).	Yeah, that one (post-test) I did horrible.	Learning math reflection
Well, I don't think you did horrible. I think that maybe you just kind of forgot. And then here but I want to show you something. Look here. 8 and 9. You just put question marks, which looks to me like you didn't try, but here, you tried, you put answers and you said I just looked at the surface. So at least you tried, you tried something right?	Yes	Learning math reflection
So do you think you improved on the second one compared to the first?	I think I did better on the first one.	Learning math reflection
I would say maybe just a little bit better. It's pretty similar, don't you think?	Yes	Learning math reflection
Is there anything else you want to tell me about using Scratch or doing this kind of project?	Scratch is really confusing and frustrating.	Scratch reaction
Scratch is confusing and frustrating.	I was wondering why when I got to the 2nd graders it was doing all this stuff to me	Scratch reaction
Like what do you mean?	When we we're doing this project without the 2nd graders, nothing was happening, it was just normal, but then once I got the 2nd graders, all these lunatic stuff started to happened like the computer shut off, these Chinese words appeared and everything got mixed up.	Computer issues during sharing with 2nd graders: Irrelevant to research questions
Yeah, that was strange	No	Computer issues

yesterday, wasn't it? How we had to shut down you computer, that was, because that hadn't happened to you this whole time?		during sharing with 2nd graders: Irrelevant to research questions
Then it suddenly did. So you said it was frustrating.	Yes	Scratch reaction
Would you ever want to use Scratch again?	Uhm…yeah, I do. And I want to make it better than the first one I want to make it more better. My voice could be talking and they could be moving and stuff.	Scratch reaction; Project reaction
OK	I don't know if I can do it again because I'll be in 6th grade.	Irrelevant to research questions
Well, you can use Scratch. The nice thing about Scratch it's free	Free? I can do it on my computer?	Irrelevant to research questions
You can download it on your computer.	How?	Irrelevant to research questions
You just have to download it from the Scratch website. Have your parents help you. Say "I want to find Scratch", and you can do it for free. So you'd be interested in using Scratch again.	Yeah.	Irrelevant to research questions
You kept telling me during the project that "when are we going to do a project that's not about shapes".	Yeah	Project reaction
Did you not like the shapes?	Well, the shapes, I, well, no, I kind of liked it.	
OK. But you kept wanting to move on to a different project?	Yeah	Project reaction
How come?	Well, the shapes. I thought it was kind of weird when they were saying, they looked like adults but they were saying they were going to see a movie about shapes.	Project reaction
What was the idea for	I don't know. It just pops up in my	Project reaction

your you know you had this story. How did you come up with all those different ideas?	head	
Just pops up in your head? OK. Do you like math?	A little	Learning reflection
Do you think you're good at math?	No, no	Learning reflection
Do you think that you could learn math using Scratch?	Maybe?	Learning math reflection
Maybe how?	The things I'm writing down are things I already know, so how could it teach me?	Learning math reflection
Great question. I don't know the answer. So what you were doing was demonstrating what you know about math in this project?	Yeah	Learning math reflection
Anything else you want to share with me about the project? Here's your chance to tell me anything you want to tell me about the project?	The things I didn't like was just, I guess I should have done better, I said it like I didn't care, like in the sounds I said it like I didn't care.	Project reaction
Oh, so you would want to redo your sounds?	Not all over cause, I was speaking like I didn't care	Project reaction
Right, didn't put a lot of emotion into it	Except for the last part	Project reaction
The last part, yeah, you definitely put a lot emotion in the last line however you said that "the shape test", which is pretty funny. Anything else I should know about working on the project, anything else you want to tell me about this	Uhm…uhm…uhm…maybe…uhm…I just know what's going to happen if I don't tell you this and then later when then maybe Monday comes I'll have something I want to tell you then it will be too late, so I'm trying to think of something.	Project reaction
I appreciate that	Uhm…well…maybe it's about how mine is really different from everybody else's. Everybody else's seemed better because they're	Project reaction

	saying "what shape is this" then you type it in.	
So to you that seemed better	Well…not…no. I don't really like doing that	Learning reflection
You don't like doing what?	The part when you say "what's this shape"	Learning reflection
Yeah, so	Well, maybe it would be fun	Learning reflection
Do you like to tell stories	Yes	Learning reflection
Do you write stories a lot?	Yes	Learning reflection
So what you did seems something that you're good at then.	Really?	Learning reflection
To me. Cause you had this very elaborate story and nobody else really had a story like you had a story, so I thought it was interesting that you just said that other kids asked what shape is this but you said well I don't really like that. So, it seems like to me in your project you did what you like to do	Well, I did	Learning reflection
Isn't that OK you did it the way you like to do it?	Well, yeah, it's OK.	Learning reflection
The way you like to do it?	Well, yeah, it's OK	Learning reflection
While I'm thinking about it, would you want to share this with your 5th grade classmates?	I'd feel too embarrassed	Project reaction
You'd feel embarrassed to share that with them? How come?	Everyone in the 5th grade is mean.	Irrelevant to research questions
Everybody in the 5th grade is mean?	Not everyone. Everyone's mean and rough and tough, and I don't want to do it. I'll be scared.	Irrelevant to research questions
OK and we're not going to do it, so I don't want you to think I'm going to do it, I just wanted to	I would do but I'll be too scared	Irrelevant to research questions

know what you think		
Yeah, I appreciate that. And do you think other 5th graders should learn how to use Scratch	They could	Irrelevant to research questions
They could learn how to use Scratch?	Yeah	Irrelevant to research questions
Do you think they'd like to learn Scratch?	Some kids but some kids would think it would be a waste of their time	Irrelevant to research questions
Why do you think some kids would think it would be a waste of their time?	Cause they're not grateful	Irrelevant to research questions
Cause they're not grateful? Anything else you want to share with me?	Probably not.	Irrelevant to research questions

Group similar themes into categories (Step 5)
This step narrows the number of themes by grouping similar themes into categories. There were 5 themes generated from the data in Step 3. These 5 themes were grouped into 3 categories.

Previously identified themes:
1. Dominic's reaction to using Scratch
2. Dominic reflecting on learning Scratch
3. Dominic reflecting on learning math during this project
4. Dominic reflecting on how he learns
5. Dominic's reaction to his project

Categories (based on grouping similar themes):
1. Dominic's response to learning and using Scratch
    a. Dominic reflecting on learning Scratch
    b. Dominic's reaction to using Scratch
2. Dominic's response to this project
    a. Dominic's reaction to his project
3. Dominic's response to his learning
    a. Dominic reflecting on learning math during this project
    b. Dominic reflecting on how he learns

Convert categories into categorical codes (Step 6)
1. Scratch: Dominic's response to learning and using Scratch
2. Project: Dominic's response to this project
3. Learning: Dominic's response to his learning

Organize data based on categorical codes (Step 7)

Scratch:

Did you enjoy using Scratch?	Well, yes.
What about using Scratch did you like?	Well, the part was making all the new sprites and editing them, like that cat right there <yes> I made her a tongue and eyelashes, made her look like a girl not a boy cat because I think every cat in here is a boy.
So you liked taking the existing sprites and changing them, right?	Yeah
OK. What else did you like about using Scratch?	Well, that there were so many sprites to use like a dragon and ghost and you can create your own sprites like raining milk.
OK. So you like that you could design your own sprites <yeah> and you also like that there were lots of other sprites that were part of Scratch that you could use?	Yes.
Is there anything else you want to tell me about using Scratch or doing this kind of project?	Scratch is really confusing and frustrating.
Scratch is confusing and frustrating.	I was wondering why when I got to the 2nd graders it was doing all this stuff to me
Like what do you mean?	When we we're doing this project without the 2nd graders, nothing was happening, it was just normal, but then once I got the 2nd graders, all these lunatic stuff started to happened like the computer shut off, these Chinese words appeared and everything got mixed up.
Yeah, that was strange yesterday, wasn't it? How we had to shut down you computer, that was, because that hadn't happened to you this whole time?	No
Then it suddenly did. So you said it was frustrating.	Yes
Would you ever want to use Scratch again?	Uhm…yeah, I do.

Yes. OK. Good. Do you think it was easy or difficult to learn how to use Scratch?	I say it was difficult.
It was difficult to learn how to use Scratch?	Yes.
What made it difficult to learn how to use?	Well, pretty much it was hard to know what to do because there was so much

	stuff. Like when you were saying *** at *** and turn around cause look at all these stuff glide 1 sens x -29 and y -10 and change x by 10 and all this other stuff.
Sure. So all those blocks, maybe there are just too many blocks showing so it gets confusing?	Yeah
OK. So because there are a lot of blocks there, what do you think would be the best way to learn how to use Scratch? Or what would be the best way for you to learn how to use Scratch?	I don't really know.
You don't really know? What would have been the best way to help you learn Scratch?	Maybe get some professional help
Get some professional help?	Yeah
What do you mean by that?	Maybe a person who's done Scratch for awhile or a person who maybe created it.
Oh, maybe the person who created it. Do you think they would be able to help you?	Yeah
What about in a classroom? How could we learn Scratch in the classroom because we probably wouldn't be able to bring in	You mean the 5th grade classroom?
Sure, in the 5th grade classroom. What would be the best way to learn Scratch? If you were going to work with your because you know something about Scratch now. How would you teach your classmates about Scratch?	Maybe one simple thing at a time.
OK. Maybe one simple thing at a time. Do you think that would help you too?	I guess but if I didn't know it, how could I teach it?
And what do you mean by one simple thing?	Like the first thing after another like creating the sprites. Then, well, first, the motion, then the looks, sound, pen, control, sensing, operation, variables.
So are you saying we should go through each block to teach you one block at a time?	Well, not all of these. That would take forever.
That would take a long time?	Yeah, just like motion and that and that and that and that and then looks
OK, so maybe do a few blocks from each of those categories?	Uh-huh (yes)
Maybe the ones you'd use the most?	Yeah
We'll go through it in a minute, OK? Anything else you learned? Anything else	Uhm…probably…uhm…maybe…mayb e learning how to do it.

you can think of that you learned while doing this project?	
Learning how to do Scratch?	Yes.
Yeah, you learned how to do Scratch a little bit because you said you, one thing you liked was drawing the sprites and editing the sprites, so you definitely learned how to do that, right?	Yeah.
Did you learn how to record your voice?	Yeah
I think you're, in fact, the only person that recorded their voice, right?	Well, yeah. I think.

Project:

Yeah, you drew a number of shapes. I see a cone, rectangular prism, cylinders even a pyramid there. You've learned how to draw them. Anything else you think you learned in this project?	Well, I did learn that…not really. I was just saying that I was a little embarrassed when I was saying my project because everything was messed up the time I did it cause that was in the wrong place, that was in the wrong place, that was in the wrong place. Everything was in the wrong place.
You mean when you were showing it to the 2nd graders?	Yes, everything was in the wrong place.
Everything was in the wrong place?	Maybe not everything. Not in the right position. They're all supposed to be. He needs to be bigger. They're all supposed to be facing.
Oh, so some of the sizes are not right	See look. See
So he's facing the wrong direction?	Yeah, that's one.
I think you were. You learned that and I don't think anybody else learned about that. When you were designing this, were you thinking about designing for 2nd graders?	I didn't even know we were going to show it to 2nd graders.
You didn't realize we were going to show it to 2nd graders?	No
OK. That's fair. Do you remember the original goal of the project?	Yeah
What was the goal of the project?	Make it creative?
To make it creative.	I don't know if that was one of them. I don't know if that was one of them.
OK. So think back to why did you design what you designed. What was this trying to show?	I was trying to make it creative and make them move and make them have a conversation but instead I was the only one talking. I thought the 2nd graders would get bored.
Well, so what happened yesterday with the	Well, they were looking at it. I don't

2nd graders? Did they get bored?	know if they got bored because I'm not them but, I don't know if it was as good as everyone else's cause they're all moving and having conversation like Nathaniel's. He was like it impressed me like fine let's go on the dragons. Duh-duh-duh. Dud-duh-duh. Fine let's go. Yee-haw. And that's what happened. And mine's not amazing as that. Mine's just blah, blah, blah, blah, blah, blah, blah. Blah, blah, blah, blah, blah, BLAH, blah. And then blah, blah, BLAH, blah. Yeah.
So first scene of your project, your telling a story. PLAY FIRST SCENE.	That's wrong. See how everything is messed up.
What's messed up here	Well, he's supposed to be facing left. He's supposed to be right there.
There's some cats in the wrong place and they're facing the wrong directions	WATCHING WOODS SCENE: Oh, come on. Ugh
He's supposed to be behind?	That's supposed to be grabbing its tail.
Did that get changed? Was it like that yesterday?	Yes.
How does the land shark	See. Everything is messed up.
That looks right to me	You know those aren't supposed to be like that
Would you ever want to use Scratch again?	Uhm…yeah, I do. And I want to make it better than the first one I want to make it more better. My voice could be talking and they could be moving and stuff.
You kept telling me during the project that "when are we going to do a project that's not about shapes".	Yeah
Did you not like the shapes?	Well, the shapes, I, well, no, I kind of liked it.
OK. But you kept wanting to move on to a different project?	Yeah
How come?	Well, the shapes. I thought it was kind of weird when they were saying, they looked like adults but they were saying they were going to see a movie about shapes.
What was the idea for your you know you had this story. How did you come up with all those different ideas?	I don't know. It just pops up in my head
Anything else you want to share with me about the project? Here's your chance to	The things I didn't like was just, I guess I should have done better, I said it like I

tell me anything you want to tell me about the project?	didn't care, like in the sounds I said it like I didn't care.
Oh, so you would want to redo your sounds?	Not all over cause, I was speaking like I didn't care
Right, didn't put a lot of emotion into it	Except for the last part
The last part, yeah, you definitely put a lot emotion in the last line however you said that "the shape test", which is pretty funny. Anything else I should know about working on the project, anything else you want to tell me about this	Uhm…uhm…uhm…maybe…uhm…I just know what's going to happen if I don't tell you this and then later when then maybe Monday comes I'll have something I want to tell you then it will be too late, so I'm trying to think of something.
I appreciate that	Uhm…well…maybe it's about how mine is really different from everybody else's. Everybody else's seemed better because they're saying "what shape is this" then you type it in.
While I'm thinking about it, would you want to share this with your 5th grade classmates?	I'd feel too embarrassed

Learning:

Well, right, but I'm saying if someone was teaching you, would it help you to do one simple thing at a time?	Yeah.
Just pops up in your head? OK. Do you like math?	A little
Do you think you're good at math?	No, no
So to you that seemed better	Well…not…no. I don't really like doing that
You don't like doing what?	The part when you say "what's this shape"
Yeah, so	Well, maybe it would be fun
Do you like to tell stories	Yes
Do you write stories a lot?	Yes
So what you did seems something that you're good at then.	Really?
To me. Cause you had this very elaborate story and nobody else really had a story like you had a story, so I thought it was interesting that you just said that other kids asked what shape is this but you said well I don't really like that. So, it seems like to me in your project you did what you like to do	Well, I did
Isn't that OK you did it the way you like to do it?	Well, yeah, it's OK.
The way you like to do it?	Well, yeah, it's OK

Sure let's talk about learning math. Do you think you can learn math while working on this project?	Umm…I really don't. Some of that stuff I already know like a pyramid. I don't know that much about pyramids but cylinder and cone I already know about those two.
OK. So you already knew about some of the math you used?	Yes
So you didn't really learn about math in this project?	No
Is there anything you felt like you did learn from this project?	Well, how to draw some of them
So how to draw those shapes?	Yeah
Do you think that you could learn math using Scratch?	Maybe?
Maybe how?	The things I'm writing down are things I already know, so how could it teach me?
Great question. I don't know the answer. So what you were doing was demonstrating what you know about math in this project?	Yeah
Well, we talked about that yesterday. What about the land shark. How does the land shark related to geometric solids?	Wait. What do you mean? Well, he went there because it's the sea and I guess he doesn't like it. Are land sharks real?
I don't think so. I like the end by the way. I like how you used your fluctuation in your voice there. So, how do all these cats, ghosts, land shark, dragon, how does those relate to teaching someone about geometric solids.	Well, the shapes are there and I said to pay well the last part when they were done that I just wanted to make sure they were paying attention I said what were the shapes in the background.
So the shapes are in the background. Do you ever talk about the shapes?	Uh, do I ever, well, when it's done I say "what shape is that?" and they're trying to guess it.
So explain that to me again	Cause when I'm done I want to make sure if they're paying attention.
So when you were done, when you watched this, so you asked, did you ask the 2nd graders "what shape is this?"	Uh-huh (yes)
So that wasn't part of your project, that was just something you just asked them?	Yeah
OK. That's fair. We asked you some questions before the project started and then last week near the end of the project, you answered those same questions. You might not have remembered it. OK, let's	Is that right or wrong?

take a look. I'll show you what I'm talking about. So this is what you did when we started the project. Remember looking at this? And this is what you did last week? So we want to compare answers. So, cylinder, cylinder, pyramid, pyramid, cone, cone, rectangular prism, rectangular prism. In the beginning and at the end, you could identify which geometric solid it is. No problem. So then here we have what is the area of the base of the prism. You said 8.	
What do you think it is?	I guess right
So how do you find area?	I forgot.
But over here you have the area of the base is 16. So it looks like	It's 8
It's 8. So you can count the cubes. 1, 2, 3, 4, 5, 6, 7, 8. But here you put 16. So one of my questions is what happened here. You forgot?	I thought it was 8 16
8 plus 8 is 16? OK, then look at here. What's the height of the prism. You have 2 and then you have 2. Is it 2?	Yes
Yeah, because you can count, so that was no problem. What is the volume of the problem	I said 16.
And then over here I can't tell if it's 16 or if that's 10.	I think it's 10.
I'm not sure how you went from here to here but when we	I think this is right.
This one's right.	Yeah
Yeah, you're right because you take	OK, which one's the one I did first?
This one's first, this one's second	Oh, OK
Then you did. You're right because you take the area of the base times the height	I think I improved more on this one (pre-test).
You think you improved more. You think you did better on this one (pre-test).	Yeah, that one (post-test) I did horrible.
Well, I don't think you did horrible. I think that maybe you just kind of forgot. And then here but I want to show you something. Look here. 8 and 9. You just put question marks, which looks to me like you didn't try, but here, you tried, you put answers and you said I just looked at the surface. So at least you tried, you tried something right?	Yes
So do you think you improved on the second one compared to the first?	I think I did better on the first one.

I would say maybe just a little bit better. It's pretty similar, don't you think?	Yes

Re-code data (Step 8)
This step was not necessary.

APPENDIX G
DATA COLLECTED FROM SCRATCH ARTIFACTS

Day	Number of sprites	Number of backgrounds	Number of scripts	Number of command blocks in scripts	Number of unique command blocks in scripts	Unique command blocks used in scripts
1	4	2	0	0	0	None
2	7	2	0	0	0	None
3	8	2	2	6	3	forever; say; when flag clicked
4	9	3	2	5	3	say; when flag clicked; wait
5	12	5	2	4	2	when flag clicked; say for secs
6	8	6	2	4	2	when flag clicked; say for secs
7	11	7	3	6	2	when flag clicked; switch to background
8	14	7	15	31	7	when flag clicked; switch to background; show; hide; play sound until done; broadcast; when I receive
9	17	7	28	58	7	when flag clicked; switch to background; show; hide; play sound until done; broadcast; when I receive
10	17	7	30	66	7	when flag clicked; switch to background; show; hide; play sound until done; broadcast; when I receive
11	18	7	36	84	9	when flag clicked; switch to background; play sound until done; broadcast; when I receive; point in direction; go to x: y:; hide; show
12	18	7	41	76	9	when flag clicked; switch to background; play sound until done; broadcast; when I receive; point in direction; go to x: y:; hide; show
13	18	7	52	129	10	when flag clicked; switch to background; play sound until done; broadcast; when I receive; point in direction; go to x: y:; hide; show; set size to
14	22	7	66	152	10	when flag clicked; switch to background; play sound until done; broadcast; when I receive; point in direction; go to x: y:; hide; show; set size to
15	22	7	84	207	11	when flag clicked; switch to background; play sound; play sound until done; when I receive; point in direction; go to x: y:; show; hide; broadcast; set size to

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BIOGRAPHICAL SKETCH

Jeffrey Boyer is a teacher and a learner in the field of educational technology. He began his teaching career as a middle school science and math teacher at Castle Rock Middle School in Billings, MT. Next, Jeffrey taught high school science courses and served as a district-level technology and curriculum coach for P. K. Yonge Developmental Research School in Gainesville, FL. Most recently, he was a visiting lecturer and a doctoral candidate in the educational technology program of the School of Teaching & Learning at the University of Florida's College of Education. As a visiting lecturer, Jeffrey taught a technology integration course that is required coursework for UF's elementary and early childhood teacher preparation programs. As a learner and a researcher in the field of educational technology, Jeffrey investigates the impact on content learning when learners construct interactive multimedia. As a teacher, he is passionate about preparing future teachers to use technology in meaningful ways with their students.